HEMODYNAMICS OF THE GALEN'S VEIN AND GENERAL ANESTHESIA

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INTRODUCTION

The magnificent progress of the modern surgical operation owes much to the development of anesthesiology; in which it is too obvious to argue the necessity of maintaining the cerebral circulation in adequate amount. In general anesthesia the patient is naturally out of his consciousness and so a due and constant attention ought to be paid to the status of the cerebral circulation during the general anesthesia.

The brain stem is primarily concerned with maintenance of life, possessing centers of respiration, circulation, blood pressure and other reflexes all of which are to be used as an indicator in conduction of anesthesia. The state of blood circulation in the brain stem, therefore, is extremely important when conducting general anesthesia. In this regard, however, there have been only a handful of dissertations reported so far, as by Laidlaw¹⁾, Shimada²⁾, Kurusu³⁾, Tanabe⁴⁾, etc., though there have been numerous re-searches done on the subject of anesthesia and cerebral circulation.

We devised a new method of studying the cerebral circulation in which the hemodynamics of the brain stem are directly determined with simultaneous measurement of hemodynamics of other parts of the brain for comparison, and since we have been engaged in the study of the cerebral circulation by means of the new method.

We wish here to deliver results of our studies on influences of various anesthetic drugs upon the cerebral circulation, particularly upon that of the brain stem. The results by the way have proven to be quite elucidating on the Pick's theory of dividing anesthetic drugs into cortical and thalamic.

METHOD OF RESEARCH

The figure 1 shows diagrammatically the résumé of setups of our experiment. An adult dog weighing about ten kg is fixed in supine position on the table under intravenous ravonal anesthesia by dose of about twenty mg per kilo. Tracheotomy is performed and a Y-shaped tube is inserted into the trachea. The tube is to be set close and air-tight on the inner surface of the trachea.

Figure 1.

One end of the intratracheal Y-tube is connected with the apparatus for recording respiratory movements. Recording of the blood pressure is undertaken by a mercury manometer which is linked to a femoral artery surgically isolated on one side.

The blood pressure and respiration are continuously recorded on the sooty roll-paper of the kymographion. A femoral vein on the other side is exposed and connected by way of a tube to an irrigator bottle for the purpose of fluid administration. On finishing the preparatory procedures above detailed we proceed to the process of fractional drainage of cerebral circulation which is the most important part of this experiment; and a dissertation by Hirai⁽⁶⁾, one of our group, is to be referred to in regard with the isolated determination of the hemodynamics of the Galen's vein which drains the venous flow from the brain stem.

After the preparatory maneuvers the experimental animal is turned and refixed from supine to prone position and the left parietal region is exposed by ordinary craniotomy technique. Two polyethylene tubes are inserted into the sinuses of the skull, one into the superior sagittal sinus and the other into

the Galen's vein via the straight sinus. As soon as inserting the tubes successfully the animal is to be heparinized sufficiently. The venous blood flow drained through each tube is lead to an electromagnetic amplifier for simultaneous recording, and then the drained blood is pooled in the irrigator and returned into the animal circulation through the femoral vein.

The Galen's vein drains the venous blood flow from the thalamus and other subcortical nuclei, lateral ventricle, lateral wall of the third ventricle, midbrain, hypothalamus and part of the medulla. At the end of each experiment a dye evans blue is poured into the Galen's vein via the polyethylene tube, and areas stained by the dye correspond to those areas mentioned above on dissection of the brain. This is to check whether the polyethylene tube has been inserted correctly or not in the experiment.

Preparations so far are to be finished with the least time and blood losses possible, and then the main portion of the experiment is to be started, though it is sometimes necessary to add some ravonal by that time. At any rate the effect of ravonal has to be almost gone and the ciliary reflex has to be positive by the time the main experiment can be started.

