

Morphometric Studies on the Spinal Cord Segments of the Domestic Rabbit (*Oryctolagus cuniculus*)

Frag, F.M., Elayat, M.A., Wally, Y.R. and ElKarmoty, A.F.

Faculty of Veterinary Medicine, Cairo University, Egypt

With 12 figures, 3 tables

Received January, accepted for publication September 2012

Abstract

Twelve adult angora and chinchillas rabbits of different ages, sex and weights were used. After the routine preparation and dissection of the specimens the spinal cord exposed for morphometric studies by using Venire Caliber and magnifying lens. The measurements taken comprised; the total length of the spinal cord, the dorsal, ventral root attachment and inter root lengths – segment lengths, the transverse and dorsoventral diameters lengths, the cervical and lumbar enlargements, as well as the conus medullaris.

Key words

Rabbit, Spinal cord, Morphometry

Introduction

The anatomical studies of the spinal cord received the attention of many anatomists. In this respect Mansour (1980), Abu-Zaid (1982), Abd Elghany (1995) gave valuable studies on the anatomy of the spinal cord in donkey, buffalo, and goat respectively. Gabr (1982) provided devel-

opmental studies on the spinal cord of the rabbit however, the present investigation aimed to extend the knowledge on the morphometric records of the spinal cord of the rabbit via the quantitative measurements.

Material and Methods

The present study was conducted on twelve adult angora and chinchillas rabbits of different sex.

The animals were prepared, scarified and bled through the common carotid arteries. The blood vessels were thoroughly washed by worm normal saline solution then injected by an amount of 150-180 cc formalin (10%). The cadavers were then preserved in 10% formalin solution for a duration ranged between 10-15 days before they manually dissected. Measurements were achieved by the aid of a magnifying lens and Venire caliper. The obtained values are recorded and tabulated.

The Nomenclature used in this study was adopted according to the Nomina Anatomica Veterinaria N.A.V. (2005).

Results

The spinal cord commences on a level with the middle of the occipital condyles where the cranial most rootlets of the first cervical spinal nerve root emerge and extends caudally to the caudal end of the second sacral vertebra where it tapers forming the Conus medullaris. Its average length ranges between 31.7 - 37.5 cm. with a mean value about 34.7 cm. The regional length values and their indices are recorded in table (1). The approximate average weight of the spinal cord in a medium sized rabbit ranges between 5-7 gm.

The spinal cord is made up of 37 segments which are regionally divided into 8 cervical, 12 Thoracic, 7 Lumbar, 4 sacral and 6 caudal spinal segments.

The Morphometric records: Include the root attachment lengths, the inter root lengths, the segment lengths, the dorsoventral and transverse diameters of each segment as well as their volumes.

The root attachment length was measured as the distance between the rostral most and the caudal most rootlet of the same spinal nerve root (Fig.1/1). **The dorsal root attachment lengths** (Chart, fig 7) are greatest at C3, T12, L1 and S1 cord segment levels. **In the cervical region**, it shows a gradual increase in values from C1 to C3 then gradual decrease from C4 to the end of the cervical region. **In the thoracic region**, it shows slight decreased val-

ues from T1 to T5, followed by a gradual increase in length till it reaches its maximum value at T12. **In the lumbar region** it bears the highest value then gradual decrease to the end of the region. **In the sacral region**, it starts with a maximum value at S1 then gradually decreased to S4.

The ventral root attachment lengths (Chart, fig 8) are greatest at C2, T12, L2 and S1. **In the cervical region** it shows a lowest value at C1 and greatest C2 followed by a gradual decrease in values till reach a minimum at C6 then increased to at C7 and C8. **The thoracic region** bears equal lengths from T3 to T6 followed by a gradual increase till reach a maximum value at T12. **In the lumbar region** L2 is the greatest value among both the spinal cord as a whole and the lumbar region (11.0 mm) then the values gradually declined to reach a minimum value (5.0 mm) at L7. **In the sacral region** it starts with a maximum length value at S1 and gradually decreased till to the end of the cord.

The values of the ventral root attachments are greater than the corresponding dorsal ones as shown in graph Fig (9).

The inter root length was considered as the distance of the cord surface between two successive spinal nerve roots and devoid of any rootlets (Fig 1/2).

Dorsal inter root lengths (Chart fig 10) are greatest at C2, T12, L5 and S1 cord segment levels. **In the**

cervical region it shows the lowest value at C1 while, the highest one is at C2 then followed by a gradual decrease in length from C3 to C7 then increases at C8. **In the thoracic region**, it starts with the lowest length at T1 followed by a gradual increase from T2 to reach maximum T12. **In the lumbar region**, from L1 to L4 the values nearly equal while the maximum value appears at L5 then gradually decreased to the end of the cord.

Ventral inter root lengths (Chart fig.11): The highest values for the ventral inter root lengths were found at C2. T12, L5 & S4 cord segment levels. **In the cervical region**, a low length value appears at C1 while, the highest one at C2 then decreases from C3 to C8. **In the thoracic region**, it starts with the lowest value at T1 followed by variable values from the T2 to T7 then gradual increase from T8 to T12. **In the lumbar region** it shows decreasing values from L1 to L4 followed by a maximum length value at L5 then decline at L6. **In the sacral region**, it slightly increases from S1 to S4.

