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Location of the spinal nucleus of the accessory nerve in the human spinal cord

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ABSTRACT

The segmental extent and topography of the spinal nucleus of the accessory nerve (SNAN) was investigated in the adult human spinal cord. Transverse sections of segments between the lower medulla and C6 were stained with cresyl violet and the motor cell columns identified according to the numerical locations defined by Elliott (1942). The segmental extent and topography of the cervical part of column 2 resembled that previously described for the SNAN of primates.

Key words: Human spinal cord; motor columns; spinal motoneurons.

INTRODUCTION

The spinal nucleus of the accessory nerve (SNAN) has been studied by many investigators in different mammals, including Kitamura & Sakai (1982) in the rat, Ullah & Salman (1986) in the rabbit, Clavenzani et al. (1994) in the sheep, Ueyama et al. (1990) in the Japanese monkey, Jenny (1988) in the cynomolgus monkey, Augustine (1986) in the baboon and many others. For the human spinal cord, Pearson (1938) tried to investigate the SNAN in the human embryo, but no attempt has been made to locate this nucleus in the adult human spinal cord. In the study of motor neuron groups and motor columns of the human spinal cord, Routal & Pal (1999) observed a long column of the lateral division running parallel to column 1 (the sole column of the medial division) throughout its extent. This column was designated as column 2, which was divided into cranial or cervical (from the lower medulla to C5) and caudal or thoracolumbosacral (from C8 to S3) part (Fig. 1). The topography and vertical extent of the cervical part of column 2 interestingly shared all the characteristic features of the SNAN in primates and human embryos. As mentioned earlier, no clinical report is available for the localisation of the SNAN in the adult human spinal cord. On the basis of the experimental reports in primates and the study on human embryos, we attempted to correlate the cervical part of column 2 of the present study with the SNAN.

MATERIAL AND METHODS

The spinal cords were removed from 8 male cadavers aged 28–60 y. The lower medulla (below the pyramidal decussation) and upper 6 cervical segments were examined for the presence of the SNAN. Segments were defined with the help of the ventral rootlets of the spinal nerves. Individual segments were identified and embedded in paraffin wax. Serial cross sections of each segment were cut at 25 μm and stained with cresyl violet.

Motor columns were reconstructed by using the procedure given by Elliott (1942). To reconstruct individual motor columns, cross sectional charts of the cord were prepared for each segmental level. Each chart represented the pattern of motoneurons of 20 successive cross sections. Motoneuron groups were identified with the help of these serially arranged charts. Motor columns were reconstructed and were designated by numbers. Numbering was performed sequentially from the medial to the lateral margin of the ventral horn. The most medially placed column at C1 was designated a column 1 and successive numbers were allotted to the columns situated lateral to it as they appeared in a craniocaudal direction. Motor