The rate of increase and decrease in the cerebral circulation is expressed in percentage against the value before the experiment, and this is pictured on the sooty roll paper of the kymographion together with the changes of the respiratory motion and blood pressure so that all these factors may be evaluated at the same time during the experiment.

Methods of administration of respective anesthetic agents are as follows:

1. Ravonal is given intravenously via the rubber tube under the irrigator in dose of 10 to 12.5 mg per kilo in a relatively short time and the moment of finishing the irrigation is considered as a starting point for the timed observation.
2. Eunal is given in the same manner as ravonal in doses of 5 to 25 mg per kilo.
3. Nitrous oxide is mixed with oxygen in a volume ratio of four to one and the mixture is kept in a gas bag. Between the bag and the endotracheal Y-tube a non-rebreathing one-way stopcock is interposed, through which the animal inhales the gas mixture.
4. Cyclopropane is inhaled via a non-rebreathing circuit through the Heidbrink anesthetic apparatus in a mixture of three volumes of cyclopropane and one volume of oxygen.
5. Volatile liquid anesthetics — ether, trilene, and chloroform — are given as

open drops through a gauzesh-covered funnel-shaped container which is linked to the endotracheal tube.

6. Though neither hypoxia nor hypercapnia per se is an anesthetic agent, they are such important factors in the conduction of anesthesia that they are included in the series of this experimental research. They are given to the animal in the same manner as the nitrous oxide. The gas bag contains mixture of zero to ten per cent oxygen and ninety to a hundred per cent nitrogen for anoxia or hypoxia, and mixture of twenty per cent carbon dioxide and eighty per cent air for hypercapnia.

When hypoxia or hypercapnia is coexistent with anesthesia, the cerebral circulation probably is effected not only by the latter but also and none the less strongly by the former. In order to clear this view-point O₂ and CO₂ gas analysis of the blood samples taken from the other femoral artery than the one linked to the manometer is performed by means of the Macro Van Slyke Neill manometric apparatus.

RESULTS OF RESEACH

1. RAVONAL (Figure 2)

When ravonal of 10 to 12.5 mg per kilo is injected into the femoral vein in a relatively fast speed, the blood pressure shows an immediate rise on conclusion of injection followed by a sudden fall which immediately returns to the original value, and afterward the blood pressure stays stable. Sometimes it shows slight decline, but it returns to the original value within five minutes.

The respiratory movement is diminished in both amplitude and frequency

Fig. 2 Ravonal

Fig. 3 Eunal

by intravenous ravonal administration, and it gradually recovers to the original level in five to six minutes. Ravonal, however, may cause apnea when injection is given too fast or repeated, or when the animal is exhausted by a prolonged experiment. In the case with apnea the animal may either resume respiration or may go down hill to death without regaining respiration.

As for the cerebral circulation both the Galen's vein and superior sagittal sinus take a smooth parabolic curve and return to the original value in five to six minutes, and the degree of rise is higher in the former than in the latter. (Galen's vein + 22%, superior sagittal sinus + 17%.)

In cases, however, which become apneic and die the cerebral circulation shows a prominent and steep rise first and then gradually declines and lastly the blood flow ceases. In those cases also the changes are more marked in the Galen's vein than in the superior sagittal sinus. As for the changes in the blood gas tension CO_2 tension rises to 107 and O_2 tension falls to 92, each against the original arbitrary value of 100.

2. EUNAL (Figure 3)

Eunal is given intravenously in varying doses of 5 to 25 mg per kilo and in each dosage the blood pressure falls abruptly on conclusion of the injection, then suddenly makes a steep and marked climb, and then gradually declines to return to the original value in course of five to eight minutes.