It is evident that the dorsal inter root length values are greater than the ventral ones (Graph fig.12)

The Segment length (Fig. 1/3 table 2) was considered as the length of the cord extending from the rostral most attachment of one spinal nerve root to the rostral most attachment of the succeeding spinal nerve root. The segmental lengths

vary along the different regions of the spinal cord. The longest segments are recorded at C2, T12, L2 and S1 while, the remaining ones are progressively shorter.

In the cervical region the segment lengths begin by a low value at C1 followed by a highest value at C2 then gradually decreased from C3 to C8.

In the thoracic region, the length values of the segments are gradually increased from T1 to T12. **In the lumbar region**, the gradual increase continues till it reaches maximum along the whole length of the spinal cord, at L2 (20.0 mm). Further back the values decrease to the end of the cord.

The contour of the spinal cord is cylindrical and compressed dorso-ventrally. Its transverse and dorso-ventral diameters show variation in dimensions in the different regions being greatest at the cervical and lumbar enlargements.

The transverse diameter (Table 2) shows a slight variation in dimensions among the different regions of the cord. They are greater at C7, T1, L7 and S1

In the cervical region, it gradually decreased from C1 to C4 then increased from C5 to C7. **In the thoracic region**, the first thoracic spinal segment has the greatest value in this region then from T2 to T12 the values are approximately of equal dimensions. **In the lumbar region**,

the first three segments have also the same value then from L4 they are gradually increased to reach their maximum value L7. **In the sacral region**, the first sacral segment has the greatest value while from S2 to S4 the values decreases.

The dorso-ventral diameters (Table 2) bear the largest values at C7, T1, and L7& S1

In the cervical region, the first four cervical spinal segments are gradually decreased while from C5 to C7 the values are slightly increased. **In the thoracic region**, the values gradually decrease from T1 to T9 While, at T10 - T12 they are nearly equal. **In the lumbar region**, the first three spinal segments have also equal values while from L4 they gradually increased to L7. **In the sacral region**, S1 is considered the greatest then decreases from S2 to S4.

Quantitative measurements

The volume of each spinal segment is shown in (table 2). It depends on the dimensional values and segment's length. It shows greatest values at the cervical and lumbar enlargements.

Intmuscentia cervicalis.

The cervical enlargement (Fig 2/1, 4/8) is formed of five segments including the last four cervical segments and the first thoracic spinal segment. Thus, it occupies the vertebral canal from the caudal half of the fourth cervical vertebra to the first thoracic one. The length, transverse and dorsoventral diameters as well as the volume of the segments

forming the cervical enlargement are recorded in table (2). Its average length is recorded in tables (3)

Intmuscentia lumbalis

The lumbar enlargement (Fig 2/2, 5,6 /9) is formed of seven segments comprising the last four lumbar segments as well as the first three sacral ones. It extends within the vertebral canal, from the caudal one-fourth of the fourth lumbar vertebra, cranially to the caudal three-fourths of the first sacral one, caudally. The values of the transverse and dorsoventral diameters as well as the volume of the segments forming the lumbar enlargement are recorded in table (2). Its average length is recorded in tables (3)

The length value of the lumbar enlargement is longer than that of the cervical one (table3).

Conus medullaris

The medullary cone (Fig 2/3, 6/8) is made up of nine segments (S2 - Ca 6) with a total length value about 30.0 mm. It begins at S2 segmental level that occupying the last lumbar vertebra L7 and terminates by the 6th caudal segment (Ca6) at the second sacral vertebra. It begins with a transverse diameter equal to 5.0 mm and tapered caudally reaching 1.00 mm at its terminal end. Its segmental length values are gradually decreased to the end of the cord.

Discussion

The current investigation recorded the start limit of the spinal cord on a level with the middle of the occipital

condyles where the cranial most rootlets of the first cervical spinal nerve root emerge. Dellmann and McClure (1975) in all domestic animals determined its beginning limit by the foramen magnum.

The present study reported that the average length of the spinal Cord was about 34.7 cm. However, Gabr (1982) gave 39.5 cm. in the same animal. Moreover, the indices of the cervical, thoracic, lumbar and sacrocaudal segments were 19.2%, 36.5%, 34% and 10.3% respectively. While Santos et al. (1999) mentioned 18.47%, 35.26%, 34.17 and 12.02 % in the same animal.

The current investigation showed that the largest values among the whole length of the spinal cord for both; dorsal and ventral root attachment lengths were reported at L1 and L2 respectively, the result which varied than other species of animals as these values were reported at C3 in the Donkey (Mansour, 1980), buffalo (Abu-Zaid, 1982) and sheep (Rao, 1990), and C5 in the camel (Mansour, 1983).

The present study revealed that the values of the ventral root attachment lengths were greater than the corresponding dorsal one. Similar observations were mentioned in the donkey (Mansour, 1980), camel (Mansour, 1983). On the other hand, Sharma et al. (1973) in goat stated that the dorsal root attachment lengths are greater than the ventral one.

In the present study the average values of the dorsal inter root lengths were greater than those of the ventral one , a result which

simulates that have been mentioned in the donkey (Mansour,1980) and camel (Mansour,1983). However, Abu-Zaid (1982) in Buffalo mentioned that both; dorsal and ventral inter root length's values are nearly equal in the lumbar and unequal in the sacrocaudal regions.