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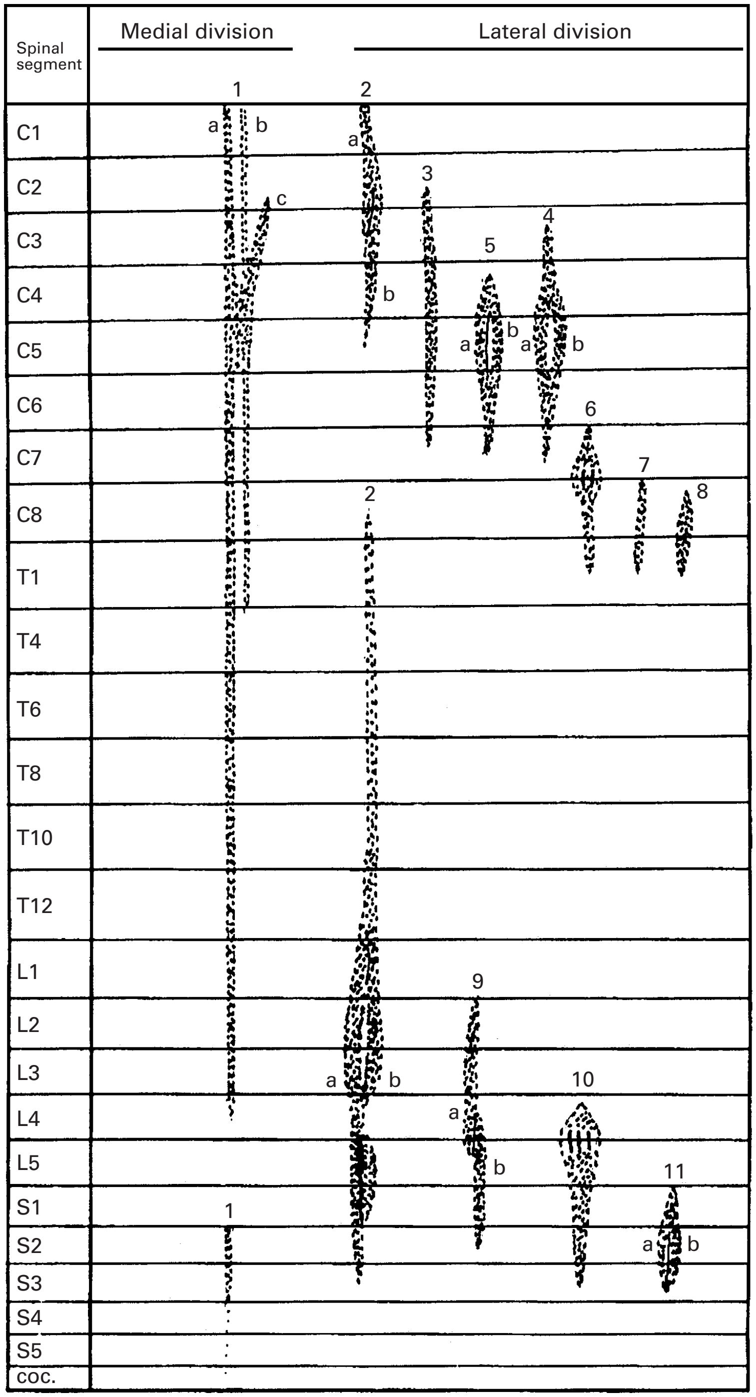

Fig. 1. Segmental extent of motor columns of complete human spinal cord.

columns were classified into medial (column 1) and the lateral (column 2 et sequ.) divisions (Fig. 1).

OBSERVATIONS (see Figs 2, 3)

At the level of the lower medulla, 2 motor columns were observed in the ventral horn. The medially placed column 1 extended through all cervical segments. Column 2 was the first column encountered in the lateral division. It formed a distinct column from the lower medulla to the cranial two thirds of C4. Caudal to C4, column 2 was ill defined, extending to mid C5 where it was represented by small groups of neurons located at short intervals.

At the level of the lower medulla and C1, column 2 formed a single column occupying a central area of the ventral horn. In this position, it was dorsolateral to the ventral subdivision of column 1, i.e. 1a, and ventrolateral to the dorsal subdivision 1b. In the caudal half of C1, column 2 shifted laterally and increased in size, especially in the ventrodorsal direction. Subsequently it divided into ventral 2a and