The respiratory movement increases both in amplitude and frequency in the first thirty seconds, and then both amplitude and frequency decrease suddenly. Later the respiration gradually returns to the original moderate type. The cerebral circulation shows a specific change, i.e., it increases in the early stage in both Galen's vein and the superior sagittal sinus and then it starts to decrease, reaching the bottom value in three minutes after injection. Later both of them start to increase again, returning to the original value in about five minutes after injection. The degree of changes is stronger in the superior sagittal sinus than in the Galen's vein both at the highest and lowest peaks. (Summit: Galen's vein + 15%, superior sagittal sinus + 30%; bottom: Galen's vein - 5%, superior sagittal sinus - 10%)

3. NITROUS OXIDE (Figure 4)

Nitrous oxide was given as a mixture of four volumes of nitrous oxide and one volume of oxygen in two to twenty minutes.

The blood pressure does not make a noticeable change, while respiration

shifts from a slightly irregular and big type to regular and moderate type of respiration both in amplitude and frequency. The cerebral circulation after the start of inhalation increases gradually both in the Galen's vein and the superior sagittal sinus and reaches the peak in about three minutes. From then on it maintains the level during inhalation of nitrous oxide, and on discontinuance of inhalation it declines gradually and returns to the original value. The peak value is higher in the Galen's vein. (Galen's vein +50%, superior sagittal sinus +25%) The tensions of O_2 and CO_2 do not show a remarkable change.

4. CYCLOPROPANE (Figure 5)

Cyclopropane was inhaled in a mixture of one volume of cyclopropane and three volumes of oxygen. The blood pressure does not change in the height, but the kymographion shows reduction of the pulse pressure. When experiments are repeated or concentration of cyclopropane is increased, the blood pressure may become prominently lowered.

The respiration is suppressed in both amplitude and frequency, particularly in the latter, by inhalation of cyclopropane, and the effect persists for a while after discontinuance of inhalation. As for the cerebral circulation both Galen's vein and the superior sagittal sinus first show a decrease of less than -10% and then start to increase up to +50% for the Galen's vein and +25% for the superior sagittal sinus. The peaks are maintained and on discontinuance of inhalation the blood flow returns promptly to the original value.

5. ETHER (Figure 6)

There was not an appreciable change in the blood pressure and respira-

tion when ether was administered for three to nine minutes by open drops in an adjusted speed that controls the depth of anesthesia not to exceed the second plane of the third stage. In this condition the cerebral circulation shows rise in both the Galen's vein and superior sagittal sinus, and the degree of rise is larger in the former than in the latter, i.e., the Galen's vein shows a peak of $+60\%$ and the superior sagittal sinus $+30\%$. They maintain the peaks and return to the original level gradually after interruption.

On the contrary when ether drops are administered heavily for more than ten minutes, the blood pressure gradually declines, while respiration, though regular in the beginning, gradually shows shortening of inspiration and prolongation of expiration, and then the animal starts to gasp and in the end gets apneic and dies. In this case the Galen's vein and the superior sagittal sinus, after reaching the peak of $+140\%$ and $+90\%$ respectively, gradually decline and descend the original level in nine to ten minutes and at last cease the blood flow.

Fig. 6 Ether

Fig. 7 Trilene

6. TRILENE (Figure 7)

As soon as inhalation of trilene is started the blood pressure begins to fall gradually and gets stable after marking a certain level. It returns to the original level on stoppage of inhalation. As for the respiration there is gradual decrease of amplitude and gradual increase of interval after the beginning of inhalation. It restores to the original stage on discontinuance of inhalation.

Both the Galen's vein and the superior sagittal sinus show prominent increase of blood flow, and the degree of increase is stronger in the Galen's vein (Galen's vein $+140\%$, superior sagittal sinus $+80\%$). There is some

difference in the way the blood flow increases upon starting of inhalation; the Galen's vein shows immediate and steep ascending curve, while the superior sagittal sinus shows a slow rise. Both of them recover to the original state relatively promptly on stoppage of inhalation.