The present result agreed with that have been mentioned by Thomas and Combs (1962) in cat, Abu-zaid (1982) in buffalo as they defined the spinal cord segment as that part lied between the rostral most rootlets attachment of the spinal nerve to the rostral most rootlets of the next nerve. While Dellmann and McClure (1975) in all domestic animals had defined the spinal cord segment as that portion of the spinal cord where rootlets of a pair of spinal nerves enter and leave the spinal cord ,the result which inconvenient to us as they ignored the inter root length which was considered as a part of the segment.

The present work revealed that the spinal cord of rabbit was formed of 37 segments, while Greenaway et al. (2001) gave 31 different segments in the same animal.

Concerning the length of the spinal cord segments in the different regions, the present work revealed that the longest segments were recorded at C2, T12, L2 and S1. However, Greenaway et al. (2001) mentioned C2, T13, L2 and S2 as the longest segments in the same animal. In the same regard, the present work recorded the longest segment along the whole length of the spinal

cord at L2. On the other hand the longest segment was C3 in goat (Sharma et al., 1973), buffalo (Abu-Zaid, 1982) and donkey (Hifny et al., 1982) or at C5 as in camel (Mansour, 1983), or in the thoracolumbar region as mentioned by Thomas and Combs (1962) in cat. Regarding the quantitative measurements of the cord's segments the present findings revealed that the most voluminous segments along the cord's regions were found at C2, T12, and L5 & S1 and the highest values along the spinal cord as a whole were found between T12 and L7 while, the lowest ones were reported at S3 & S4. On the other hand, the account given in the same animal by Greenaway et al. (2001) was varied as the segment volume C3, T13, L2 and S1 were the most voluminous cord segments in the respective cord regions.

In rabbit, the cervical enlargement was formed between C5 - T1, a result which simulates that mentioned by Gabr (1982) in rabbit. Its formed between C7 - C8 in pig (Dellmann and McClure, 1975), C6 - T1 in the dog (Miller et al., 1964) or between C6 - T2 in buffalo (Abu-zaid, 1982) and in camel (Mansour, 1983) or C5 - T2 in Indian sheep (Rao, 1990) and in donkey (Mansour, 1980).

In rabbit, the lumbar enlargement was formed between L4 - S3. In the donkey, it is found between L2 - S1 (Mansour, 1980), between L6 - S1 in camel (Mansour, 1983), between the last three lumbar and first two sacral in buffalo (Abu-zaid, 1982),

between L4 - S1 in sheep as mentioned by Rao (1990), between L6 - L7 in the pig and L4 - S1 in the dog (Dellmann and McClure, 1975).

The present study revealed that the lumbar enlargement is longer and more voluminous than the cervical one, while Abu-zaid (1982) in buffalo and Mansour (1983) in camel gave a controversial opinion as the cervical enlargement was longer than the lumbar one.

In rabbit the termination of the spinal cord was at the caudal end of 2nd sacral vertebra. On the other hand it terminated between S3-S4 (Greenaway et al., 2001) or between S1 and S4 (Santos, et al., 1999) in the same animal.

The present work reported the lengths of the medullary cone in rabbit as (29.94 mm.) On the other hand Santos et al. (1999) gave 45.1 mm in rabbits

References

- Abd El-ghany N, A, A, N. (1995):
Some anatomical studies on the spinal cord of the goat with special references to its meninges and vascularization PH.D Thesis, (Anatomy) Faculty of vet. Medicine, Cairo University.
- Abu-Zaid, S.M.S. (1982):
"Some gross anatomical studies on the prenatal and postnatal morphological features on the spinal cord of the water buffalo (*Bos Bubalis* L.) PH.D Thesis, (Anatomy). Faculty of vet. Medicine, Cairo University.

- Dellmann H.D. and R.C. McClure (1975): Central nervous system of domestic animals in "Sisson-Grossman" anatomy of domestic animals). 5th edition Vol.2 reviewed by R.Getty. W.B. Saunders-Philadelphia, London, Toronto.
- Gabr M. (1982): "A study on the development of the spinal cord of the Rabbit". Thesis, M.D. (Anatomy). Faculty of medicine, Assuit University.
- Greenaway, Partlow, Gonsholt and Fisher (2001): "Anatomy of the lumbosacral spinal cord in rabbits". J. of the American animal hospital association, Vol.37.Issue 1, 27-34.
- Hifny A., A.K. Ahmed and A.A. Mansour (1982): "Anatomy of the spinal cord segments of the Donkey". Assiut Vet. Med. J. Vol.10, No.19.
- Mansour A.A.K. (1980). "Some morphological features of the spinal cord in Donkey". M.V.SC thesis (anatomy). Faculty of vet. Medicine, Assuit University.
- Mansour A.A.K. (1983). "Some anatomical features of the systema nervosum centrale of *Camelus dromedarius*". PH.D. Thesis (anatomy). Faculty of vet. Medicine, Assuit University.
- Miller, M.E., G.C. Christensen and H.E-Evans (1964): Anatomy of the Dog, 1st. Ed. W.B. Saunders Comp. Philadelphia, London, Toronto.
- Nomina Anatomica Veterinaria (2005): 5th Ed. prepared by the International Committee on Veterinary Gross Anatomical Nomenclature (I.C.V.G.A.N.) and authorized by the General Assembly of the World Association of Veterinary Anatomists (W.A.V.A.), Knoxville, TN, USA. Published by the Editorial Committee, Hannover, Columbia, Gent, and Sapporo
- Rao G.S. (1990): "Anatomical studies on Ovine spinal cord". Anatomischer Anzeiger, V.1 71, P 261-264.
- Santos A.L.; Lima E.M.M. and Santana M.I. (1999): "Length of the spinal cord and Topography of medullary cone in rabbits". Bioscience Journal, V.15, N.2, P.45-62.
- Sharma D.N., Y.singh and L.D. Dhinger (1973). "Anatomical studies on the spinal cord segments of Goat (*Capra hircus*)". Haryana Agriculture University. J. of research, 3 No.2, 87-92.
- Thomas C.E. and C.M.Combs (1962): "The spinal cord segments". Anatomy Gross structure in the adult Cat. American j. Anat., 110, 37-47.