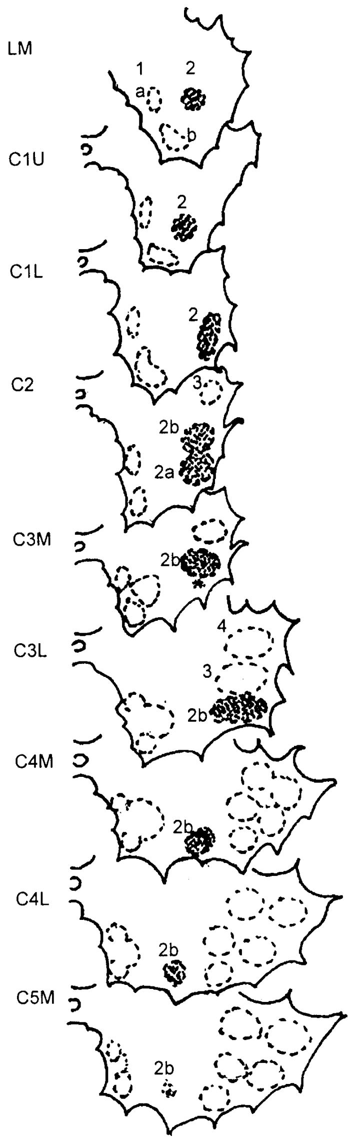

Fig. 2. Cross sections at different segmental levels between lower medulla and C5 to show position of column 2 in the ventral horn and its relation to other motor columns. C, cervical; L, lower; M, middle; LM, lower medulla; U, upper.

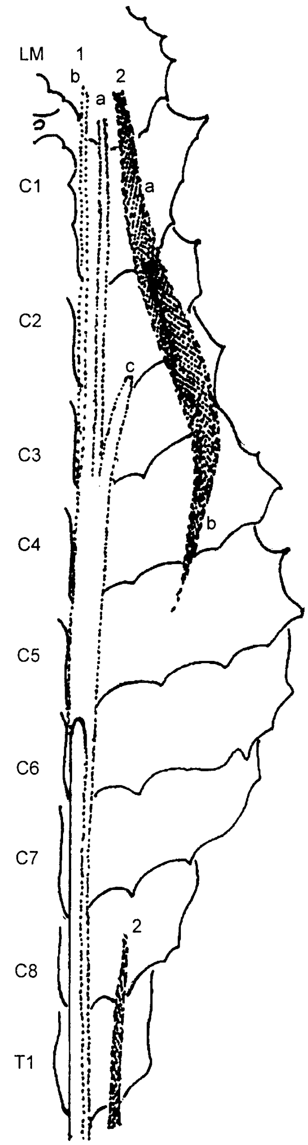

Fig. 3. Segmental extent and subdivisions of motor column 2 in the cervical region. For reference, column 1 is shown as stippled lines.

dorsal 2b subdivisions. These 2 subdivisions were partly fused. Caudal to C2, 2a gradually decreased in size and ultimately terminated at mid C3. With the disappearance of 2a, there was a marked increase in the size of 2b. Thus 2b was a prominent column at C3 and the upper two thirds of C4. From the caudal third of C4, 2b decreased in size and eventually disappeared in mid C5. In the cervical region column 2 maintained a constant relation to column 1 (medial to it) and column 3 (dorsal and later lateral to it).

Although the cervical part of column 2 was composed of 2 subdivisions, except at C2 and the cranial third of C3 it was represented by a single column as the 2 subdivisions were situated in craniocaudal positions. Unlike column 1, column 2 followed a curved route along its caudal–rostal axis. As a result, its position in the ventral horn altered between segments. Its cranial part at the level of the lower medulla and the cranial half of C1 was located centrally. In the caudal half of C1, it shifted laterally. Its middle part (from caudal C1 to the cranial two thirds of C4) occupied a lateral position in the ventral horn while its caudal part from the lower third of C4 again shifted in ventromedial direction and occupied almost the same position in the ventral horn as observed at its cranial end.

DISCUSSION

All neuroanatomical textbooks (Larsell, 1951; Carpenter, 1977; Williams, 1995) agree with the classification of motoneuron groups in the spinal

