COLUMNAR ORGANIZATION OF THE NEURONS IN THE VENTRAL HORN OF THE CERVICAL AND UPPER THORACIC SPINAL CORD IN ALBINO RAT

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SUMMARY

The columnar organization of the motoneurons in the ventral horn of the cervical and upper thoracic spinal cord in adult albino rat was studied by Elliott's method. The motoneurons were not homogeneously distributed throughout the ventral grey, but instead formed relatively well defined groups if seen in cross sections, or nearly continuous columns if seen in longitudinal sections. Some of these columns extended throughout the entire length of the cervical and upper thoracic spinal cord; others were present only in the cervical enlargement. Between 5th cervical and 1st thoracic segments more cell columns were noticed than those in the rostral and caudal segments. This increase in columns occurred in the ventrolateral and dorsolateral groups which formed several sub-groups, however, some degree of fusion existed between few of the columns described.

INTRODUCTION

While there is an abundant and elaborate information on the arrangement of the neuronal groups or columns in the spinal cord of the various species of animals, both adult and foetal, and to the relation between these columns and the peripheral nerves or muscles[1-18] , very little is known concerning the columnar organization of neurons in the cervical and upper thoracic spinal cord of an easily manageable experimental animal, the adult albino rat.

The purpose of the present study was to ascertain the columnar organization of neurons in the cervical and upper thoracic spinal cord of adult albino rat as a preliminary study for the localization of motoneurons forming some of the major forelimb nerves in adult albino rat by horseradish peroxidase method of tracing neuronal connections.

MATERIAL AND METHODS

In the present study , which was carried out that the Department of Anatomy, B.M.S.I, J.P.M.C , Karachi , five adult albino rats, 60 to 150 days old, weighing between 150 and 200 gms were used. The animals were deeply anaesthetised with intraperitoneal injection of chloral hydrate solution and perfused through the left ventricle with 50 ml of isotonic saline followed by 500 ml of 10% formalin. Dorsal laminectomies were performed and the spinal cord extending between C1-T2 segments was removed as a single block. The relevant segments of the excised portion of the spinal cord were identified with reference to the entry of dorsal rootlets[15] and were marked with Indian ink on the left side under the dissecting microscope. Each minute mark was made midway between the caudal and rostral rootlets of the two adjacent segments. The spinal cord was

stored in 10% formalin for 24 hours for proper fixation. The cord was divided into segmental blocks which were processed for routine paraffin technique and 20 um thick sections were cut from each block in serial orders; three specimens were sectioned transversely, one sagittally and one coronally. The complete series were mounted on albuminised slides and stained with 0.5% cresyl violet.[19]

The reconstruction drawings were made according to the method devised by previous worker.[8] Images of the sections were projected with Leitz micro projector. The outline of the grey matter of the first section of the series was traced on a sheet of paper and the position of each cell image in the ventral horn was marked by a dot. The peripheries of the succeeding 25-30 sections were then made to fit accurately to the pencil outline so that the corresponding portion of all the sections should successively fall on exactly the same portion of the drawing and the cells in these sections were recorded by dots. Following this, new outlines were drawn for every 25-30 consecutive sections and the position of neurons in these sections were entered as dots in the new outlines. By doing so, three representative drawings were made for each segment of the spinal cord studied indicating as rostral (R), middle (M) and caudal (C) third of the relevant segment.

RESULTS

According to the present study, the nuclear masses in the ventral horn of the spinal cord were observed to be arranged into four major groups, the medial, ventrolateral, dorsolateral and retrodorsolateral groups, each of which occupied the position indicated by its name. These groups in turn were subdivided into 13 smaller subgroups extending longitudinally through series of rostrocaudal segments in the cervical and upper thoracic cord with ascending numerals.

The relative position of the different columns was consistent and showed marked coincidence in different animals. The arrangement of cell columns appeared complicated between middle C5 and caudal T1 segments and fusion between some columns at different levels was also observed. This organization corresponded fairly well with the cervical enlargement which was demonstrated by the cross sectional reconstruction drawing of the various segments of the cervical spinal cord (Fig-1).