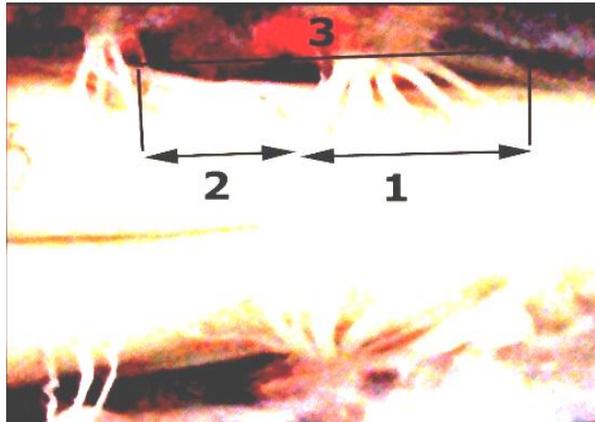


Fig (1): A photograph showing :

- 1) Root attachment length,
- 2) Inter-root length,
- 3) Segment length (1+2).

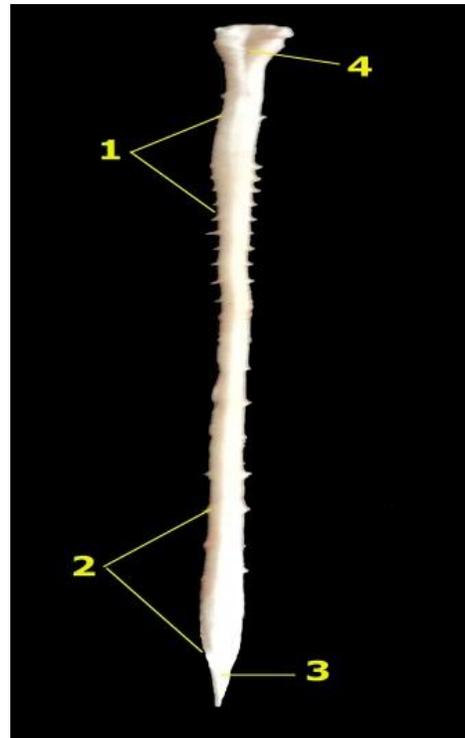


Fig (2): A Photograph showing the spinal cord of the rabbit.

- 1) Intumescentia cervicalis,
- 2) Intumescentia lumbalis,
- 3) Conus medullaris,
- 4) Rhomboid sinus.

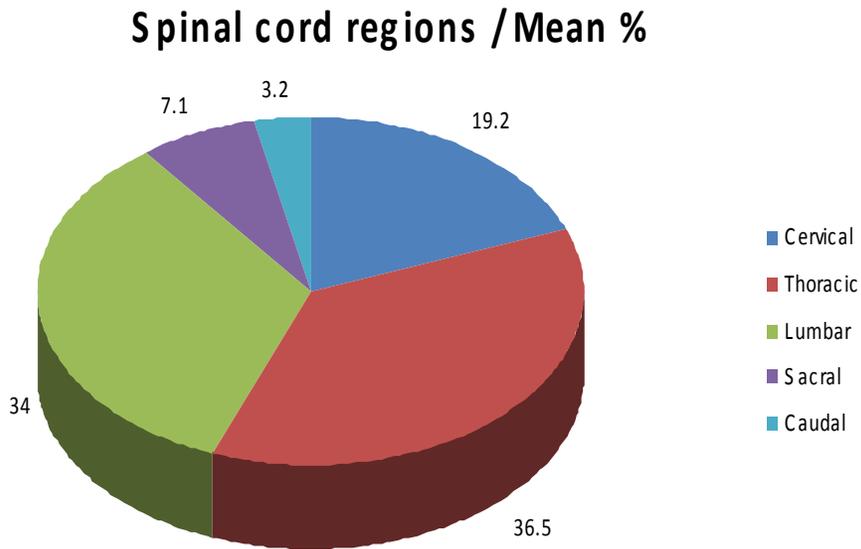


Fig (3): A Diagram showing spinal cord region indices.

