EFFECTS OF HEMISECTION OF MEDULLA IN PUPPIES AND ADULT DOGS

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In considering compensation of function, the aftereffects of damage to the medulla are of great practical interest, and one of the foremost problems is that of how to maintain an experimental animal alive for a long time after inflicting different kinds of damage. It is known that the most serious aftereffects are those following the damage to this region, and the outcome is frequently lethal on account of involement of the respiratory and cardiovascular systems [1, 3, 4, 11]. The surgical and neurophysiological aspects of cases where there has been recovery from circumscribed damage to medullary structures have sometimes been reported [4, 13]. In the last few years in our laboratory we have made a study of the aftereffects of damage to this region. In dogs, B. D. Stefanksov [12], and B. D. Stefanksov and V. N. Drozdova have studied the effect of permanent destruction of the dorsal motor nucleus of the vagus.

The object of the present investigation has been to study methods of preserving life for a considerable period after hemisection of the medulla, and also to determine the type of disturbances and the recovery process which occur.

METHOD

A lateral hemisection of the upper third of the medulla was performed in three adult dogs and in thirteen puppies aged 4-8 months. In four of the puppies, the cerebral cortex of one side was removed after the limit of functional restoration had been reached.

Measurements were made of respiration, muscle tone of the limbs, and of the skin temperature of the external ear and limbs. Still photographs and motion picture films were also made.

RESULTS

In three of the adult dogs, a lateral hemisection of the medulla caused breathing to stop immediately. Although artificial respiration applied for $1\frac{1}{2}$-2 hours restored normal breathing the animal died after 12-15 hours from bulbar paralysis and pulmonary edema. On puppies, the result of the operation was different. Of the 13 operated puppies, five died on the first day after the operation; four died on the fourth day, and four survived and were maintained under observation for a long time. In eight, respiration stopped at the time the hemisection was made, and in five the breathing became more rapid. Normal breathing was restored by artificial respiration applied for from 10-15 minutes to 1-$1\frac{1}{2}$ hours. As a rule, after the operation, respiration was unilateral and confined to the operated side (Fig. 1a). Bilateral pulmonary respiration was restored very gradually over a period of months. For a long time there was a difference both in frequency and amplitude of the respiratory movements on the two sides of the chest (see Fig. 1b and c). In most puppies there was a well marked Claude Bernard-Horner syndrome (Fig. 2): the eyeball was sunken, the orbital fissure and pupil were narrowed (sympathetic ophthalmoplegia). There was also a paresis or paralysis of the left hypoglossal nerve. In some cases there was a vestibular disturbance shown by a nystagmus which consisted of a rotation of the eye round the longitudinal body axis. Finally, in almost all the puppies the head was rotated so that the left ear was lowered.

It must be noted that unilateral hemisection of the medulla in puppies caused a bilateral disturbance of standing and locomotion. For the first week after the operation, all the animals lay on the side opposite to that on which the operation was performed, and were unable to change their body position. Gradually they learned to use their limbs, and were then able to sit or stand by resting one side against a wall. Muscle tone in the limbs was reduced, and there was also a reduced resistance to passive movement. Not until the 20-23rd day after the operation did the animals begin to walk, and their progress was then unsteady. After 2-3 months, standing and walking became almost normal. After 2-3 months changes in the skin temperature of the external ear and limbs, and also the thresholds of excitability of the flexor reflexes were not well shown.

Thus, the respiratory and locomotor disturbances following unilateral hemisection were compensated after a sufficient time, while the Claude Bernard-Horner

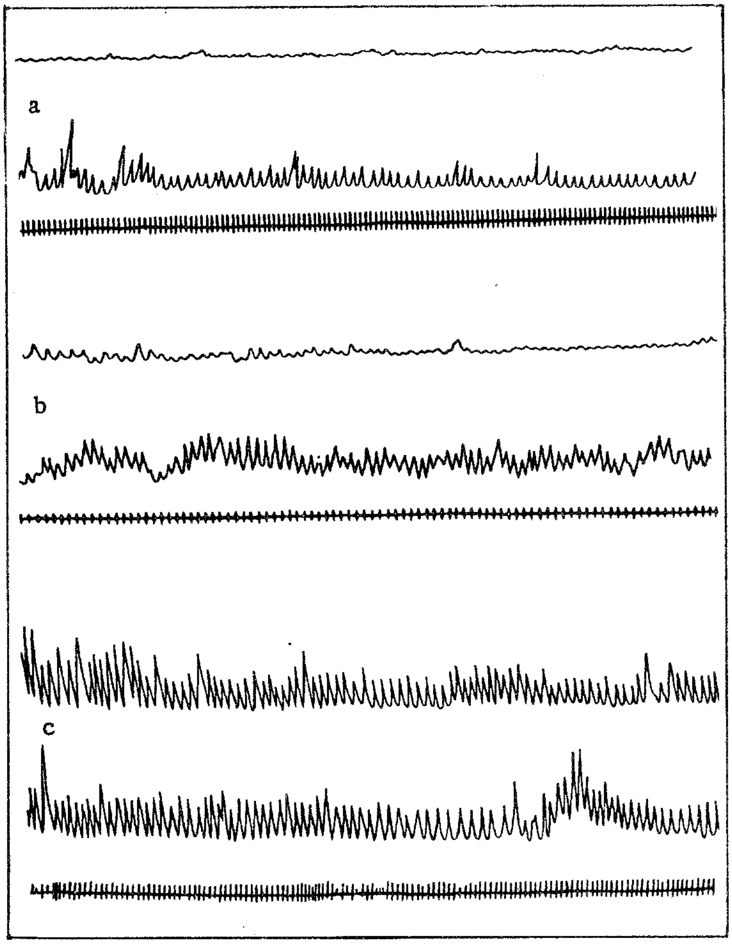

Fig. 1. Change of respiratory movement in the puppy Chita after left medullary hemisection. a) On the 12th day, b) on the 21st day, and c) on the 92nd day after the operation. Uppermost line--respiratory movements of the right side of the thorax; middle line--respiratory movements of the left half of the thorax; lower line--time marker (1 sec).

syndrome and XIIth nerve damage showed no improvement.