The neuronal cell columns of this study were numbered according to the nomenclature devised by an earlier worker[3,4]. The medial group was subdivided into three columns: column 1,2 and 3 ; the ventrolateral group into five columns: column 4,5,6,7 and 8 ; dorsolateral group into four columns: column 9,10,11 and 12 and retrodorsolateral group displayed no subdivision and was designated as column 13.

The position, compactness and extent of various columns is well illustrated in Fig-1. The description of the columns is as follows:

Column 1

The column extends uninterrupted throughout the entire length of the cervical cord and 1st two thoracic segments and is located in the medial margin of the ventral horn.

Column 2

The longitudinal extent of this column corresponds to column 1. At the beginning it is very large, but is reduced towards the middle of C3 segment, occupying the most ventral part of the ventral horn, but in the succeeding segments it shifts gradually medially to lie just anterolateral to column 1 through its remaining extent, however, fusion between both the columns is observed at few locations.

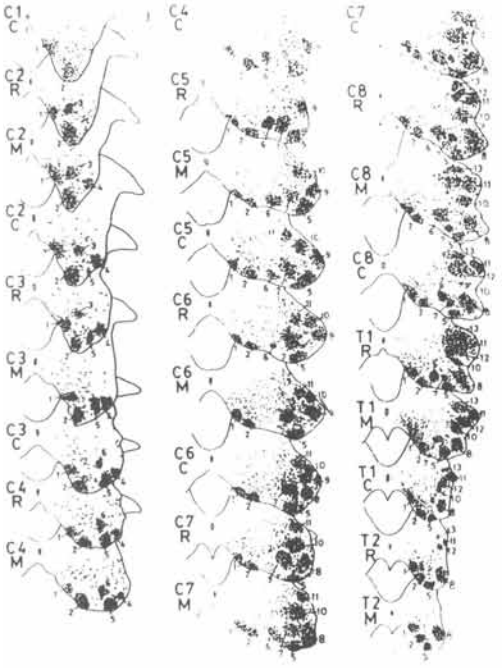

Fig. 1 Photograph of projection drawings of serial transverse sections of the right ventral horn showing the relative position of various cell columns in the cervical and upper thoracic spinal cord in adult rat. R, M and C indicate the rostral, middle and caudal parts of the relevant segment respectively. x 20

Column 3

Appears lateral to column 1, towards the centre of the ventral grey. It extends between the rostral part of C2 segment and the rostral part of the C3 segment.

Column 4

It makes its appearance in the middle of C2 segment, lying dorsolateral to column 2 and extends caudally to the middle of C4 segment. In the rostral part of the C3 segment, its medial border fuses with the lateral border of column 5 but at mid C4 level it appears to merge with column 5.

Column 5

Appears in the caudal part of C2 segment as a small group of cells midway between column 2 and column 4. As it extends caudally, the thickness of the column increases, but from the rostral part of C8 segment dwindles to the middle of T2 segment. It occupies the ventrolateral edge of the ventral grey through most of its extent, but caudally a medial shift occurs, so that at the middle of T2 segment, occupies the ventromedial edge of the ventral grey. In the middle of C7 segment, its lateral edge fuses with the medial edge of the column 8.

Column 6

This column appears in the caudal part of C3 segment where it lies dorsal to column 5. In C4 and C5 segments the column gradually shifts ventrally. At the beginning of the C6 segments, the column reduces greatly in size, disappears in the middle of C6 segments but reappears as a well defined oval group of cells, dorsomedial to column 5 in middle of C7 segment and continues caudally to its termination in the rostral part of the T1 segment.

Column 7

This column extends between the rostral part of the C5 segment and the middle of T1 segment. Throughout its length, it lies dorsomedial to column 5, however, in the caudal part of C8 segment, it appears to fuse with column 6. Further, the column in the middle of C8 segment occupies a relatively ventral position as compared to its position in other segments.

Column 8

This makes its appearance in the caudal part of C6 segment as a solid, compact, rounded mass of cells, which continues uninterruptedly to the middle of T2 segment. The density of cells of this column increases greatly in C7 and C8 segments. It is the

lateral most column in the ventrolateral group of cells of ventral grey. There exists a fusion of this column with column 5 in the middle of C7 and rostral part of C8 segments and with column 7 in the caudal part of C8 segment.