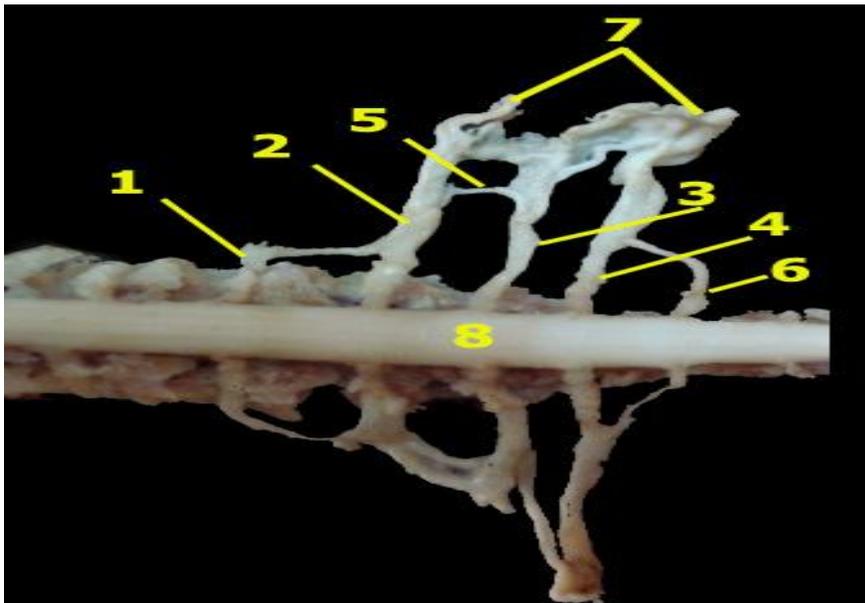


Fig (4) A photograph Showing the Cervical enlargement and Brachial plexus. (Dorsal view)

1 N. spinalis cervicalis V, 2 N. spinalis cervicalis VI, 3 N. spinalis cervicalis VII,
 4 N. spinalis cervicalis VIII, 5 Ramus anastomoticus, 6 N. spinalis thoracicalis I,
 7 Plexus Brachialis, 8 Intumescentia cervicalis.

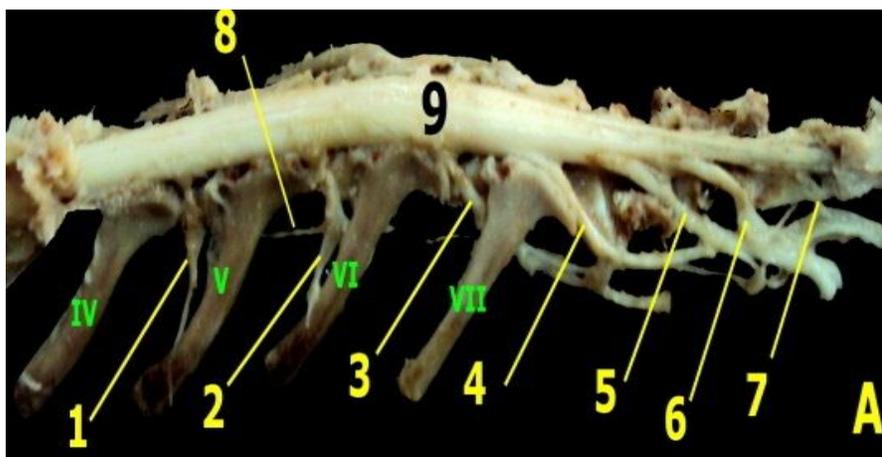


Fig (5): A Photograph Showing Dorsolateral view of the lumbar enlargement, lumbar and sacral nerves.

1 N. spinalis lumbalis IV, 2 N. spinalis lumbalis V. 3 N. spinalis lumbalis VI, 4 N. spinalis lumbalis VII, 5 N. spinalis sacralis I, 6 N. spinalis sacralis II, 7 N. spinalis sacralis III, 8 Ramus anastomoticus, 9 Intumescentia lumbalis, IV-VII: processus transversus Ad Vertebrae lumbalis

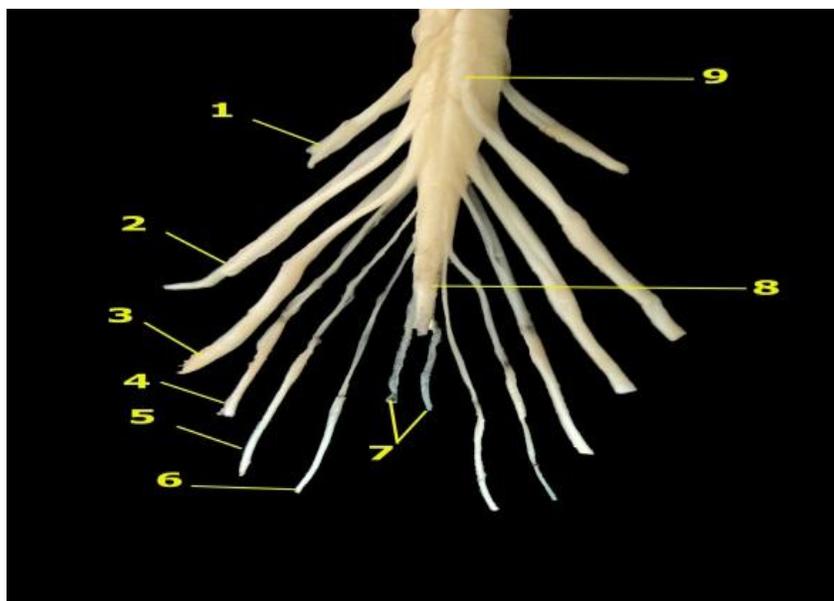


Fig (6): A photograph Showing Cauda Equina.