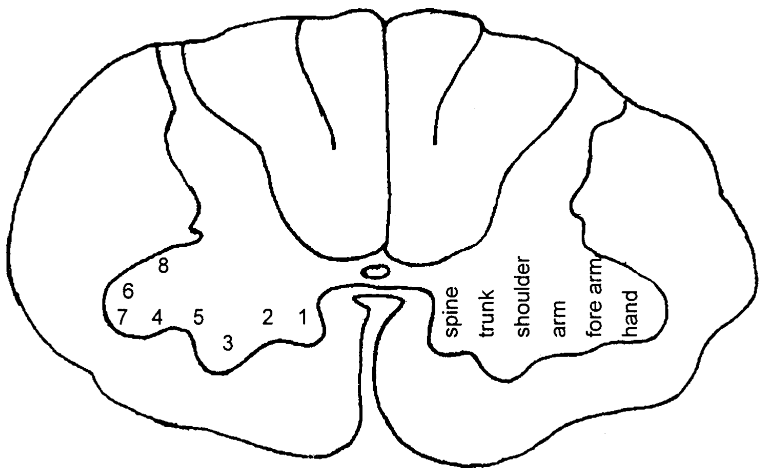

Fig. 4. Schematic representation of motor columns of the present study in the cervical spinal cord (Rt) and somatotopic representation of body and limb muscles as described by Carpenter (1977) (Lt).

ventral horn into a medial division (innervating axial muscles) and a lateral division (innervating limb muscles). Carpenter (1977) described the somatotopic organisation of motoneuron groups in the human spinal cord: on tracing motoneuron groups from medial to lateral, in the cord, the successive innervation is to the spine, trunk, limb girdle, upper arm, forearm and hand (Fig. 4). Therefore the column for the trunk muscles is situated between the column for spinal (medially) and those for limb muscles (laterally). In the present study, column 1 being the most medial column, can be considered to innervate spinal muscles, whereas columns 3 to 8, as they are confined to those spinal segments contributing to the brachial plexus, probably innervate the limb muscles. Therefore column 2 can be considered to innervate the trunk muscles (Figs 1, 4). Cervical column 2 obviously projects to the neck region, which prompts us to consider it as the SNAN.

With respect to the segmental extent and topography of the SNAN, reports vary between various species and even for the same species (Kitamura & Sakai, 1982; Ullah & Salman, 1986). However in primates, there is general agreement regarding the segmental extent and topography of the SNAN (Augustine & White, 1986; Jenny et al. 1988; Ueyama et al. 1990).

Segmental extent

In the Japanese monkey (Ueyama et al. 1990) and savana baboon (Augustine & White, 1986) the SNAN has been identified to span between the lower medulla and C5, while in the cynomolgus monkey (Jenny et al. 1988) it was located between the lower medulla and C4. In human embryos (Pearson, 1938), it extended from the junctional region of the lower medulla and C1 to C6 but was less distinct in the last 2 cervical segments. Many neuroanatomical textbooks (Larsell, 1951; Crosby et al. 1962; Carpenter, 1977; Williams, 1995) described the SNAN as extending from lower medulla to C5 or C6. Thus almost all reports agreed that the SNAN is a prominent column from the lower medulla to C4. In the present study, the cervical part of column 2 extended from lower medulla to mid C5. However, it was less distinct in C5.

Topography

In mammals (other than primates), the SNAN is composed of 2 to 3 columns. (Flieger, 1964, 1966, 1967; Kitamura & Sakai, 1982; Clavenzani et al. 1994). This might be due to the fact that in mammals the sternocleidomastoid and trapezius are composed of 2 to 3 distinct elements, which might be reflected in the pattern of their SNAN. However, in the rabbit, the SNAN is a single column (Ullah & Salman, 1986).

Experimental studies in primates have demonstrated that the SNAN is a single column (Augustine & White, 1986; Ueyama et al. 1990). Similarly in human embryos (Pearson, 1938), this nucleus was reported to be a single column. In the present study, the cervical part of column 2 formed a single column but was composed of 2 subdivisions (2a, 2b). These occurred in a craniocaudal direction. The cranial half of the column 2 was represented by 2a and its caudal half by 2b. However at C2 and the upper third of C3, both were observed together (Fig. 3) and in cross sections they resembled a figure 8 (Fig. 2). No subdivisions have been reported in primates and human embryos. In fact in all those studies, the results were represented in cross sections and no attempt was made to reconstruct the column. It is interesting that in primates (Augustine & White, 1986; Ueyama et al. 1990), neurons of the SNAN from the lower medulla to C2 projected to the sternocleidomastoid which corresponds to the segmental extent of 2a of the present study, while motoneurons innervating trapezius were located between C2 and C5 corresponding to 2b of the present study. Thus, in primates at the level of C2, the SNAN presents a common pool for sternocleidomastoid and trapezius. Corresponding to this fact 2a and 2b were observed together at the level of C2 with an appearance of a figure 8 in cross sections (Fig. 2).

