

Muscular Layer of the Small Intestine. Can Two Models Coexist? A Critique of the Anatomical Literature

Capa Muscular del Intestino Delgado. ¿Pueden Coexistir Dos Modelos? Una Crítica de la Literatura Anatómica

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SUMMARY: The circular arrangement for the inner layer and the longitudinal arrangement for the outer layer was the traditionally accepted model by the scientific community in terms of the orientation of the muscular layers of the small intestine's muscular coat. However, in the middle of the 17th century, that model began to be questioned and a new spiral model for the orientation of the muscular layers was introduced, which was believed by various researchers throughout history. Due to this controversy, the International Anatomical Terminology still maintains both terms, contrary to its principles of maintaining a single term. In order to find a solution to this historical controversy, a bibliographic research on different works on the orientation of the muscular layers of the muscular coat was carried out. Moreover, a review of anatomy and histology papers in the library of the Institute of Anatomy of the department of Medicine at Universidad de Chile and papers used in current curriculum of scientific degrees. Some researchers have described a circular model for the internal layer and a longitudinal model for the external layer, others a spiral model. However, the main anatomy and histology texts still maintain the traditional description. As a result, the aim of this study was to solve this contradiction.

KEY WORDS: Anatomical terminology; Muscular layer; Internal circular; External longitudinal; Spiral model.

INTRODUCTION

The orientation of the muscular layers of the small intestinal muscular coat has been the subject of controversy throughout history (Williams, 2001) and remains an unsolved problem for morphological sciences (Federative International Programme for Anatomical Terminology, 2019). The model traditionally accepted by the scientific community is a circular arrangement for the inner layer and a longitudinal arrangement for the outer layer. This model has been questioned since the beginning of the 20th century, when a new spiral model was proposed with a tight spiral (or short pitch helical) arrangement for the inner layer and an elongated spiral (or long pitch helical) arrangement for the outer layer (Carey, 1921). As a result of this controversy, anatomical terminology still retains both terms, which contradicts its principles (Latarjet & Ruiz-Liard, 2019).

Anatomical terminology refers to two models to describe the orientation or disposition of the muscular layers of the small bowel's muscular coat. On the one hand, it employs the description of circular for the internal layer and

longitudinal for the external layer, as well as tight spiral (or short pitch helical) for the internal layer and elongated spiral (or long pitch helical) for the external layer (Federative Committee on Anatomical Terminology, 1998, 2001; Federative International Programme for Anatomical Terminology, 2019). The work mentioned in the anatomical terminology to describe a spiral orientation of the muscular coat is a 1921 report by Eben Carey entitled "Studies on the Structure and Function of the Small Intestine", in which the author criticizes the traditional model of internal circular and external longitudinal, considering it "a faulty anatomical heirloom".

Carey, using the pig as a model, describes the structure of the inner layer of the muscular coat as, on the one hand: "The inner muscle coat of the small intestine is not composed of circular or annular rings contiguously placed, but is a continuous muscular sheet wound into a close helix". On the other hand, related to the other layer the author points out: "The outer muscle coat of the small intestine is

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not composed of longitudinal fibers parallel to the long axis, but of elongated fibers, at an acute angle to the long axis of the intestine, which tend to pursue a spiral course", representing a left or counterclockwise spiral direction (Carey, 1921). It should be noted that these statements were widely accepted by authors in journal articles and textbooks (Elsen & Arey, 1966).

As a result, the controversy has been a historical problem since the 17th century, when the traditional model of an internal circular and external longitudinal arrangement was criticized because different researchers affirmed an internal circular and external longitudinal arrangement, while others stated a spiral arrangement for the layers of the muscular coat of the small intestine.

MATERIAL AND METHOD

An extensive bibliographic research on the structure and orientation of the muscular layers of the muscular coat of the small intestine was performed. Additionally, anatomy and histology texts were reviewed. Those texts were available in the library of the Department of Anatomy and Legal Medicine of the department of Medicine at Universidad de Chile, as well as texts/books used in the current curriculum of health professionals of this university.

RESULTS

Historical account of the controversy. First, it is of paramount importance to mention that in 1676, Cole presented to the Royal Society of London a research paper on the structure of the muscular coat of the intestine, using different animals such as ox, sheep, and calf as models. The paper, considered a forgotten anatomical relic, in which the author declares: "That those fibers which have been esteemed annular, might perhaps be spiral, and so continued down in one tract to the lowest extremity of the intestines...But the general conclusion reached is that the fibers altogether form one concave helical muscle...", presenting a right or horary spiral direction for the muscle layers (Cole, 1676). Secondly, 57 years later, Boot (1733) described (quoted by Elsen & Arey, 1966): "The inner layer, whose dense and numerous fibers encircle the intestinal tube in true continuation in a circular manner, certain ones with-drawing themselves in the midst of the journey and neighboring ones connecting. Many authors deceived by this, think that these fibers run down in a spiral manner", presenting a circular arrangement for the inner layer (Boot, 1733).