1 N. spinalis lumbalis VI, 2 N. spinalis lumbalis VII. 3 N. spinalis sacralis I. 4 N. spinalis sacralis II. 5 N. spinalis sacralis III. 6 N. spinalis sacralis IV. 7 N. spinales caudales. 8 Conus medullaris. 9 Intumescentia lumbalis

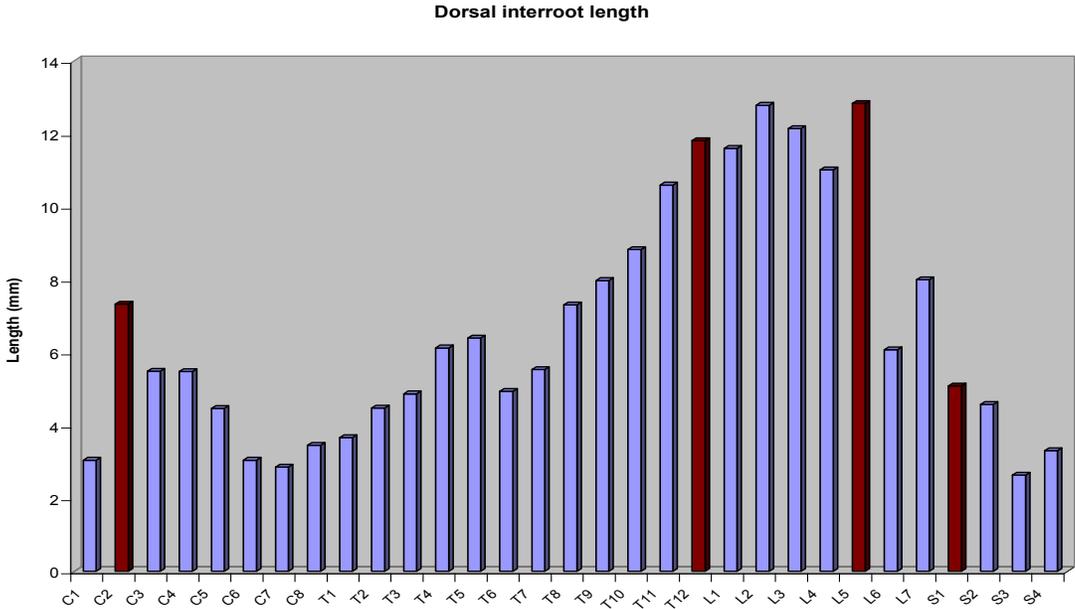


Fig (7): A chart showing correlation of the dorsal root attachment lengths. Note the greatest lengths at C3, T12, L1, S1

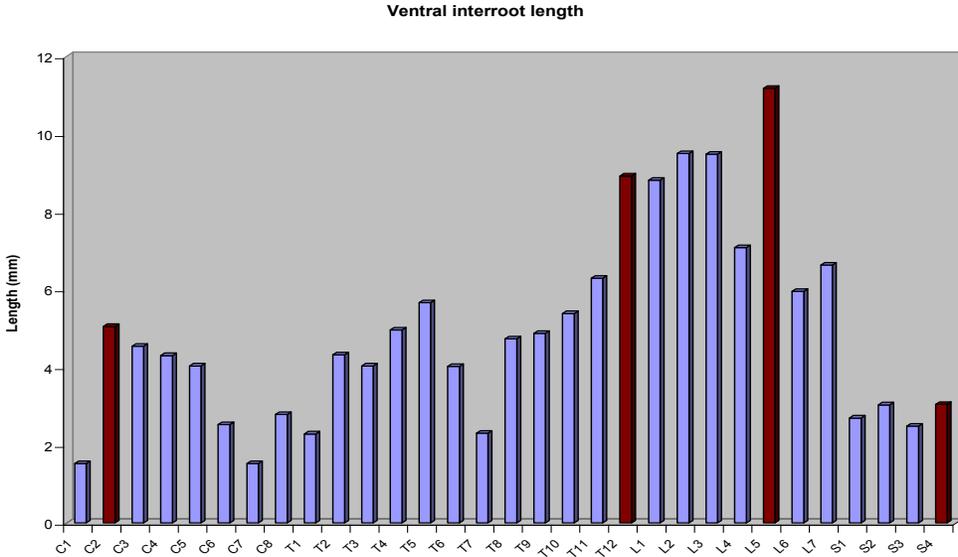


Fig (8): A chart showing correlation of the ventral root attachment lengths. Note the greatest lengths at C2, T12, L2, S1.