7. CHLOROFORM (Figure 8)

The blood pressure denotes a progressively and gradually falling curve after beginning of inhalation and the decline of the blood pressure becomes irreversible in most cases when inhalation continues for more than four minutes. The figure 8 is a case in which inhalation was continued for 2 minutes and 45 seconds and as the picture shows the change of the blood pressure was reversible. As for the respiratory movement it seemed that the amplitude tended to be slightly decreased and the frequency tended to be increased.

In the beginning of inhalation of chloroform the blood flow of the Galen's vein increases rapidly from the onset, while the flow of superior sagittal sinus decreases slightly or maintains the original level in the first two to three minutes and afterward it starts to increase. The degree of increase is greater in the Galen's vein (Galen's vein $+110\%$, superior sagittal sinus $+55\%$). As the figure shows the peak of the flow is reached somewhat later than stoppage of inhalation and followingly the blood flow showed a rapid fall to return to the original value.

8. HYPOXIA (Figure 9)

No prominent changes were encountered when 5% O₂ was given for four minutes or 10% O₂ for 15 minutes except some activation of respiration in the latter. Changes that will be described below, therefore, were elicited by inhalation of pure nitrogen. (Figure 9. Inhalation for one minute and thirty seconds).

The blood pressure starts to show a progressive and continuous rise on beginning the inhalation and it keeps the high level for more than a minute after stoppage and then it declines relatively repidly and restores the original value.

As for the respiration the animal shows a prominent hyperpnea after beginning of respiration, and suddenly it gets apneic and in the end of twenty to thirty seconds spontaneous respiration is restored. In the first the respiratory amplitude is small and the respiratory interval is large, and suddenly and stepwise followingly hyperventilation is wrought in, and again in the end the previous quiet respiration is restored. As for the cerebral circulation both the Galen's vein and the superior sagittal sinus show a prompt rise and in three minutes after inhalation the former reaches a peak of +160% and the latter +140% and from there on they decline repidly to return to the original value.

9. HYPERCAPNIA (Figure 10)

A mixture of 20% carbon dioxide and 80% air was inhaled for one minute and thirty seconds to seven minutes. The blood pressure was unchanged or slightly decreased in some cases, and it increased in other cases. In either

Fig. 10 Hypercapnia

case it returned to the original value on discontinuance of inhalation. In both cases there was a prominent activation of respiration in both amplitude and frequency.

The increase of the cerebral circulation is different in degree according to the types of change of the blood pressure. In cases which show no change or slight decrease of the blood pressure there is increase of the blood flow in the Galen's vein of +90% and in the superior sagittal sinus of +60%, while in cases which show increase of the blood pressure there is increase of the blood flow in the Galen's vein of +170% and in the superior sagittal sinus of +140%. The figure 10 is of a case which showed a slight decrease of the blood pressure. The blood gas tensions in this case at four minutes after beginning of inhalation are 130 for CO₂ and 97 for O₂ as compared with 100 for each original value.

DISCUSSION

In this chapter the results of our experiments on effects of various anesthetic drugs will be scrutinized by reviewing the bibliographies on the same line, and the results will be evaluated from physiological and clinical standpoints.

1. RAVONAL

Some authors ⁸⁾—¹²⁾ state that the blood pressure does not change under ravonal anesthesia, and others ¹³⁾—¹⁶⁾ state that it decreases. Generally speaking the blood pressure under ravonal anesthesia is influenced upon by the way of induction and doses ¹⁷⁾ ¹⁸⁾. In our results the blood pressure was unchanged in most cases, and it decreased in some cases. As for the respiration under ravonal anesthesia both amplitude and frequency are said to be depressed, ¹¹⁾ ¹²⁾ ¹⁹⁾ ²⁰⁾ and this was the case also in the results of our experiments.

A notion goes widely that a decrease of the brain metabolism is associated with decrease of the cerebral circulation, and from this viewpoint researches have been accumulated in order to elucidate the influence of ravonal upon the cerebral circulation ⁸⁾ ^{21—26)}. Almost all of the workers who studies from the standpoint of the brain metabolism claim that ravonal decreases the cerebral circulation, but views of other workers with different methods and standpoints are varied respectively.

