Original article

Histo-topographic study of the longitudinal anal muscle

VERONICA MACCHI (*) - ANDREA PORZIONATO (*) - CARLA STECCO (*)
FILIPPO BENETTAZZO (*) - ANTONIO STECCO (*) ANNA PARENTI (**) - GIUSEPPE DODI (***)
and RAFFAELE DE CARO (*)

(*) Section of Anatomy, Department of Human Anatomy and Physiology, University of Padova, Italy
(**) Section of Pathologic Anatomy, Department of Medical Diagnostic Sciences and Specialist Therapies, University of Padova, Italy
(***) Section of Surgery, Department of Oncological and Surgical Sciences, University of Padova, Italy

Abstract: The longitudinal anal muscle (LAM) has been described as a layer of muscular tissue interposed between the external and internal anal sphincters but there is no general agreement in the literature on its attachments and constitution. The aim of the study was to investigate its topography for surgical purposes, with particular reference to its origin, insertion. After in situ formalin fixation, the pelvic viscera were removed from 8 male and 8 female cadavers (age range: 52-72 years). Serial macrosections of the bladder base, lower rectum and pelvic floor complex, cut into horizontal (6 cases) and coronal (6 cases) planes, underwent histological and immunohistochemical study. The remaining 4 specimens were plastinated. The LMA was identified in 10/12 of specimens (83%). In both coronal and transverse sections, it appeared as a layer of muscular tissue. From the anorectal junction it extends along the anal canal, receives fibres from the puborectalis and medial part of the pubococcygeus muscles, and terminates with fibro-elastic septa (7-9) which penetrate the external anal sphincter, reaching the deep part of the dermis. In the transverse plane, the mean thickness of the LAM was 1.63 ± 0.44 mm. Immunohistochemical staining showed that it consists predominantly of striated muscle fibres, with scarce smooth muscle fibres. Due to its attachments, the LMA may play a role in supporting and binding the internal and external sphincter complex together.

Key words: Plastination; Pelvic floor; Incontinence; Longitudinal anal muscle; Sphincters.

INTRODUCTION

The longitudinal anal muscle (LAM) has been described as a layer of muscular tissue interposed between the external anal sphincter (EAS) and internal anal sphincter (IAS) [1] but there is no general agreement in the literature on its attachments and constitution.

Lesshaft [2] stated that the posterior part of the levator ani from the sacrococcygeal column goes down to the posterior part of the perineal portion of the rectum. The external fibres are inserted in the pelvic aponeurosis (tensor fasciae pelvis), and the internal ones inserted in the context of the internal sphincter and the deep part of the anal skin. Cruveilhier in 1852 [3] described that the levator ani contributes with some fibres towards augmenting the outer muscle coat to form the conjoint longitudinal muscle of the anus. Milligan and Morgan in 1934 [4] attributed the contribution to the LAM to the puborectalis posteriorly and the deep EAS anteriorly, whereas Courtney [5] described the LAM as a vertically oriented, striated muscle, which receives contributions from the puborectalis, pubococcygeus and ileococcygeus muscles. Shafik [6] subdivided the LAM into three layers (medial, intermediate, lateral), separated by four fascial septa, which split and decussate below the lower end of the longitudinal muscle to form the "central tendon". In their review, Lunniss and Phillips [7] reported that the LAM composed of a muscular part formed by the fusion of striated muscle fibres from the puboanalis, the innermost part of the puborectalis, with smooth tissue from the longitudinal muscle of the rectum. The layer then becomes completely fibro-elastic and splits into septa, running between bundles of the subcutaneous external sphincter, to terminate in the perianal skin. More recently, Petros (2004) [8] described the contribution to the LAM by the levator ani plate, the lateral part of the pubococcygeus muscle and the puborectalis muscles. The LAM partly surrounds the rectum posteriorly, but is not inserted into it, and runs inferiorly into both deep and superficial EAS.

There is no agreement either on the nomenclature of the LAM, which has also been called rectococcygeus muscle, retractor of the anus of Treitz, tensor fascia pelvis of Kohlrausch, ligamentum suspensorium of Berau, and levator ani proprius of Lesshaft. The LAM is not listed in the last edition of Terminologia Anatomica (FCAT, 1998) [9] and in Gray's Anatomy [1], it is called the conjoint longitudinal coat.

From the functional point of view, Shafik [6] hypothesized that the LAM helps to fix the anal canal to the side wall of the pelvis during defecation, preventing anal prolapse. More recently, the Integral Theory of Petros [8, 10] attributed a key role to the LAM in the closure and opening of the urethra and recto-anal canal.