Third, it is worth mentioning that the works of W. Cole and P. Boot are the only ones recorded before Carey, which were ignored or unknown by Carey (1921).

Moreover, a year after Carey's publication, Sykes (1922) worked on this problem in the Anatomical Laboratory at Harvard University and confirmed what W. Cole had stated, pointing out that the direction of the muscle layers was in a spiral direction, to the right or horary (Lewis, 1922; Elsen & Arey, 1966). However, shortly after this publication, Brandt (1923) presented at a meeting of the German Anatomical Society in Heidelberg his work on the orientation of the muscle layers of the muscular coat in preparations of the human intestine, mentioning that he had not found any discernible spiral disposition in the outer layer, which was longitudinal, or in the inner layer, which was circular, except for some fibers that showed a certain degree of connection between them (Brandt, 1923; Elsen & Arey, 1966).

Furthermore, years later, Goerttler (1932) studied the structure of the connective tissue surrounding the muscular tissue of the intestinal wall in a human model using polarized light microscopy. He observed that the scaffold of connective tissue surrounding the inner layer had a circular disposition with some fibers staggered in an overlapping manner, and for the outer layer it had a longitudinal disposition parallel to the axis of the intestinal tube (Goerttler, 1932; Elsen & Arey, 1966).

Later, in 1938, Franklin and Maker-Loughnam found that cat and rabbit intestinal segments corresponded to a spiral arrangement of muscle in a left or counterclockwise spiral direction (Franklin & Maker-Loughnam, 1938; Elsen & Arey, 1966).

Álvarez-Morujó (1949) claimed to have confirmed Carey's findings on the spiral structure of the muscular coat of the intestine, as well as the left or counterclockwise spiral direction of the muscular layers. Finally, Elsen & Arey (1966) studied the structure of the muscular coat of the intestinal wall in several animal models (dog, cat, pig and human) and showed that, despite some deviations with respect to the circular and longitudinal direction and some exchange of fibers between adjacent circular muscle rings, their fibers did not describe spiral paths and they concluded that "Methods of stripping did not demonstrate a significant spiral course of fibers within longitudinal muscle coats... Bands of muscle stripped from circular coats of the small intestine of the dog and hog came off overwhelmingly in complete rings. Stripping of the human intestine did not yield complete rings" (Elsen & Arey, 1966).

Current situation of anatomy and histology texts

A review of the historical and bibliographical background of 57 texts belonging to the library of the Department of Anatomy and Forensic Medicine at the department of Medicine at Universidad de Chile, indicate

that since the 19th century, texts/books used in the study programs of health professions, on the orientation of the muscular coat of the small intestine, demonstrates that the traditional description of circular for the internal layer and longitudinal for the external layer is maintained in 86% of them (Fig. 1; Table II).

Only, eight texts add a spiral or helical description to the one already described classically, using as reference the work of Carey (1921) and/or the International Anatomical Terminology (1998; 2001) (Table III). In addition, these texts do not include research after 1921 that defends the spiral model, such as Sykes (1922), Franklin & Maker-Loughnam (1938), and Álvarez Morujo (1949).

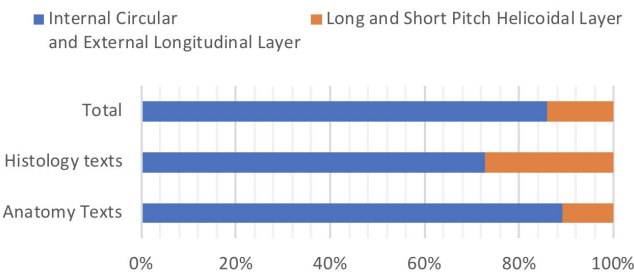


Fig. 1. Text Library Department of Anatomy and Forensic Medicine, Universidad de Chile.

Table I. Summary models of the orientation of the muscular layers of the muscular coat of the small intestine.

Internal Circular and External Longitudinal Layer	Counterclockwise Long Pitch Helical Layer	Hourly Short Pitch Helical Layer
<i>P. Boot</i> , 1733.	<i>E. Carey</i> , 1921.	<i>W. Cole</i> , 1676.
<i>W. Brandt</i> , 1923.	<i>K. Franklin</i> , 1938.	<i>G. Sykes</i> , 1922.
<i>K. Goerttler</i> , 1932.	<i>A. Alvarez-Morujo</i> , 1949.	
<i>J. Elsen & L. Arey</i> , 1966.		

Table II. Texts describing an internal circular and external longitudinal orientation for the muscular layers of the muscular coat of the small intestine.