Workers who claim that ravonal decreases the cerebral circulation are

Shimada²⁾, Tanabe,¹⁵⁾ and Bennett²⁷⁾ by thermostromuhr, Schmidt²⁸⁾ by bubble flow meter, Horsley²⁹⁾ by the cerebrospinal fluid pressure and Schmidt,²¹⁾ Himwich²⁴⁾, etc., by nitrous oxide method. These works and those researches from the metabolic standpoint are both classified under the indirect method in the broad sense.

Some clinicians claim that there is not a remarkable change in the cerebral hemodynamics under ravonal anesthesia.^{30) 31)}

Contrary to those mentioned above some workers claim that ravonal anesthesia increases the cerebral circulation, i.e., Laidlaw¹⁾ by histopathological approach, Ghersi³²⁾ by ventriculography and Sohler,³³⁾ Finesinger¹⁴⁾ and Hirata^{34) 35)} by the skull window method. Hirata³⁵⁾ states that the dilating effect on the cerebral vessels of ravonal does not necessarily persist all the while, but no constrictor effect is seen at any moment during anesthesia. In our results there is increase of the blood flow in the Galen's vein of +22% and in the superior sagittal sinus of +17%. As the skull window method catches instant change under direct vision, so our research pursues the cerebral hemodynamics directly without missing any instant change. It is, therefore, an undeniable fact that ravonal causes, even if transiently, increase of the cerebral circulation or dilatation of the cerebral vessels. In regard with each view on the effects of ravonal upon the cerebral circulation self-criticisms by some workers^{13) 24) 30)} are to be referred to as to why there are three contradictory data of ravonal causing decrease, no change and increase in the cerebral circulation.

2. EUNAL

Nishimura^{37) 38)}, Shimada³⁹⁾ and Yamamoto et al¹⁷⁾ reported on the hemodynamics under eunal anesthesia, and they all pointed out the effect of eunal for raising the blood pressure. In our experiments also there was a prominent rise of the blood pressure. As for the effect of eunal upon respiration it is said by many workers that eunal augments respiration^{17) 37) 39) 40)}. In our results a transient hyperventilation by intravenous injection of eunal and following compensatory respiratory depression are clearly visible on the kymographion.

In regard with the cerebral circulatory influence by eunal administration no work has been published up to this date bibliographically. In our data as were previously described the cerebral circulation increases in the beginning, then decreases and after transcending the original level it again

starts to climb up and return to the original value in five to six minutes after injection of eunal. It is stressed that the amplitudes of changes both at the peak and bottom are greater in the blood flow of the superior sagittal sinus than in the Galen's vein.

It is construed that though eunal essentially is a cerebral vasoconstrictor the blood pressure raising effect of eunal in the beginning induces passive dilatation of the cerebral blood vessels by overcoming the vasoconstrictor effect and causes increase of the cerebral blood flow, and by the time the blood pressure returns to the original value the constrictor effect becomes manifest, and as a net result such a characteristic curve of the cerebral circulation is produced for eunal. It is interesting that passive fluctuation of the cerebral blood flow is greater in amplitude in the superior sagittal sinus than in the Galen's vein which drains the venous blood from the vitally important brain stem for maintaining life.

3. NITROUS OXIDE

The nitrous oxide anesthesia does not cause remarkable changes in the brain pressure, circulation, respiration and other vital signs^{18) 31) 41)} and if they show a definite change it is not due to nitrous oxide itself but is due to complications of anesthesia such as accumulation of carbon dioxide or shortage of oxygen. In our results also there was not a remarkable change in the blood pressure and respiration, and the arterial O₂ and CO₂ tensions were found to level within normal limits. Despite the stability of those vital signs under the nitrous oxide anesthesia there is increase of the cerebral circulation, and this indicates the cerebral vasodilator effect of nitrous oxide. The increase is +50% in the Galen's vein and +25% in the superior sagittal sinus, indicating augmentation of the blood flow in the brain stem under nitrous oxide anesthesia.