The aim of the present work is to give a morphological and topographical description of the LAM, for surgical purposes, with particular reference to its origin, insertion, and histological and immunohistochemical characteristics.

MATERIALS AND METHODS

Sampling of the pelvic viscera

The specimens were obtained from 8 male and 8 female cadavers (age range 52-72 years), without a history of pelvic pathology. The pelvic viscera with the surrounding connective tissue and pelvic floor were harvested en bloc from unembalmed cadavers 24 hr after death, according to previously described technique by De Caro,[11] Macchi [12] and Porzionato.[13]

Histology and immunohistochemistry

Twelve adult specimens were prepared for histological and immunohistochemical study. They were fixed in 10% formalin for 15 days, and 5-mm thick slices were cut in transverse and coronal planes with a slicer. The slices were embedded in paraffin and then cut into 10-_m thick sections, which were stained with hematoxylin and eosin (H.E.), azan-Mallory (a.M.), and Weigert's stain for elastic fibers. In the histological sections, the morphology of the muscle was evaluated with particular reference to its shape and its attachments. Morphometric evaluation was carried out with the help of image analysis software (Qwin Leica Imaging System, Cambridge, UK). The following parameters were recorded: on the transverse sections the mean thickness of the IAS, EAS and LAM; on the coronal sections, the mean thickness of the EAS and LAM at the level of their proximal and distal attachments and at a mid-level.

Immunohistochemical evaluation was performed with monoclonal anti-human alpha-smooth muscle actin (mouse IgG2a, kappa, Dako-Smooth muscle actin 1A4, Code No.

M151, 1:50 solution in phosphate-buffered saline (PBS)) and monoclonal anti-rabbit sarcomeric actin (mouse IgM, kappa, Dako-Sarcomeric actin, Alpha-Sr-1, Code No. M874, 1:50 solution in PBS) (Dako A/S, Glostrup, Denmark).[13,14] The distribution of smooth and/or striated muscle fibers within the LAM was evaluated in the immunostained sections.

Plastination

The remaining 4 adult pelvic blocks were frozen at –20 C° and cut with a slicer into 2-3 mm transverse serial sections. After dehydration in acetone at –25 C° for 2 weeks and degreasing in acetone at room temperature for 1 week, vacuum impregnation was performed with an epoxy resin E12 mixture (BiodurTM Products, Heidelberg, Germany). After vacuum impregnation, the specimens were cured by exposure to ultraviolet light and heat (50 C°).[11,13,15-18]

RESULTS

In coronal sections, stained with H.E. and azan-Mallory (a.M.), the LAM was identifiable in 5/6 of specimens (83%). It appeared as a layer of muscular tissue interposed between the IAS and EAS. It was recognisable at the recto-anal junction; at a *more anterior level*, it extends along the anal canal (Fig. 1), receives fibres from the puborectalis muscle (Fig. 2), and terminates with 7-9 fibro-elastic septa (Fig. 3) which penetrate the EAS, reaching the deep part of the dermis. The muscle fibres show a predominantly vertical course and no fibres directed from the LAM to the IAS are recognisable. At a *more posterior level*, the LAM receives fibres from the medial part of the pubococcygeus muscle, and gives rise to fibrous septa along its course and at its distal end. Some of these septa run towards the separation between the deep and superficial parts of the EAS. Other very thin septa run through the IAS, reaching the submucosal plane. The muscular fibres show a predominantly oblique course. The mean thickness was 2.09 ± 0.32 mm at the origin, 1.38 ± 0.38 mm at the middle level, 1.23 ± 0.05 mm at the distal attachment.. At its proximal attachment, the LMA seems in continuity with the longitudinal muscle of the rectum. In all the cases, Weigert's staining showed the presence of elastic fibres in the distal attachments of the LAM.

