THE INFLUENCE OF LABOR ON THE CEREBRAL VASCULAR SYSTEM OF CERTAIN ANIMALS

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At the time of labor the fetus is subjected to a series of influences which may lead to oxygen deficiency and to disturbance of the cerebral circulation. Abnormal labor is often accompanied by fetal asphyxia, characterized by signs of profound disturbances of the cerebral circulation (hemorrhage, hyperemia and so on). It may be assumed that normal as well as abnormal labor affects the cerebral circulation of the fetus, the changes in which may be temporary in character and not expressed outwardly in the condition of the newborn infant.

In view of this we considered the problem of the character of the changes in the vascular system of the brain in the fetus during labor. For this purpose we investigated the filling and the morphological state of the vascular system of the cerebral hemispheres in fetuses of certain laboratory animals shortly before birth, immediately after birth and a few hours or 1 day after birth.

EXPERIMENTAL METHOD

Experiments were carried out on cats and rabbits. Twenty-six pregnant cats were used altogether, from which 15 fetuses and 42 newborn kittens were obtained, and 14 pregnant rabbits, from which 54 newborn rabbits were taken for the experiment.

The blood supply of the cerebral hemispheres of the fetuses shortly before birth was investigated only in cats. Rabbits were used for determination of the amount of blood in the cerebral hemispheres immediately after birth and a few hours or 1 day after birth. The fetuses were obtained either after decapitation of the pregnant cat (without anesthesia), followed by rapid opening of the peritoneal cavity and extraction of the fetuses from the uterus, or by extraction of the fetuses from the uterus of the pregnant cat under local anesthesia (with novocain). Immediately after extraction the fetuses were decapitated, as also were the newborn animals.

The blood volume was estimated colorimetrically after the hemoglobin had been extracted from the brain tissue and blood of the animal with acetone acidified with hydrochloric acid [1]. Usually only one hemisphere was used for determination of the blood volume; the second cerebral hemisphere was treated histologically to reveal the capillary network and the blood vessels (staining with acid fuchsin by Eros's method and silver impregnation by Klosovskii's method). In some cases series of sections were prepared through the whole brain of kittens and rabbits immediately after birth and these were stained with acid fuchsin to show any possible hemorrhages. The blood volume was expressed as a percentage of the weight of fresh tissue.

EXPERIMENTAL RESULTS

The results of the estimations are shown in Tables 1, 2 and 3.

As may be seen from Table 1, the quantity of blood in the cerebral hemispheres of cat fetuses (13-14 cm in length) shortly before birth varied between limits of 0.79-1.22%, or was on the average 1.06%. In cases where

TABLE 1

Volume of Blood in the Cerebral Hemispheres of Cat Fetuses and of Newborn Kittens

Expt. No.	A. Quantity of blood in the cerebral hemispheres of the fetuses, %	Expt. No.	B. Quantity of blood in the cerebral hemispheres of newborn kittens	Expt. No.	C. Quantity of blood in the cerebral hemispheres of kittens a few hours or a day after birth, %
1a	0,79	1	1,41	1a	0,70
1b	1,07	2a	1,40	2	1,10
1c	1,19	2b	1,37	3a	0,88
1d	1,16	3a	1,67	3b	0,91
2d	0,97	3b	1,65	4a	0,74
2e	1,01	4a	1,44	4b	0,82
3	1,16	4b	1,03	5	0,82
3b	1,09	5b	1,26	—	—
3c	1,22	6a	1,57	—	—
4a	0,97	6b	1,49	—	—
—	—	7a	2,09	—	—
—	—	7b	2,00	—	—
—	—	7c	1,69	—	—
—	—	8	1,93	—	—
—	—	9a	1,54	—	—
—	—	9b	1,22	—	—
—	—	10a	1,43	—	—
—	—	10b	1,34	—	—
—	—	10c	1,51	—	—
—	Average 1,06	—	Average 1,53	—	Average 0,81

Note: The letters attached to the numbers of the experiments in this and the succeeding tables imply kittens of the same litter.

the experiment was done on kittens immediately after birth and before suckling (5-30 minutes after birth), the quantity of blood in the cerebral hemispheres was 1.22-2.09%, or on the average 1.53%. Apart from one case (Table 1,B, experiment 4b), in all the cats of this group the values of the quantity of blood in the cerebral hemispheres were higher than in the fetuses before birth, by on the average 44%. The wide limits of variation of the blood volume in different animals are most probably the result of differing conditions of labor in each case.

The fact that the progress of the fetus along the maternal passages during labor can itself lead to a corresponding reaction in the vascular system of the brain is clearly proved by the following. The maximum values of the quantity of blood in the cerebral hemispheres were observed in the kittens which were born from cats in which labor lasted longest and was most difficult. Furthermore those cases are noteworthy of which the experiments shown in Table 1,A (experiments 2d, 2e) and in Table 1,B (experiments 7a, 7b, 7c) are an example. The kitten of experiment 7a was born first. Immediately after birth it was decapitated. The blood volume in the cerebral hemispheres of this kitten was 2.09%. The kitten of experiment 7b was born second. The cerebral hemispheres of this kitten contained 2% of blood. After the birth of these two kittens the cat was killed and the remaining fetuses were rapidly extracted from the uterus. In the next fetus, the head of which was already presenting, the cerebral hemispheres contained 1.69% of blood. The blood content of the cerebral hemispheres of the next two fetuses, which were found in the posterior segments of the uterus, was 0.97 and 1.01% (experiments 2d, 2e). Thus in the kittens which had passed along the labor passages, the blood content of the cerebral hemispheres was almost twice as high as in those fetuses not yet born. We observed an increase in the blood content of the cerebral hemispheres in kittens immediately after birth in all cases, irrespective of whether the kitten was born first, second or subsequently.

A few hours after birth, when the kitten was dry and began to suck the cat, the blood content of the cerebral hemispheres decreased. It follows from Table 1,C that the blood content of the cerebral hemispheres of sucking kittens in the first 24 hours after birth is between 0.7-1.1% (on the average 0.81%). Individual variations

TABLE 2

Quantity of Blood in the Cerebral Hemispheres of Newborn Rabbits

Expt. No.	A. Quantity of blood in the cerebral hemispheres of rabbits immediately after birth, %	Expt. No.	B. Quantity of blood in the cerebral hemispheres of rabbits a few hours or one day after birth, %
1a	1,87	1a	1,31
1b	1,82	1b	1,25
2a	1,65	2a	0,99
2b	1,74	2b	1,20
3a	1,55	3a	1,25
3b	1,56	3b	1,20
3c	2,07	3c	0,94
4a	1,48	3d	1,16
4b	1,52	3e	0,46
4c	1,87	4a	0,97
4d	1,43	4b	1,14
4e	1,31	5a	1,10
5a	1,09	5b	1,07
5b	1,33	5c	1,12
5c	1,25	6	1,11
6a	1,41	7a	0,53
6b	1,17	7b	0,75
6c	1,58	7c	0,89
6d	1,60	—	—
6e	1,68	—	—
6f	1,75	—	—
7a	1,65	—	—
7d	2,59	—	—
7c	1,66	—	—
7d	1,76	—	—
7e	2,23	—	—
7f	1,97	—	—
7g	1,39	—	—
7h	2,61	—	—
7i	1,76	—	—
—	Average 1,68	—	Average 1,02

in the value of the blood content in the cerebral hemispheres of these kittens are outside the limits of the variations in kittens immediately after birth. The fact that the reduction in the blood content of the cerebral hemispheres takes place within a few hours is shown by the following experiment (Table 1,B, experiment 5b and Table 1,C, experiment 1a). The kitten in experiment 1a was born first. After 4 hours, when it was dry and began to suck the cat, it was killed. The cerebral hemispheres of this kitten contained 0.7% of blood. The kitten in experiment 5b was born second and was decapitated immediately after birth.

The blood content of the cerebral hemispheres of this kitten was 1.26%, i.e. 80% above that of the kitten in experiment 1a.

Thus the blood content of the cerebral hemispheres, which rose during labor, fell again within a few hours after birth, on the average by 88%.

Analagous results were obtained in rabbits (see Table 2). Just as in the kittens, rabbits immediately after birth usually lay on their side, were wet and had not yet begun to suck the mother. The cerebral hemispheres of such rabbits contained 1.09-2.61% of blood, on the average 1.68%. These values of the blood content of the cerebral hemispheres of the young rabbits are close to those of kittens immediately after birth. In rabbits which were sucking, usually at the end of the first 24 hours after birth, the blood content of the cerebral hemispheres was 0.46-1.31%. or on the average 1.02%. In contrast to the kittens, the high values of the blood content of the cerebral hemispheres in the rabbits were maintained for a longer time after birth. In individual kittens, for example, the blood content of the cerebral hemispheres fell to low values (0.7%) after only 4 hours, whereas in the young rabbits high values of the blood content were maintained for 8-10 hours, and in some cases for 24 hours.

TABLE 3

The Effect of Prolonged Starvation on the Blood Content of the Cerebral Hemispheres of Newborn Kittens

Experiment No.	Blood content of cerebral hemispheres, %
A. Newborn kittens, before sucking, taken for the experiment immediately after birth	
1a. 5 hours after birth	1,23
1b 5 " " "	1,52
2a. 5-7 " " "	1,33
2b 5-7 " " "	1,87
3. 8 " " "	1,93
Average . . .	1,57
B. Kittens taken for the experiment at the end of the first day after birth (before the experiment were sucking the cat)	
1. Starved 5 hours	0,95
2a " 8 "	0,77
2b " 8 "	0,81
2c " 8 "	0,96
Average . .	0,87

Hence the blood content of the cerebral hemispheres in rabbits as also in kittens falls on the average by 64% in the course of the first 24 hours after birth.

It might be supposed that the fall in the blood content of the brain during the first few hours after birth is the result of the transfer of the animal to pulmonary respiration in atmospheric air, when the oxygen saturation of the blood of the newborn animal rises sharply by comparison with the blood of the fetus before birth [5, 6]. However it was shown by specially conducted experiments in which kittens, immediately after birth and not yet sucking the mother, were kept for a long time in a warm place (for up to 8 hours), but without the mother cat, that the breathing of atmospheric air alone still does not lead to a fall in the blood content of the brain. From Table 3, A it may be seen that the cerebral hemispheres of kittens 5-8 hours after birth and not yet sucking was 1.23-1.93%, or on the average 1.57%. Individual variations and the average values of the blood content in this case are practically the same as those in kittens killed immediately after birth. As was shown above, the blood content of the cerebral hemispheres of kittens which began to suck the mother cat soon after birth fell considerably within 4-5 hours (on the average to 0.81%). Consequently the act of sucking is of essential importance in restoration of the normal cerebral circulation after birth. The view that prolonged starvation of newborn animals, not yet sucking, may lead secondarily to an increase in the blood content of the brain, is not upheld by special experiments. It was shown in these experiments that prolonged starvation (5-8 hours) of day-old kittens, which previously had been with the mother cat from the moment of birth, does not lead to an increase in the blood content of the brain (see Table 3, B).

The cerebral hemispheres of these kittens contained 0.77-0.96% of blood, or on the average 0.87%, i.e. practically the same as in normal kittens of the same age.

Histological examination of the second cerebral hemisphere of the animals under study showed that the hemispheres of fetuses extracted from the uterus soon before birth contained little blood. In sections stained by Eros's method it could be seen that the cerebral cortex contains hardly any capillaries full of red cells. In some cases, when the plasma and the vessel walls were stained with acid fuchsin, it could be seen that the vessels contain very few or no red cells but much plasma. In the larger vessels, red cells were arranged in isolated groups,

separated by plasma, and not in a continuous mass. In the subcortical nuclei there were rather more capillaries filled with blood than in the cortex. In the white matter, in almost every case could be seen distended veins, densely packed with red cells. Here also could be found capillaries well filled with blood. The vessels of the pia mater were constricted and contained very little blood.

In sections impregnated with silver, the majority of the capillaries were constricted and unequal in diameter. The tone of the vessel wall or capillary loops was low. This condition of the intracerebral vessels, and also the staining of the plasma, the vessel walls and the paraplastic substance with acid fuchsin demonstrates that the brain of the fetus shortly before birth is in an edematous state.

We observed quite a different picture when we examined the network of vessels and capillaries of the cerebral hemispheres in kittens immediately after birth. In all sections of the cerebral hemispheres of these kittens a severe hyperemia was apparent. The capillaries of the cortex, the white matter and the subcortical nuclei were well filled with blood. Red blood cells lay in a continuous mass in the arteries and veins, which under these conditions were grossly distended; distension of the veins was particularly marked. The vessels of the pia mater were also dilated and well filled with blood. In some cases the capillaries in many areas of the cerebral cortex contained little blood. However the vessels of the white matter, the subcortical nuclei, the pia mater and the larger veins of the cortex were wide and densely packed with red cells.

Only a few hours after birth, the gross hyperemia was replaced by a state of edema. In the cortex and white matter of the cerebral hemispheres of newborn kittens which had survived for a few hours or a day, the capillaries were filled, mainly with plasma (which can be seen particularly clearly on examination of sections stained by Masson's method), and contained few red cells. The general state of the network of vessels and capillaries of the cerebral hemispheres of such kittens was extremely like its state in fetuses before birth. Here also, with constriction of the majority of the cerebral vessels, dilated veins are observed in the white matter, and the network of vessels and capillaries in the subcortical nuclei is quite well filled with blood. As previous investigations showed, the cerebral vessels of the kittens remain in such a condition for a long period of time after birth [2].

We obtained similar results from an analysis of the histological preparations from young rabbits immediately after birth and up to 24 hours afterwards.

On examination of serial sections, stained with acid fuchsin, from the brain of the kittens and young rabbits killed immediately after birth, recent small hemorrhages were often found. These were most often found in the ependyma of the lateral ventricles, but they could sometimes be seen in the cortex and the white matter. Usually escape of red cells into the substance of the brain was not accompanied by rupture of the capillary wall. As a rule the more blood was contained in the cerebral vessels, the more pronounced was their dilatation and the more frequent was the occurrence of hemorrhages. However we could not always demonstrate such a relationship between the quantity of blood in the brain and the number of hemorrhages. Sometimes with a sharp increase in the blood content of the cerebral hemispheres, hemorrhages were solitary or completely absent; on the other hand, hemorrhages were numerous in cases of comparatively slight increase in the quantity of blood in the brain.

Investigation of the vascular system of the brain in animals immediately after birth thus shows that labor has a marked influence on the cerebral circulation. The changes found in the vascular system of the brain during the progress of the fetus along the maternal passages in labor, both morphologically and by the quantity of blood present, are very similar to the changes in the brain during the artificial induction of asphyxia in newborn animals [3, 4]. Consequently the conditions of oxygen lack which may arise to some degree in the fetus as it progresses along the maternal passages in labor lead to corresponding reactions in the vascular system of the brain. These reactions of the cerebral vessels, shown collectively as an increase in the quantity of blood present therein, die out within 24 hours after birth. The repeated acts of sucking, which the animals perform soon after birth, must be regarded as an essential factor in the restoration of the normal cerebral circulation.

SUMMARY

The author studied the effect of labor on the cerebral vascular system of certain animals (cats, rabbits). The hemoglobin content and the morphological state of the vasculocapillary network of cerebral hemispheres was studied on fetuses of cats shortly before birth, directly after birth, in a few hours, and 24 hours following birth (in cats and rabbits). It was demonstrated that while the fetus is passing through the birth canal the quantity of blood in the large cerebral hemispheres is increased by 44% (on the average) in comparison with that in the

fetuses before birth. In a few hours following birth the blood content in the hemispheres is decreased both in kittens and in rabbits by 88% and 64% respectively. The repeated act of sucking is of importance for the change of cerebral circulation after birth. The quantitative changes in the blood content of the cerebral hemispheres were confirmed by histological examination. The latter show certain peculiarities in the changes occurring in the vascular system of the brain under the effect of labor.

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