4. CYCLOPROPANE

Cyclopropane when in the concentrations clinically used (1st plane 7.4%, 2nd plane 13.1% 3rd plane 23.3%) does not change¹⁸⁾, or slightly decreases⁴¹⁾ the blood pressure, but in the higher concentrations it decreases the blood pressure⁴³⁾. In our experiments using 25% cyclopropane there was not a remarkable change in the blood pressure but there was decrease of the pulse pressure. In regard with the respiratory effect cyclopropane causes no irritation of the upper respiratory tract as is seen in the induction stage of ether

and nitrous oxide anesthetics, but it induces "quiet respiration" from the beginning and maintains it until there comes respiratory depression of the fourth plane of the third stage¹⁸⁾. A slight decrease of the respiratory amplitude and a prominent prolongation of the respiratory interval are clearly visible from the beginning of cyclopropane inhalation on the kymographion obtained in our experiments.

As for the effect of cyclopropane upon the cerebral circulation Bennett²⁷⁾, by thermostromuhr, and Gherzi³²⁾, by ventriculography, inferred that cyclopropane dilates the cerebral vasculature. Collins³¹⁾, however, states that cyclopropane does not alter the intracranial pressure. Our experiments not only showed increases of the cerebral circulation but also made comparative determination of the increase of the blood flow in the divided areas of the brain, i.e., +50% increase in the Galen's vein and +25% increase in the superior sagittal sinus. Cyclopropane, therefore, keeps the blood supply well for the brain stem which is most important for maintenance of life, and owing to its potent narcotic effect it has a practical advantage in that it can be used in a low concentration itself in combination with high concentrations of oxygen.

5. ETHER

In the induction stage of ether anesthesia the blood pressure may rise somewhat¹⁴⁾ ¹⁸⁾ ⁴⁴⁾ or it may fall suddenly and transiently⁴¹⁾, but in most cases it stays stable. In the stage of the surgical anesthesia the blood pressure stays almost unchanged¹³⁾ ¹⁸⁾ ⁴⁶⁾ or it shows a mild gradual decrease. In our results the blood pressure stayed almost unchanged. Many workers have published dissertations on the subject of ether and the cerebral circulation. They say that ether causes dilatation of the cerebral blood vessels or increase of the cerebral circulation—Berezin⁴⁷⁾, Finesinger¹⁴⁾ and Seze⁴⁸⁾ directly by the skull window method, respectively; Suenaga⁴⁶⁾, Koopmans⁴⁹⁾, Bedford⁵⁰⁾, White⁴²⁾, Goodman¹⁸⁾ and Collins³¹⁾, indirectly by alterations in the cerebrospinal fluid pressure, respectively; Shimada²⁾, Tanabe¹⁵⁾ and Kurusu³⁾, by thermostromuhr; Gherzi³²⁾ by ventriculography; and Laidlaw¹⁾, by histopathological technique. Yamakita¹³⁾ and Bennett²⁷⁾, however, claim that ether decreases the cerebral blood flow. Among them Laidlaw¹⁾ and Kurusu³⁾ take the same attitude as we do, and they study the cerebral hemodynamics not as a whole but in separate parts of the brain. In their results it seems that ether causes vasodilatation preferably in the cortex, while, on the contrary, our experiments have disclosed that ether makes, as the other anesthetic

drugs do, the blood supply good in the brain stem that contains centers of various primitive reflexes and functions necessary for maintenance of life.

6. TRILENE

Bibliographically there have been no works that treat the influence of trilene upon the cerebral circulation. Our experiments show that despite fall of the systemic blood pressure trilene increases the blood flow prominently both in the Galen's vein and in the superior sagittal sinus, and the increase is greater in degree in the former. In this regard trilene resembles chloroform well. They have been favored by clinicians as handy anesthetic agents partly because they keep the cerebral blood flow, particularly that of the brain stem, in sufficient supply in spite of the fall of the blood pressure.

