Studies on Brain Stem

IX. Comparative Anatomical Study of Brain Stems of some Species of Bats

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In our previous "Studies on Brain Stem VIII. On the Positions of Abducens Nucleus and Abducens Root of Birds"¹⁾, we have pointed out that in birds the abducens nucleus and its root characteristically appear rather to the caudal side than the facial nucleus and its root. Now, the bats of course belong to the mammalian kingdom, but they are one with birds in their habit of flying with their patagia. With reference to this habit of flying, we tried to investigate the influence of this habit on the anatomy of the brain stem including the relative positions of the abducens and the facial nuclei, in comparison with birds on the one hand and with other mammalia incapable of flying on the other.

As materials, we used Pal-carmine stained serial transverse sections of the brains of a South American vampire bat (*desmodus rufus*), a Japanese greater horseshoe bat (*rhinolophus*), an Indian tuber-nosed bat (*harpyiocephalus leucogostra*) and an Indian kalong (*pteropus edulis*), which we examined serially from the caudal side upwards to the cranial.

EXPERIMENTAL

Findings

Vampire bat (desmodus rufus): The abducens nucleus and its root make their appearance at a level far more caudal than the appearance of the facial nucleus and its root, indeed at the same level with the fila radicularia n. vagi et glossopharyngici. The pyramidal tract is almost unobservable both while the abducens nucleus is visible and in the sections more cranial to it. The olivary nucleus is seen on either side of the raphe in good development, occupying the position of the pyramidal tract in other mammalia. The vestibular nucleus is not so strongly developed as in birds, but

Fig. 1. Transversal section of brain stem in vampire bat, Pal-carmin staining, low power view. A abducens nucleus; a abducens root; v fila radic. n. vagi et glossoph. ; O olivary nucleus; G gracile nucleus; C cuneate nucleus.

Fig. 2. Transversal section of brain stem in greater horseshoe bat, Pal-carmin staining, low power view. A abducens nucleus; a abducens root; v fila radic. n. vagi et glossoph. ; O olivary nucleus; M medial vestibular nucleus; S spinal vestibular nucleus.

better than in other non-flying mammalia. The development of this nucleus was appreciated by ocular estimation of the ratio of the area it takes in against the total cross-area of the section.

Greater horseshoe bat (rhinolophus): Similar to the case of the vampire bat above, the abducens nucleus and its root appear much more caudally than the facial nucleus and its root, at the same level with the fila radicularia n. vagi et glossopharyngici. The facial nucleus becomes visible only after the abducens nucleus has entirely disappeared from the field. The pyramidal tract is very weak in development, so that we were almost led to deny its existence, its proper position being taken up by the olivary nucleus. The vestibular nucleus was found comparatively well developed.

Tuber-nosed bat (harpyiocephalus leucogotra): The abducens nucleus be-

gins to appear at the ventro-lateral side of the genu of the facial root as the facial nucleus almost goes out of sight, similar to other mammalia in this respect. At the level where the facial nucleus disappears completely, the abducens nucleus does not attain full development. The pyramidal tract is considerably well developed. On the level where the olivary nucleus comes into view on the caudal side, the pyramidal tract exists on the ventral side of the olivary nucleus close to it, adjacent to either side of the rhapshe; the olivary nucleus is not situated on the lateral side of the pyramidal tract, as in other mammalia, but adjacent to the latter in vertical positions on either side of the rhapshe. As we go up more cranially, the olivary nucleus gradually develops, so that the pyramidal tract is pushed by to the lateral side, only a very small portion remaining on the ventral

Fig. 3. Transversal section of brain stem in tuber-nosed bat, Palcarmine staining, low power view. A abducens nucleus; Os superior olive; g genu of facial root; f facial root; L lateral vestibular nucleus; M medial vestibular nucleus; P pyramidal tract.

side of the olivary nucleus in a posture as if crushed down by the latter. At more cranial levels, when the olivary nucleus begins to decrease in size, the pyramidal tract on the lateral side of it begins to invade the space occupied by the olivary nucleus, while the portion crouched down on the ventral side thereof begins to enlarge. These two strands of the pyramidal tract show the appearance of two independent tracts, the one coming back from the lateral position taking in the more dorsal position. Soon after the facial nucleus makes its appearance, the dorsal bundle first decussates, the ventral bundle decussating at the rostral level. The vestibular nucleus is not better developed than in other mammalia in any marked degree.