Column 9

This column appears in the caudal part of C4 segment, occupies dorsolateral margin of ventral grey and extends to the caudal part of C6 segment as a well defined group of cells. It is located anterolateral to column 10 between the middle of C5 segment and its termination.

Column 10

It appears in the middle of C5 segment located dorsomedial to column 9 as a somewhat oval, dense mass of cells which continues caudally to its termination in the caudal part of T1 segment. There appears to be a slight ventral and medial shift of this column in C7 segment but through the rest of its extent it is located ventral to column 11 and 12, but in the middle and the caudal parts of T1 segment it lies ventromedial to column 12. The density of cells reduces greatly in the caudal part of C8 and rostral part of T1 segments. Also there exists a considerable fusion with the dorsolaterally lying column 12 in the middle and caudal parts of T1 segment.

Column 11

It makes its first appearance in the caudal part of C5 segment located dorsomedial to column 10 and extends caudally to the rostral part of T2 segment. At the caudal C7 segmental level it is placed dorsolateral to column 10. This column enjoys a great degree of fusion with column 10,12 and 13 at difference levels of its extent.

Column 12

This column appears as a compact group of cells located dorsomedial to column 11 at the caudal part of C7 segment and extends to the rostral part of T2 segment. It takes a ventral shift in the rostral part of C8 segment due to the emergence of column 13 lying dorsomedial to it at this level. The column becomes quite thick in the caudal part of C8 and rostral part of T1 segment. This column also exhibits great fusion with column 11,13 and 10.

Column 13

The only column which constitutes the retrodorsolateral group of the nuclear mass of the ventral horn, becomes visible dorsal to column 12 in the rostral part of C8 segment and extends caudally to terminate in the rostral part of T2 segment. The fusion of this column with column 11 and 12 is apparent in the Fig-1.

DISCUSSION

Many excellent investigations have been made to elucidate the details on the organization of the neurons in the ventral horn of the spinal cord in various species of animals including man but almost no attention has been paid to the neuronal localization in terms of anatomical cell groups in the ventral horn of the cervical and upper thoracic cord of adult rat despite the fact that columnar organization of motoneurons in rodents have well differentiated pattern which does not resemble other animals.[9] With regard to the arrangement of ventral horn neurons in the rat cervical cord, there appears no study in the literature except by one investigator[3] using the new born rat. It is rather unfortunate that no study is available for comparison and determination of the validity of the present work regarding establishment of columnar organization in the cervical cord of adult rat.

The present study reveals thirteen separate longitudinally arranged columns in the ventral horn of the cervical and upper thoracic cord. Although the nomenclature of

the previous investigator[3] has been adopted, the numerals used to designate the various columns of cells in this study have no bearing on the numbers used by earlier worker.[3] The columns are numbered mostly in order of appearance on following the sections cephalocaudally.

Comparing the two studies, it is quite evident that there is a considerable degree of agreement between the present and that of previous study[3] albeit with certain differences. It appears that the columns 2,3,4,6,7 and 8 of the previous study[3] represent, respectively, the columns described here under the numbers 3,1,2,6,7 and 5 while columns 8,9,10,11,12 and 13 of this study correspond to columns 9,10,11,12 and 13 of the earlier study.[3] The column 5 of the earlier study[3] appears to have merged with its column 7 with the advancement of age as no such well developed column 5 described by previous worker[3] is seen at C5 through C7 segments. Further column 7 of this study is quite well developed while that of the previous study[3] is quite attenuated in C5 and C6 segments, so it could be concluded that during the course of maturation column 5 of the new born rat has advanced towards column 7 to form a well developed column 7 of the adult rat.

It seems that columns 8 and 9 of the present study correspond to column 9 of the earlier study.[3] To add further , column 4 of this study which extends from caudal part of C2 segment to the middle of C4 segment does not seem to have its homologue in the previous study[3] and it appears that this column merges into column 5 in the middle of C4 segment resulting in a well developed column 5 at the caudal level of C4 segment.

The comparison thus concludes that the motor nuclei in the ventral horn of the cervical and upper thoracic spinal cord of albino rat at birth are almost in a fully differentiated mature form. In addition these cell columns or nuclei are not compact bodies of cells belonging to a single nerve as has been seen that the motoneurons forming the ulnar and radial nerves overlapped in many instances in various cell columns which will appear somewhere else in the literature.

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