7. CHLOROFORM

Several workers^{13) 14) 18) 46)} point out that inhalation of chloroform lowers the systemic blood pressure, and characteristically for chloroform the fall of the blood pressure is continuous and progressive¹⁸⁾. Results of our experiments coincide with that of those other investigators. It is said that chloroform dilates the cerebral vasculature or increases the cerebral circulation despite the fall of the blood pressure^{13) 14) 31) 32) 46) 47) 49) 51)}, and this is also the case in our experiments. Suenaga⁴⁶⁾ among them tells that the cerebral blood flow shows a slight decrease at the very beginning influenced by the fall of the blood pressure and then immediately it increases. It is interesting enough that what Suenaga said coincides with the attitude of the blood flow in the superior sagittal sinus in our experiments. By the way Takayama⁷⁾ showed that passive decrease of the cerebral blood flow due to fall of the systemic blood pressure is bigger in degree in the superior sagittal sinus than in the Galen's vein. In our results the blood flow in the Galen's vein increases rapidly after beginning of inhalation and reaches +110%, while the blood flow in the superior sagittal sinus does not change appreciably in the beginning and starts to increase suddenly in two to three minutes after beginning of inhalation to reach +55%.

In chloroform again it is shown that the hemodynamics of the brain stem are different than that of the cortex against the actions of the anesthetic drugs.

8. HYPOXIA

Many authors⁵²⁻⁶²⁾ agree that hypoxia induces rise of the blood pressure

and our experiments also showed a prominent rise of blood pressure by hypoxia. It is widely said that hypoxia dilates the cerebral vasculature or increases the cerebral circulation.^{3) 8) 28) 42) 63—77)} Among them, however only Schmidt⁷⁵⁾ and Kurusu³⁾ take the attitude to pursue influences of hypoxia upon the cerebral circulation in the divided areas of the brain. Our experimental data, therefore, obtained by means of newly devised method of determination of the hemodynamics of the Galen's vein are new and valuable assets in the study of this field; it is found that hypoxia causes prominent increase of the blood flow of +160% in the Galen's vein and of +140% in the superior sagittal sinus, respectively. It is reasonable that a living animal reacts with increase of the cerebral blood flow when confronted by hypoxia which may jeopardize his life and it is quite meaningful that the blood supply is preferably bettered in the brain stem.

9. HYPERCAPNIA

The effects of carbon dioxide in the blood upon the hemodynamics consist of stimulation of the vasomotor center and dilatation of the peripheral blood vessels. In regard with the blood pressure the two factors counteract each other, and it is interpreted that how the blood pressure changes under hypercapnia is determined according to the depth of anesthesia and other conditions which sway the balance between them. In our results the blood pressure changed it three ways—fall, no change and rise, and in each case there was increase of the cerebral circulation. In the group with rise of the blood pressure the increase of the blood flow was +140% for the superior sagittal sinus and +170% for the Galen's vein, while in the group with fall or no change of the blood pressure the increase of the blood flow was +60% for the superior sagittal sinus and +90% for the Galen's vein. The rate of increase of the cerebral circulation in group with rise of the blood pressure, therefore, is explained as a sum of increase of the cerebral blood flow due to primary cerebral vascular dilator effect of carbon dioxide as is seen in the group with fall or no change of the blood pressure and increase of the cerebral blood flow due to passive vascular dilatation secondary to elevation of the blood pressure. Many works have been published on the subject of the influence of hypercapnia upon the cerebral circulation, and they are in agreement that carbon dioxide causes cerebral vascular dilatation and increase of the cerebral blood flow^{3) 33) 36) 42) 48) 49) 54) 56) 63—65) 69—73) 76—89)}. Only Kurus³⁾, however, among them employs a method by which he pursues the

cerebral hemodynamics against carbon dioxide in two separate parts of the brain independently and simultaneously as we do in our experiments.

