Conus Medullaris Level in Mammals as a Basis for Filum Disease in Humans

Miguel B. Royo-Salvador

Institut Chiari & Siringomielia & Escoliosis de Barcelona

INTRODUCTION

Immense variability exists in the position of the ***conus medullaris*** across the animal kingdom. The anatomical position of the *conus medullaris* determines the structural and functional properties of the *filum terminale*. The ***filum terminale*** is a ligament extending caudally from the *conus medullaris*, traversing the dural sac, and inserting into the coccygeal region.

Phylogenetic analysis of the *filum terminale* is critical to elucidate the variability of its position in humans and its involvement in conditions such as **Arnold-Chiari syndrome type I**, **idiopathic syringomyelia**, **idiopathic scoliosis, tethered cord syndrome**, and **craniocervical junction malformations**. The *filum terminale* exerts a central pathophysiological role in these diseases due to its strategic anatomical placement between the spinal cord and the vertebral column. The developmental growth mechanisms of the spinal cord and the spine differ significantly, exhibiting an asynchronous pattern. The collective involvement of the *filum terminale* in this spectrum of conditions serves as the pathological basis for the **Filum Disease framework**.

PRIMARY OBJECTIVES

1. Highlight the **asynchronous growth** between the spinal cord and the spine across the mammalian class.
2. Demonstrate the **universal anatomical existence** of a *filum terminale* in all mammals.
3. Provide evidence that *Filum* disease constitutes a possible **pathological entity** in all **mammals**.

METHODOLOGY

DATA ACQUISITION AND LITERATURE REVIEW

Bibliographic material was systematically obtained through treatises on Embryology and Biology, PubMed, and other indexed scientific publications.

HUMAN ANATOMICAL ASSESSMENT

The description of the anatomical position of the *conus medullaris* in humans relies on multiple bibliographic sources. Furthermore, it incorporates primary anatomical data derived from the authors' previously published observations and ongoing human specimen dissections specifically aimed at characterizing the *conus medullaris* and the *filum terminale*.

STATISTICAL ANALYSIS

The extracted observational data were analysed, and statistical correlations were applied when sufficient data volume permitted. The analysis evaluated the following anatomical relationships:

1. The relationship between the development of the extremities and the anatomical level of the *conus medullaris* apex.
2. The relationship between tail development and the anatomical level of the *conus medullaris* apex.
3. The relationship between the extremities' growth coefficient and the tail.

RESULTS

1. PHYLOGENETIC CLASSIFICATION OF THE FILUM TERMINALE

- **Vertebrates without *filum terminale*:** Species within the Sauropsida clade (reptiles and birds), urodele amphibians, and most fish present a spinal cord and vertebral column of equal length.
- **Vertebrates with *filum terminale*:** Mammals, anuran amphibians, and select fish evidence a spinal cord that is shorter than the spine.

2. STATISTICAL ANALYSIS OF THE CONUS MEDULLARIS (CM) POSITION

1. A significant negative correlation was identified between the CM apex level and the species' average tail length (ρ = -0.67, p < 0.05).
2. A significant negative correlation was observed between the CM apex level and the species' average body length (ρ = -0.79, p < 0.05).
3. A significant positive correlation exists between the CM apex level and the ratio of average tail length to average body length (ρ = 0.69, p < 0.05).

These coefficients demonstrate that the CM apex adopts a more caudal anatomical position as tail length increases relative to total body length.

3. PROMINENT COMPARATIVE FINDINGS

Hominoids and Primates: In humans, the CM is located at the most cranial level recorded (T12-L1). The common chimpanzee, the only evaluated primate species alongside humans lacking a tail, is the closest evolutionary relative and positions its CM at the L2 level.

Quadruped Mammals: The most cranial CM positions are found in the short-beaked echidna and the European hedgehog (T7) , whereas the most caudal positions (S3) are observed in species such as the ocelot, domestic water buffalo, and impala.

Anatomical Extremes: The ocean sunfish (*Mola mola*) presents the most extreme configuration, featuring a spinal cord under **25 mm** and a CM located entirely inside the brain.

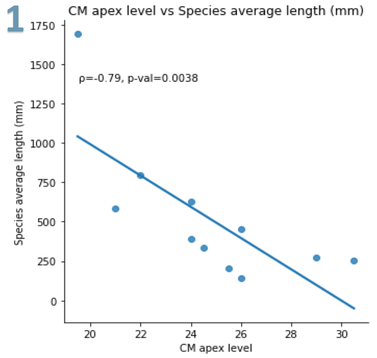


Figure 1: Scatter plot illustrating the significant negative correlation between the CM apex level and the species' average body.

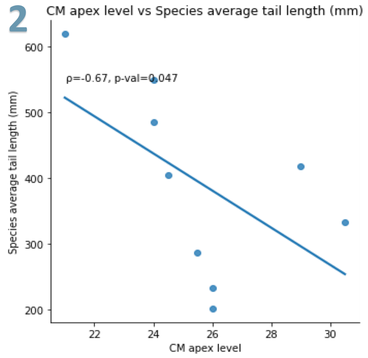


Figure 2: Scatter plot demonstrating the significant negative correlation between the CM apex level and the species' average tail length.