Indian kalong (pteropus edulis): The abducens nucleus and its root begins to appear more cranially than the facial nucleus and its root. The pyramidal tract is rather strongly developed and its relation to the olivary nucleus is similar to that of the organs in the tuber-nosed bat described above: before the appearance of the olivary nucleus, the pyramidal tract is

Fig. 4. Transversal section of brain stem in kalong, Pal-carmin staining, low power view. A abducens nucleus; Os superior olive; g genu of facial root; f facial root; L lateral vestibular nucleus; M medial vestibular nucleus; P pyramidal tract.

found lining both sides of the raphé, dorsal to which the nucleus makes its appearance and the subsequent growth of the latter forces the larger part of the tract laterally, except a tiny strand left on the ventral side of the expanding nucleus. Later on, when the olivary nucleus begins to diminish in size, the lateral and ventral bundles composing the pyramidal tract come back to reassume the position usurped by the olivary nucleus till at the level where the latter ends its existence, the pyramidal tract is reinstituted in the original medial position. At approximately the same level, the strands of the pyramidal tract begin to decussate. The vestibular nucleus in this kind of bats is of ordinary development, not stronger than in other non-flying mammalia in any sense.

DISCUSSION

The four species of chiroptera studied above are not much different in their ecology, including their common habit of aviation, though some difference may exist in their food habit. However, it is of interest to note that the four fall into two distinct groups in view of the structure of their brain stem; the one comprises the vampire and the greater horseshoe bats, the other the tuber-nosed bat and the kalong. In the first group, the abducens nucleus appears at a more caudal level than the facial nucleus—an arrangement similar to the characteristic relative positions in birds. It is accepted that the birds have no pyramidal tracts; in this group of bats, the pyramidal tract does exist, but in an extremely weak development, almost only in a trace of it. The vestibular nucleus, the nucleus of equilibrium, is also much better developed in this group than in other non-flying species of mammalia, though, maybe, in a lesser degree than in birds. Such observations indicate a brain stem anatomy much closer to birds than to ordinary mammalia.

On the other hand, in the specimens belonging to the latter group, the relative positions of the abducens nucleus and the facial nucleus are quite the same as in other families of mammalia, the abducens nucleus coming into view at a level near the cranial end of the facial nucleus. The pyramidal tract is rather well developed, while the vestibular nucleus is not so unusually developed as in the first group.

Bats, both of the first and the second groups above, are all one in their birdlike habit and capacity of flying through the air, and it has been established by Spillmann²⁾, Koike³⁾ and others that their patagia come into form in early embryonic stage, and yet, interestingly enough, only four specimens studied by us showed that they are divisible into two distinct groups, one with the anatomy of the brain stem nearer to birds than other mammalian species and the other quite vice versa.

However, there is one common point between the two groups, that is, the mutual relation of the pyramidal tract and the olivary nucleus. The olivary nucleus is located close to either side of the raphe and is rather well developed in both groups, but in the first group comprising the vampire bat and the greater horseshoe bat, the pyramidal tract is almost rudimentary, which in the second group comprising the tuber-nosed bat and the kalong, where the pyramidal tract is rather well developed, it is side-tracked to a lateral position by the olivary nucleus, so that their relative positions are just the reverse of those in other mammalian brain stems. The pyramidal tract recovers its original position only at the level where the olivary nucleus has ceased to exist. It may be said that the pyramidal tract has surrendered its right of way to the olivary nucleus as far as the latter continues to exist. This fact seems to indicate that, in bats, the olivary nucleus takes precedence over the pyramidal tract in the anatomy of the brain stem, showing here also an affinity to birds in this respect. As Brehm⁴⁾ has pointed out, the bats are not at all inferior to birds in the ability and delicate aptitude of their flight, and it is no wonder that the olivary nucleus belonging to the extrapyramidal tract takes in a superior position over the pyramidal tract in bats.

Anyhow, it may be clearly noted that the observations on the brain stems of bats show some points of resemblance in their anatomy to those of birds.

SUMMARY

1. The abducens nucleus, the pyramidal tract and the vestibular nucleus of a vampire bat and a greater horseshoe bat show an arrangement more resembling birds rather than other members of mammalia.
2. These organs of a tuber-nosed bat and kalong are almost identical

with other non-chiropteral mammalia in their positions and development.

3. The olivary nucleus takes precedence over the pyramidal tract in all the four specimens of bats studied.

References

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