10. Disputes on the selective distribution of the anesthetic drugs in the central nervous system and our view on it.

Since Pick⁵⁾ divided the anesthetic drugs into cortical and thalamic in 1927, there came out works one after another aiming at clarification of the site of action of the anesthetic drugs in the central nervous system. Keeser⁹⁰⁾ in 1927 and Quastel⁹¹⁾ in 1932 in the first place showed selective distribution of barbiturates in the center by chemical and histological methods, but Kópanyi⁹²⁾ denied it in 1934. In the next place Feitelberg⁹³⁾ in 1939, Laidlaw¹⁾ in 1940, Chang⁹⁴⁾ in 1940, Etsten²³⁾ in 1946, Himwick²⁴⁾ in 1947, Wilkins²⁶⁾ in 1950, etc. took part in the dispute and they claimed the selective distribution and function of the anesthetic drugs in the central nervous system by respective methods and reasonings, but Maynert⁹⁵⁾ found that radioactive isotope of barbital did not localize in the specific area of the central nervous system in 1950. Shimada²⁾ in 1953, Kurusu³⁾ in 1955, Tanabe⁴⁾ in 1957, Urabe⁹⁶⁾ 97) in 1959 and 1960, etc. are to be referred to in our country as to the dispute.

There are numerous works on the subject of influence of anesthetic drugs upon the cerebral circulation, but only those works introduced above divide the central nervous system and pursue the hemodynamics in the separate sites of the brain. The subject, therefore, has not been sufficiently elucidated. No answer is available as to this problem even in the excellent treatises⁹⁸⁾ 99) recently published. As our research pursues the action of various anesthetic drugs upon the brain stem independently from that upon the cortex by means of a newly devised method of determination of the hemodynamics of the Galen's vein, it offers a sharp answer from a new standpoint in the history of the protracted dispute on the notion of selective action of the anesthetic drugs in the central nervous system. According to the data of our experiments anesthetic drugs except eunal increase the cerebral blood flow both in the brain stem and in the cortex, and the increase in the Galen's vein is always greater in degree than in the superior sagittal sinus. The secondary change, however, of the cerebral circulation associated with change in the blood pressure is greater in degree in the cortex than in the brain stem, as is seen particularly in cases of eunal and chloroform. In a word the blood flow in the brain stem as compared with that in the cortex tends to be augmented by anesthesia and tends to stay more stable against fluctuation of

the blood pressure during anesthesia. The classification of the anesthetic drugs after Pick is not justified as long as it is based on the idea that the specific actions of anesthetic drugs stem from the specific distribution of the drugs by the blood supply to the brain stem and the cortex.

CONCLUSIONS

Experimental studies on dogs were performed to clarify the influence of various anesthetic drugs upon the circulation of the brain stem by means of a newly devised method of determination of the hemodynamics of the Galen's vein.

Agents used were ravonal, eunal, nitrous oxide, cyclopropane, ether, trilene and chloroform. In addition hypoxia and hypercapnia were subjected to the same study, for they are common complicating factors encountered in conduction of anesthesia.

Results are as follows:

1. Ravonal, nitrous oxide, cyclopropane, ether, trilene and chloroform increase the cerebral blood flow, and the degree of increase is always more marked in the brain stem than in the cortex.
2. Eunal causes a unique change in the cerebral blood flow.
3. Both hypoxia and hypercapnia cause increase of cerebral blood flow, and increase of blood flow in the brain stem is more marked than that in the cortex.
4. Generally speaking the blood supply in the brain stem tends to be adequately maintained under general anesthesia, while the blood flow in the brain stem shows a more stable attitude than that in the cortex against fluctuation of the systemic blood pressure during conduction of anesthesia.

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