Internal Circular and External Longitudinal Layer
<i>Cruveilhier</i> , 1863, 1874; <i>Richet</i> , 1866; <i>Tillaux</i> , 1877, 1887; <i>Sappey</i> , 1889; <i>Fort</i> , 1902; <i>Spalteholz</i> , 1903, 1956, 1959, 1970; <i>Poirier & Charpy</i> , 1904, 1909; <i>Testut</i> , 1912; <i>Rouvière</i> , 1920, 1962; <i>Gerard</i> , 1921; <i>Tandler</i> , 1928; <i>Kopsch</i> , 1929; <i>Okajima</i> , 1934; <i>Gray</i> , 1943, 2016; <i>Johnston</i> , 1945; <i>Schaeffer</i> , 1947; <i>Testut & Latarjet</i> , 1949; <i>Maisonnet & Coudane</i> , 1950; <i>Netter</i> , 1962, 2023; <i>Gardner, Gray & Rahilly</i> , 1963; <i>Rouvière & Delmas</i> , 1972, 1987, 2005; <i>Patton & Thibodeau</i> , 2000, 2013; <i>FCTA</i> , 2001; <i>Latarjet & Ruiz</i> , 2019; <i>Tortora & Derrickson</i> , 2006; <i>Eynard</i> , 2008; <i>Lippert</i> , 2010; <i>Cui</i> , 2011; <i>Lockhart</i> , 2012; <i>Piezzi & Fornés</i> , 2013; <i>Brüel, Christensen, Trantum-Jensen & Geneser</i> , 2015; <i>Lowe & Anderson</i> , 2015; <i>Fortoul</i> , 2017; <i>Fawcett</i> , 2018; <i>Pawlina</i> , 2020; <i>Kierszenbaum & Tres</i> , 2020; <i>Dalley & Agur</i> , 2023.

Table III. Texts describing a spiral orientation for the muscular layers of the muscular coat of the small intestine.

Long and Short Pitch Helicoidal Layer
<i>Braus</i> , 1924; <i>Orts Llorca</i> , 1962; <i>Bannister</i> , 1998; <i>FCTA</i> , 2001; <i>Pró</i> , 2014; <i>Leeson</i> , 1989; <i>Gartner</i> , 2023.

DISCUSSION

Throughout anatomy history, different models have been presented regarding to the orientation of the muscular layers of the small intestine's muscular coat, which is an issue that morphological sciences must address in order to solve this historical controversy, as it remains an unsolved issue to the present day (Federative International Programme for Anatomical Terminology, 2019).

The lack of dissemination of the different articles has caused their absence in texts and publications of later years (Sykes, 1922; Brandt, 1923; Goerttler, 1932; Franklin &

Maker-Loughnam, 1938; Álvarez-Morujo, 1949) which was also presented in this review.

In addition, the use of two terms or models to describe the orientation of the muscle layers is contrary to the principles of anatomical nomenclature established in the first edition of the Anatomical List by the International Anatomical Nomenclature Committee (IANC) in Paris in 1955 (VI International Congress of Anatomists).

Therefore, the vast majority of the studies in the

sources cited above used animal models to develop their research, such as pig, cat, rabbit, or dog. Others have used human samples, and some have used both models, which would not necessarily show a coincident pattern between the origin of the specimens and the arrangement of the muscle layers (Elsen & Arey, 1966).

Finally, it is also worth mentioning that, unlike what occurred in classical anatomy books with regard to citations supporting a claim, this is not evident in current textbooks; moreover, references are made to this topic without adding new evidence.

CONCLUSIONS

In the case of the orientation of the muscular layers of the muscular coat of the small intestine, The International Anatomical Terminology contradicts its own principles by using two terms to describe it. Furthermore, it only mentions a single work as a reference article, to state the description of spiral or helical, ignoring that in the previous and subsequent years several works presented significant differences both in the orientation and in the direction of the muscular layers, contradicting or modifying what was presented in the aforementioned article (Table I).

Furthermore, the vast majority of the works reviewed here were performed using animal tissues, and evidence indicates that it is a mistake to extend the conclusions to human anatomy.

Current anatomical textbooks are cited one after the other, with no indication of criteria for the adoption of one model or the other, without adding new research.

Despite the fact that several models of the spatial arrangement of the muscle layers have been proposed in the literature to date, it is obvious that it is not advisable to take a position on any of them.

Therefore, we conclude the need to generate a research work to resolve this controversy.

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RESUMEN: Se realizó una revisión de artículos de anatomía e histología de la biblioteca del Instituto de Anatomía de la Facultad de Medicina de la Universidad de Chile, así como de los utilizados en los planes de estudio de las carreras científicas. Algunos investigadores han descrito un modelo circular para la capa interna y un modelo longitudinal para la capa externa, mientras

que otros proponen un modelo espiral. Sin embargo, los principales textos de anatomía e histología aún conservan la descripción tradicional. Por consiguiente, el objetivo de este estudio fue resolver esta contradicción.

PALABRAS CLAVE: Terminología anatómica; Capa muscular; Interna circular; Externa longitudinal; Modelo espiral.

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