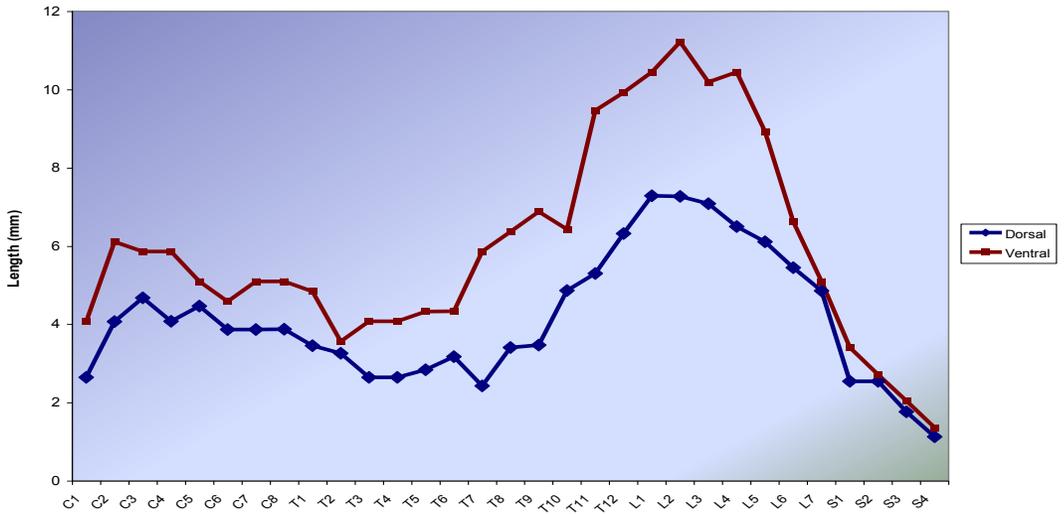


Fig (9): A graph showing the relationship between the dorsal and ventral root attachment Note that the ventral values (red) are greater than the dorsal ones (blue).

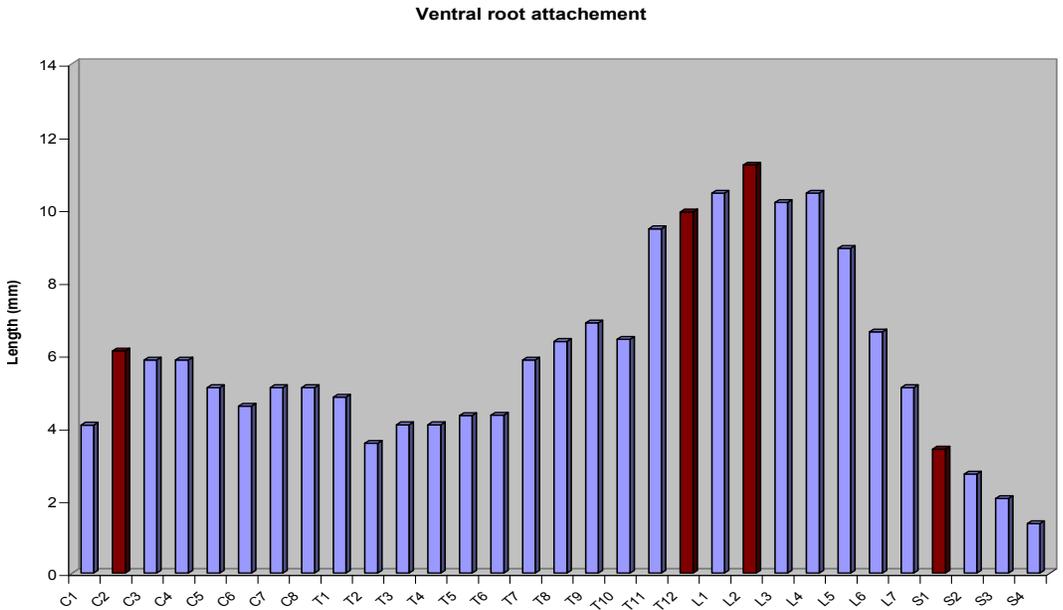


Fig (10): A chart showing correlation of the dorsal inter root lengths. Note the greatest lengths at C2, T12, L5, S1.

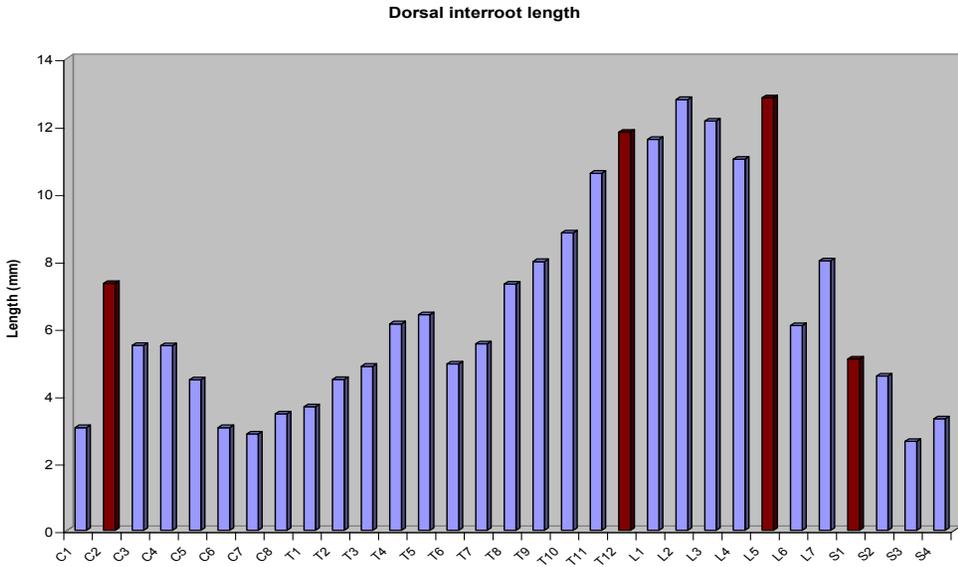


Fig (11): A chart showing correlation of the ventral inter root lengths. Note the greatest lengths at C2, T12, L5, S4.