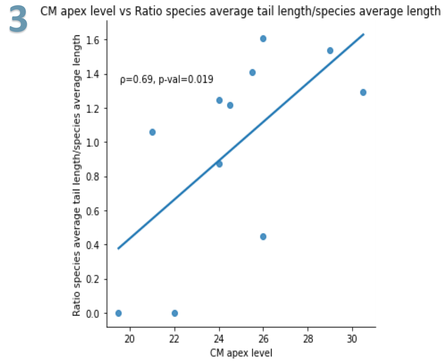


Figure 3: Scatter plot showing the significant positive correlation between the CM apex level and the ratio of average species tail length to average species body length.

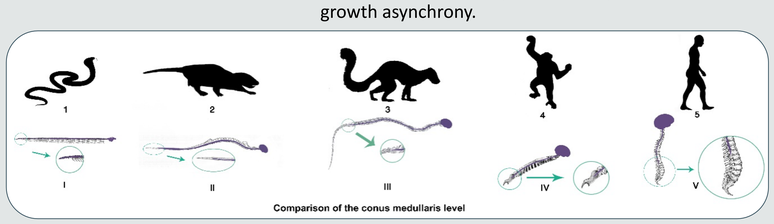
DISCUSSION

LOCOMOTION AND UPRIGHT POSITION

The anatomical level of the *conus medullaris* is governed by a phylogenetic progression through three distinct phases: the **quadruped phase**, the **simian phase** (climbing behavior), and **the hominid phase** (bipedalism). Bipedalism dictates a massive hypertrophy of the lower extremities and pelvis without proportional spinal cord elongation, driving the neuroaxis-spine growth asynchrony.

ANATOMICAL CHANGES DUE TO LARGER LOWER HEMIBODY

Disproportionate growth between the caudal and cranial extremities, particularly the hypertrophy of the pelvis and lower limbs, influences a greater ascent of the spinal cord within the spine.



Comparison of the conus medullaris level

TYPE OF NERVE AND MUSCLE FIBRE

Muscle contraction speed is inversely proportional to nerve length. Animals requiring rapid, powerful lower-limb movements present a lower-lying spinal cord. Conversely, the human requirement for slow-twitch, fatigue-resistant fibers to maintain upright posture correlates with a more cranial *conus medullaris*.

THE DISAPPEARANCE OF THE TAIL

The evolutionary loss of the tail in certain primates and hominids eliminated the need for distal motor and sensory control, contributing directly to the shortening of the neuroaxis.

CLINICAL CONSEQUENCES (Filum Disease)

1. The Mechanical Conflict: The evolutionary neuroaxis-spine growth asynchrony generates an abnormal mechanical traction on the spinal cord through the ***filum terminale***.

2. Histological Factor: In human adults, the *filum terminale* is predominantly composed of rigid type I and type III collagen fibers, lacking the necessary elasticity and compounding the biomechanical conflict.

3. Pathogenic Expression: This mechanical traction syndrome acts as the primary etiological mechanism for **Filum disease** expressions, directly triggering conditions such as Arnold-Chiari syndrome type I, idiopathic syringomyelia, and idiopathic scoliosis.

CONCLUSIONS

NEUROAXIS-SPINE ASYNCHRONY: The hypothesis of spine-spinal cord growth asynchrony is confirmed across the Mammalia class and anuran amphibians, whereas it is absent in the Sauropsida and Caudata clades.

PHYLOGENETIC DETERMINANTS: The anatomical position of the *conus medullaris* is directly modulated by evolutionary adaptations, specifically tail regression, muscular histological composition, and shifts in locomotion.

THE HOMINID SHIFT (BIPEDALISM): In humans, the evolutionary transition to bipedalism required massive hypertrophy of the lower extremity and pelvic skeleton without a proportional elongation of the spinal cord. This anatomical divergence, combined with the loss of the tail, results in a significantly more cranial *conus medullaris* compared to other primates.

CLINICAL IMPLICATION (FILUM DISEASE): This pronounced evolutionary growth asynchrony generates an intense neuroaxis-spine conflict. The resulting mechanical traction structurally alters the *filum terminale*, acting as the primary pathogenic mechanism responsible for the conditions and malformations that define **Filum disease**.

REFERENCES

- Royo-Salvador MB. *Aportación a La Etiología de La Siringomielia [Contribution to the Aetiology of Syirngomyelia]*. Universidad Autónoma de Barcelona; 1992.
- Royo-Salvador MB. [Syringomyelia, scoliosis and idiopathic Arnold-Chiari malformations: a common etiology]. *Rev Neurol*. 1996;24(132):937-959.
- Royo-Salvador MB, Sola-Llenas J, Domenech JM, Gonzalez-Adrio R. Results of the section of the filum terminale in 20 patients with syringomyelia, scoliosis and Chiari malformation. *Acta Neurochir (Wien)*. 2005;147(5):515-523. doi:10.1007/s00701-005-0482-y
- Haller B. Über das Zentralnervensystem, insbesondere über das Rückenmark von Orthagoriscus mola. *Morphologisches Jahrbuch*. 1891;XVII.
- WANG LC, KERNELL D. Fibre type regionalisation in lower hindlimb muscles of rabbit, rat and mouse: a comparative study. *J Anat*. 2001;199(6):631-643. doi:10.1046/j.1469-7580.2001.19960631.x
- Bauer DF, Tubbs RS, Chambers MR. Study of the effects of flexion on the position of the conus medullaris: follow-up study using MR imaging in non-human primates. *Child's Nervous System*. 2009;25(8):977-979. doi:10.1007/s00381-009-0877-8

Dr. Miguel B. Royo-Salvador
mroyo@institutchiaribcn.com