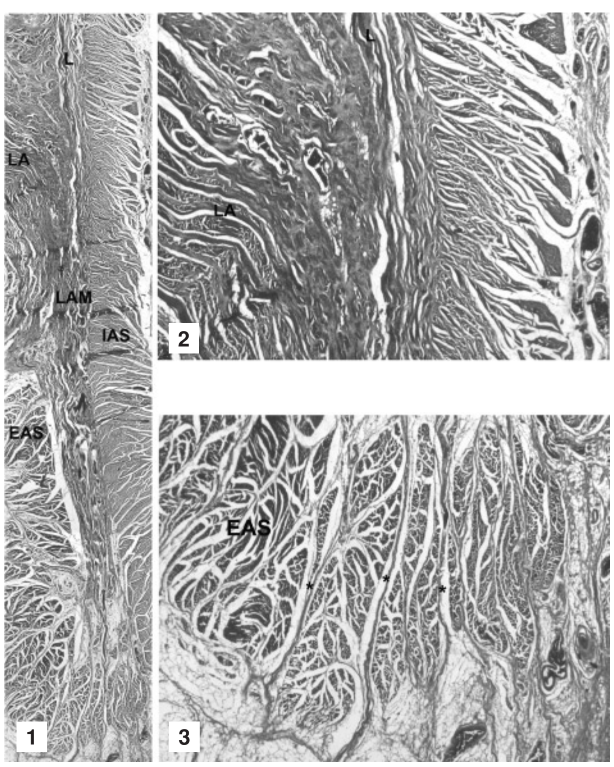

Fig 1. – Coronal section of the right wall of the anal canal, showing the longitudinal anal muscle (LAM) between the internal (IAS) and external anal sphincter (IAS). L, longitudinal muscle of the rectum.
Fig. 2. – Magnification of the upper part of fig 1 showing the contribution of the levator ani (LA) to the LAM.
Fig. 3. – Magnification of the lower part of fig. 1 showing the LAM that terminates with fibroelastic septa (asterisks). (azan Mallory staining, original magnification X 2.5).

In the transverse sections, the LAM showed a circular configuration, interposed between IAS and EAS. The mean thickness of the LAM was 1.63± 0.44 mm, of the IAS 2.69 ± 0.53 mm, and of the EAS 2.95 ± 0.89 mm. The fibres showed prevalent transverse (4/6) and oblique (2/6) courses. In 5/6 cases, the fibres were more densely packed on the anterior side.

Immunohistochemical staining showed that the muscle consisted predominantly of striated muscle fibers, with a few smooth muscle fibres.

In the transverse plastinated specimens, the LAM was located between EAS and IAS, and recognizable on the lateral and posterior aspects of the anal canal; the muscle bundles of the LAM were directed postero-anteriorly.

DISCUSSION

A review of the literature concerning the anatomy of the LAM revealed little uniformity in description of the origin and contribution by surrounding muscles and in the medial, outward and inferior extensions.[7] Nevertheless, a functional role has been suggested for the LAM in the dynamics of pelvic floor function and dysfunction.

From the surgical point of view, knowledge of the topography of the LAM is important when developing minimally invasive solutions for patients with faecal incontinence. Surgical treatment is indicated according to the severity of the condition. Many surgical options for both urinary and faecal incontinence have been developed in the last two decades, but the surgical community continues to search for simple, inexpensive and minimally invasive solutions. Many techniques to treat urinary incontinence have been adapted and applied to faecal incontinence: artificial sphincters, neuromodulation of the sacral nerves, and bulking agents.[19-21] The adaptation of these techniques require a detailed knowledge of the topographical relations between EAS, IAS and LAM. Our study confirms the intersphincteric location of the LAM, interposed between IAS and EAS, with mean thicknesses of 1.63 mm (LAM), 2.69 mm (IAS), and 2.95 mm (EAS). These data partially fit those of Gerdes et al.,[22] who reported a mean thickness of the LAM of 2.85 mm and of the EAS of 3.62 at the level of the dentate line. These differences may be ascribed to different fixation and level of section.

The different appearance of the LAM in the coronal section at anterior or posterior levels may explain the differing descriptions in the literature. In fact, as regards the extension of the muscle, our study shows that its appearance is quite different from anterior to posterior levels. In the anterior level, 7-9 fibro-elastic septa are predominantly located at the distal end and penetrate the EAS, reaching the deep aspect of the dermis. This description fit that of Shafik,[6] who described 6 fascial septa in relation to the different parts of the muscles of the anal canal, which run downwards, and then split, and decussate at their termination, to form the central tendon from which multiple septal prolongations in different directions arise. On the posterior plane, the LAM gives rise to fibrous septa along its course and at its distal end. Some of these septa run towards the boundary between the deep and superficial parts of the EAS. Other very thin septa run though the IAS, reaching the submucosal plane. This description is in accordance with those of Abel [23] and Milligan and Morgan.[4] The former reported that the LAM passes between the superficial and deep parts of the EAS and around the sphincter. The latter described two septa, one constant, passing between the superficial and subcutaneous components of the EAS, and one inconstant, between the deep superficial parts.

As regards muscle characteristics, the LAM is described as being a direct continuation of the outer muscle coat of the rectum, receiving contributions from the surrounding pelvic muscles. Cruveilhier [3] reported contributions from the levator ani, Milligan and Morgan [4] from the puborectalis posteriorly and the deep EAS anteriorly, Courtney [5] from the puborectalis, pubococcygeus and ileococcygeus, Shafik [6] from the pubococcygeus, and Petros [8] from the lateral part of the pubococcygeus and puborectalis. