

“On Cerebral Anæmia and the Effects which follow Ligation of the Cerebral Arteries.” By LEONARD HILL, M.B. Communicated by Dr. MOTT, F.R.S. Received March 22,—Read May 17, 1900.

(Abstract.)

1. *Cerebral Anæmia produced by Immobilisation in the Erect Posture.*

Many hutch rabbits when immobilised in the erect posture become convulsed and after a short period of time die (10'—20') from failure of respiration.\*

The blood, owing to its weight, congests within the abdominal vessels, while the abdominal viscera drag on and so kink the vena cava inferior. The heart, therefore, gradually empties, and the cerebral circulation ceases. These results are due to the flaccid and atonic nature of the abdominal wall of the hutch rabbits. Chloralisation hastens the onset of death by dilating the arteries and by stopping the convulsions, for the spasms help to return the venous blood to the heart. Compression of the abdomen by a bandage, or immersion of the animal in a bath of water up to the neck, entirely prevents the onset of symptoms. In the case of the bath the hydrostatic pressure of the water outside balances, but not completely, the hydrostatic pressure of the blood within. At the same time the water causes the viscera to float upwards, and so removes the kinking of the vena cava inferior.

Wild rabbits, owing to the better tone of their abdominal muscles, are not affected by immobilisation in the erect posture until after the lapse of some hours, and the same is the case in respect of dogs, cats, and monkeys. When the tone of the skeletal and vascular muscle becomes exhausted in these animals, owing to exposure, shock, &c., or is abolished by anæsthetics, the blood congests to the lower parts. Death finally results from cerebral anæmia. Immersion in a bath or compression of the abdomen has the same restorative effect on the circulation of these animals as on that of the hutch rabbit.

Intense congestion and œdema of the lower parts, accompanied by thirst, is said to occur in men under like conditions, and death no doubt results from cerebral anæmia.

Hutch rabbits, when thrown into syncope by immobilisation in the erect posture, recover almost immediately on their return to the horizontal position, or on immersion in a bath, or on compression of the abdomen. The animals when returned to the horizontal posture may

\* This fact was noted by Salathé.

be paralysed for a few minutes, and tumble and walk on the back of the fore-paws, but these symptoms quickly disappear even though the pupils' light reflex may have been abolished for 15'—20'.

## 2. *Cortical Excitability after Ligation of Cerebral Arteries.*

The author has produced contra-lateral clonic spasms in himself by sudden compression of one carotid artery. Consciousness of the cortical discharge arises from the sensations received from the parts in movement. The cortical discharge itself is unaccompanied with consciousness.

The cortex cerebri of dogs remains excitable and even hyper-excitable to electrical excitation after both carotid and vertebral arteries have been tied. The brain under these conditions is supplied with blood by the branches of the superior intercostal artery which enter the anterior spinal artery.

The brain is, however, rendered profoundly anæmic by the operation, and the animals are in consequence rendered more or less demented, anæsthetic, and paralysed. The paralysis results from a block established by the anæmia in the sensory projection, and association fields of the cortex cerebri for the motor cells are unaffected, in so far as not only purposive movements but typical fits can be excited on stimulating the "motor area." The "motor centres" are clearly not autonomous, and these experiments confirm the previous deductions concerning the origin of the paralysis which was obtained by Mott and Sherrington after division of the posterior nerve-roots of a limb, and by Exner after circumvallation of the cortex. Isolation of the cortical motor cells from sensory impulses produces paralysis, although the cells remain directly excitable.

In many monkeys the two carotids, and even the two carotid and one vertebral artery, can be tied without lessening the cortical excitability. The ligation of all four arteries is followed within one minute by loss of cortical excitability. In some monkeys (especially those in bad condition) ligation of both carotids abolishes the excitability.

## 3. *The Effect of Absinthe after Ligation of the Cerebral Arteries.*

The injection of absinthe, after ligation of the four cerebral arteries in cats and of the two carotid arteries in monkeys, produces as a rule only extensor rigidity of the fore limbs and dyspnoëic respiration. No clonic convulsions occur. On loosening the carotids violent clonic and tonic convulsions ensue, and these can be again cut short by re-clamping the carotids. So soon as the carotids are re-clamped, the extensor rigidity reappears. It is deduced from these experiments that clonus is of cortical, and tonus of sub-cortical, and probably of cerebellar, origin.

#### 4. *The Late Effects which follow Ligation of the Four Cerebral Arteries.*

These vary in different animals. Almost all rabbits die from failure of respiration within three minutes, after convulsions of an asphyxial type. There occur vagal inhibition of the heart, general vaso-constriction, and a high arterial pressure, prior to the failure of the circulatory system. The symptoms are in every way similar to those produced by clamping the trachea.

Cats become comatose and die within a few hours from respiratory paralysis, which is gradual in onset. Cheyne Stokes respiration sometimes results, and at a later stage long-drawn spasmodic gasps of the diaphragm occur at rare intervals. Extensor rigidity often occurs before death. Cats may survive the ligation of the two carotids and one vertebral artery.

Dogs recover from ligation of the four cerebral arteries, some after scarcely any symptoms, others after passing through a stage of dementia, accompanied by paralysis and anæsthesia, which lasts three or four days. The dogs during this period of dementia behave exactly like the dogs in which Goltz produced extensive destruction of the cerebrum. The spatial sensations depending on the nerves of skin, joints, and muscles are no longer brought into association with the sensations which are derived from the higher senses. Reflex defence and locomotor movements alone persist. Monkeys almost all die within twenty-four hours after ligation of the two carotids and one vertebral artery. The animals become soporose and then comatose. Extensor spasms, extensor rigidity, and failure of respiration follow. Monkeys recover without symptoms after ligation of both carotids.

In one monkey, after the two carotids and one vertebral artery had been tied, there ensued extensor rigidity and profound paralysis and dementia. This animal was kept alive by spoon feeding and continued in the same state. It was killed on the fifth day. The stage of sopor and coma or dementia may not appear in dogs or monkeys for an hour or so after the ligation of the arteries has been effected. On recovering from the anæsthetic the animals may at first appear lively and intelligent.

In man the ligation of one carotid artery is not free from risk, while the ligation of both carotids is recognised as a most dangerous operation. The two arteries can be tied successfully at intervals of time.

Attention is more particularly drawn to the following conclusions deduced from this research:—

1. The cerebral circulation of man, in the erect posture, depends on the tone and activity of the skeletal and respiratory muscles. The blood and lymph are returned from the lower parts to the heart by the expressive action of the muscles and constant change of posture.

2. The functions of the brain may continue after a great diminution

in blood supply. This substantiates previous work of the author in regard to the slight metabolism of the brain as measured by the exchange in blood gases. At the same time it does not favour the anæmic theory of sleep.

3. The electrical excitability of the motor area of the cortex cerebri persists when the sensory side of the brain is to a large extent paralysed, and the animals rendered more or less demented by profound cerebral anæmia.

4. The functions of the brain rapidly return so soon as efficient anastomosis is established. The period of partial paralysis and dementia lasts in dogs two or three days. Rabbits recover after the pupil reflex has been abolished for 15"—20".

5. The limits between the degree of anæmia required to produce dementia and that which paralyses the respiratory centre are extremely narrow. For example, monkeys recover *without symptoms* after ligation of both carotids, but as a rule die after ligation of both carotids and one vertebral artery.

6. There is considerable variation in the number of arteries which can be safely tied in various animals; *e.g.*, in man, birds, goats, and horses (Mayer) one carotid; in monkeys both carotids; in rabbits and cats both carotids and often both carotids and one vertebral; in dogs both carotids and both vertebrales.

7. The four cerebral arteries can be safely tied in monkeys in successive operations.

8. The cortex cerebri is the place of discharge of clonic convulsions. Tonus is of sub-cortical origin. The clonic stage of an epileptic fit can be cut short by compression of both carotid arteries.

Dr. Mott, to whom I am greatly indebted for help and advice in this research, has determined by microscopical examination of the anæmic brains by Nissl's method, that—

1. The cortical cells in the brains of the demented animals are swollen and diffusely stained. The stichochrome granules are absent. The nuclei are swollen. The veins are congested and there may occur hæmorrhages in the cortex.

2. The large pyramidal cells are least affected.

3. The changes occur very rapidly after ligation of the cerebral arteries, and disappear synchronously with the recovery of the animals from the stage of dementia.

In the case of the monkey, described above, the cerebrum was softened in patches, many of the cortical cells were degenerated, and there were signs of active phagocytosis. No changes in the neurons were displayed by the Golgi method.

The expenses of this research have been met by grants from the Royal Society Government Grant.