To determine the extent to which the cerebral cortex was involved in this compensation, cortical extirpations were made. The cortex of one hemisphere was removed in four of the puppies, in two the hemisphere removed was that on the operated side and in two it was the opposite hemisphere. The latter two puppies died on the third day after the operation from hemorrhage. In two others, removal of the left hemisphere caused recurrent motor disturbances. The animals attempted to rise at the end of the first week, but their movements were uncertain, and the foot was often turned onto the dorsal surface. At first they could stand and walk only with support; by the 21st-23rd day they could run or walk rapidly, but the limb movements were poorly coordinated, and the animals frequently deviated to the side of the operated cortex ("circus" movements).

Removal of the homolateral cortex caused a mild but prolonged respiratory disturbance. After the operation, pulmonary respiration continued to be bilateral, but was asynchronous: On the right the frequency was 30 and on the left 42 per minute, i.e., the rates were the same as were found to occur immediately after the left hemisection of the medulla (Fig. 3).

In these two animals, when no further improvement in standing or in locomotion occurred the second half of the cerebral cortex was removed. This operation caused permanent and irreversible disturbances of stance and locomotion. The animals were unable to stand at all, and made no attempt to rise onto their feet. Periodically there were motor spasms in which the limbs made stepping movements and there was a rotation along the longitudinal body axis. Respiration was bilateral and synchronous, but very variable and the frequency was greatly increased after even short periods of movement. Just as after unilateral decortication, permanent disturbance of the sympathetic enervation to the eye and cranial nerves was maintained.

Histological studies of the brain carried out by F. A. Brazovskaya on three puppies showed that in all cases the upper third of the medulla had been cut through halfway.

Fig. 2. Chita on the 16th day after left medullary hemisection.

The fact that in puppies as opposed to adult dogs life can be preserved after lateral medullary hemisection may evidently be explained as being due to the fact that structural and functional specialization and localization of function in the central nervous system has not been completed. On this account the nervous system of the puppy is more plastic and better able to restore the impaired functions. Evidence obtained earlier by our co-workers [7, 8] and by others [2, 6, 14] confirm that hemisection of the spinal cord carried out during the first months of life cause less marked and less prolonged functional disturbance than does the same operation in adult dogs.

Unilateral respiratory disturbance occurring after lateral medullary hemisection may perhaps be explained as being due to the fact that the connections of the bulbar with the spinal respiratory centers are crossed. The question as to where the crossing takes place has not yet been decided. It has been reported [17] that the spinal projections of the bulbar respiratory structures pass along the anterior and anterolateral fasciculi of the spinal cord. The investigations of Rossi and Brodal [16] on cats have shown that fibres from the cerebral cortex to the reticular formation of the medulla run in the pyramidal tracts. From our results it would appear that the tracts leading from the bulbar structures of the respiratory center to the corresponding spinal centers cross at the same level as do the pyramids. The result of hemisection is therefore to paralyze respiratory movements of the opposite side of the thorax. It may be that pathways crossing, as Pill [15] supposes, above the bulbar respiratory center also play an important part.

Disturbance of stance and locomotion may easily be explained as being due to damage to the extrapyramidal, cerebellar, and other pathways. By comparing the aftereffects of lateral spinal section and lateral medullary hemisection in puppies we can observe a difference in the extent and duration of the impaired supporting and locomotor functions. In the first case, restoration of function occurs much more rapidly and completely. It may be that this is because the medulla even at this age shows greater localization and specialization than the spinal cord, and is of greater importance in controlling these functions. However the problem requires further investigation.

Permanent functional disturbance of the cranial nerves results from the destruction of their nuclei. Sympathetic ophthalmoplegia following lateral medullary hemisection evidently results from damage to the bulbar sympathetic pathways and the results agree with reports [5, 10] that in bulbar paralysis there is damage to the sympathetic supply to the eye.

SUMMARY

The result of lateral hemisection of medulla oblongata was studied on puppies and adult dogs. It was found possible to keep the operated puppies alive, whereas the adult dogs died within 24 hours of the operation. Lateral hemisection of the medulla oblongata led to the development of unilateral reversible disturbances of pulmonary respiration and of locomotion; there was a permanent functional impairment of the cranial nerves and of the sympathetic innervation of the eye (Bernard-Horner syndrome).

Removal of one cerebral hemisphere caused a return of the motor disturbances.

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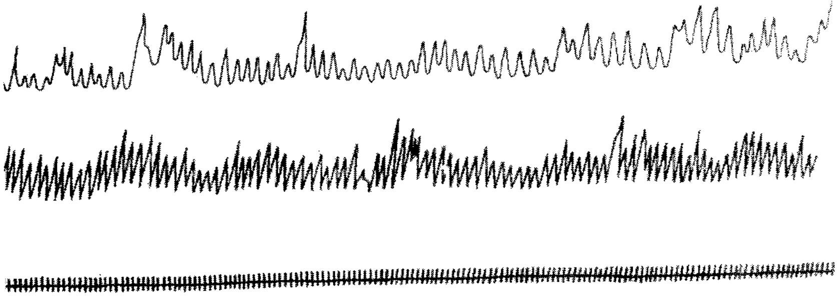

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