Shifting of the column

When tracing vertically, a curved course for the SNAN was a characteristic feature observed in primates. Augustine & White (1986) described shifting of this nucleus in the ventral horn in great detail. According to them, the rostral part of the SNAN occupies a central position within the ventral horn at C1, while its intermediate part at C2 and C3 occupies a lateral position and its caudal part from C4 to C5 is located again in a central position. Carpenter (1977), Crosby et al. (1962) and Williams (1995) were also of the opinion that the SNAN, as it proceeds craniocaudally, changes its position within the ventral horn at different segmental levels. However, Pearson (1938) failed to find any similar shifting in position of the SNAN in human embryos. He described this nucleus as a straight column. In the present study, we observed that the cervical part of column 2 shifted from its original position in the same direction and almost at the same segmental levels as described by Augustine & White (1986) (Figs 2, 3). The curvature of the cervical part of column 2 can be explained as follows. At the level of lower medulla column 2 was the only column of the lateral division, observed with column 1. In the absence of Rexed lamina VIII, column 2 occupied a central position in the ventral horn. With the appearance of lamina VIII column 2 shifted laterally. Thus caudal to C1 it occupied a lateral position in the ventral horn which also reflects the role of trapezius (C2 to C5) in the shoulder girdle. As the other columns of the lateral division (columns 3, 4, 5) appeared dorsal to column 2, the caudal end of column 2 shifted more ventrally and eventually medially along the ventral border of the grey matter. Thus caudal to mid C4, cervical column 2, again occupied a medial position in the ventral horn. However the ventromedial shifting at the caudal end was also observed in other columns of the cervical region. Being the first column of the lateral division, the cervical column 2 changed its direction at its cranial and caudal ends, which enhanced its curvature. It is evident that the findings of Pearson (1938) in human embryos do not tally with those of primates and the present study, the reason being that the embryonic patterns are under a developmental process, and hence they may differ from the adult.

Functional and developmental aspects

In relation to the functional aspects of the SNAN, all experimental evidence indicates that motoneurons of the SNAN show a craniocaudal somatotopic organisation (Kitamura & Sakai, 1982; Augustine & White, 1986; Ullah & Salman, 1986; Ueyama et al. 1990; Clavenzani et al. 1994). Cranial neurons of this nucleus project to the sternocleidomastoid, while the caudal half of this nucleus innervate the trapezius. With regard to the segmental extent and topography, the cervical part of column 2 of the present study presented a reasonably close correspondence with the SNAN of primates. On the basis of experimental evidence (Augustine & White, 1986; Ueyama et al. 1990), 2a and 2b of the present study can be considered as subdivisions projecting to the sternocleidomastoid and trapezius respectively.

According to Williams (1995), the spinal root of the accessory nerve is the sole motor supply to the sternocleidomastoid, whereas the innervation of the trapezius is more complex. The upper part of this muscle is innervated by the spinal root of the accessory nerve, while the lower two thirds receives a motor supply from the cervical plexus. However, in some individuals, following sacrifice of both the accessory nerve and the cervical plexus, the trapezius is observed to receive its motor supply from other sources, probably the thoracic nerves. With regard to its development, the trapezius has been described as a muscle of mixed origin, i.e. from the branchial arch and cervicothoracic somites (Keith, 1948; McKenzie, 1955). This correlates with the extensive origin of the trapezius (from the skull to the 12th thoracic vertebra) and its multiple innervation. It seems unlikely that the spinal root of the accessory nerve would be the sole motor supply for such an extensive muscle. It seems logical that the thoracic part of the trapezius might receive innervation from the thoracic spinal segments. The lower half of column 2 of the present study was located from C8 to S3 (Fig. 1). It is quite possible that its motoneurons from C8 to T12 might project to the thoracic part of the trapezius.

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