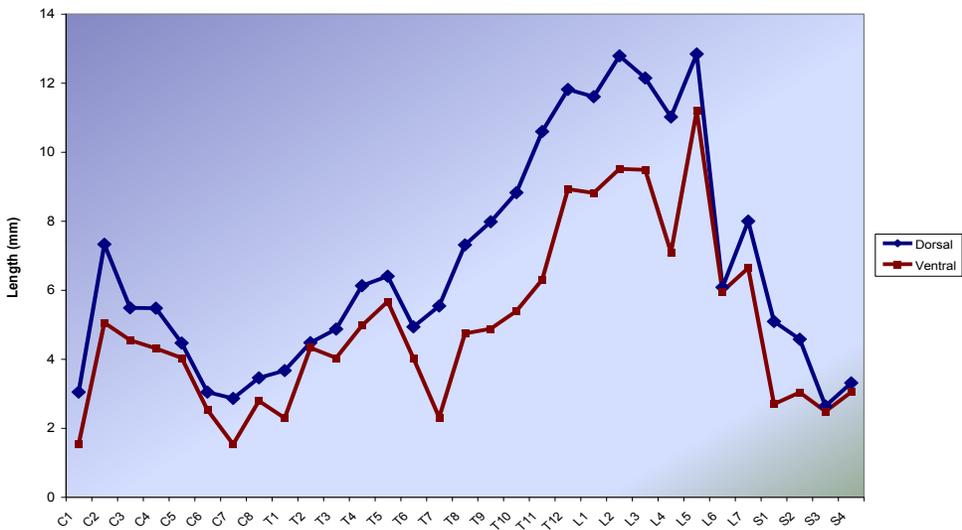


Fig (12): A graph showing the relationship between dorsal and ventral inter root lengths. Note that the dorsal length values (blue) are greater than the ventral ones (red).

Table (1): showing the regional lengths (mm) and indices:

Region/values	Average	Mean(mm)	Indices (%)
Cervical	60.3-72.7	67.0	19.2
Thoracic	110.35-139.5	127.8	36.5
Lumbar	106.9-139.7	119.0	34
Sacrocaudal	13.4-30.5	34.8	10.3

Table (2): showing the length, dorsoventral and transverse diameters and the calculated volume of the spinal cord segments.

Segment No.	Segment's length	Dorsoventral diameter	Transverse diameter	Volume mm ³
C1	5.7	4.5	6.6	173.5
C2	11.4	4.0	6.0	284.0
C3	10.00	3.5	5.0	185.5
C4	9.5	3.5	5.6	191.0
C5	8.9	4.0	6.0	223.0
C6	6.9	4.0	6.6	187.0
C7	6.7	4.5	6.6	205.5
C8	6.7	4.0	6.0	168.0
T1	7.00	4.0	5.5	163.0
T2	7.7	3.5	4.5	127.0
T3	7.5	3.0	4.0	94.0
T4	8.8	3.0	4.0	109.5
T5	9.2	3.0	3.5	100.9
T6	8.00	3.0	3.5	88.5
T7	7.9	3.0	3.5	87.0
T8	10.7	3.0	4.0	134.0
T9	11.5	2.5	4.0	119.0
T10	13.7	3.0	4.0	172.0
T11	15.9	3.0	4.0	199.0
T12	18.5	3.0	4.0	227.0
L1	18.9	3.5	4.0	236.8
L2	20.0	3.5	4.0	291.5
L3	19.2	3.5	4.0	279.5
L4	16.9	4.0	5.0	352.0
L5	18.9	4.0	6.0	472.4
L6	11.5	4.5	6.0	322.0
L7	12.8	4.5	6.6	391.5
S1	7.6	3.5	5.5	153.0
S2	7.00	4.5	5.0	111.0
S3	4.5	4.0	4.0	45.8
S4	5.5	3.5	3.5	29.0

Table (3): showing the length values of the Cervical and Lumbosacral enlargement (mm):

	Range	Mean
Cervical Enlargement	31.6-40.8	37.3
Lumbosacral Enlargement	53.9-86.7	69.6

Animals of this issue

European rabbit (*Oryctolagus cuniculus*)



Kingdom: Animalia & Phylum: Chordata & Subphylum: Vertebrata & Class: Mammalia & Order: Lagomorpha & Family: Leporidae & Genus: oryctolagus

Rabbits are small mammals in the family Leporidae of the order Lagomorpha, found in several parts of the world. There are eight different genera in the family classified as rabbits, including the European rabbit (*Oryctolagus cuniculus*), cottontail rabbits (genus *Sylvilagus*; 13 species), and the Amami rabbit (*Pentalagus furnessi*, an endangered species on Amami Ōshima, Japan). There are many other species of rabbit, and these, along with pikas and hares, make up the order Lagomorpha. The male is called a *buck* and the female is a *doe*; a young rabbit is a *kitten* or *kit*.

The rabbit's long ears, which can be more than 10 cm (4 in) long, are probably an adaptation for detecting predators. They have large, powerful hind legs. The two front paws have 5 toes, the extra called the dewclaw. The hind feet have 4 toes. They are plantigrade animals while at rest; however, they move around on their toes while running, assuming a more digitigrade form. Wild rabbits do not differ much in their body proportions or stance, with full, egg-shaped bodies. Their size can range anywhere from 20 cm (8 in) in length and 0.4 kg in weight to 50 cm (20 in) and more than 2 kg. The fur is most commonly long and soft, with colors such as shades of brown, gray, and buff. The tail is a little plume of brownish fur (white on top for cottontails).

(Source: Wikipedia)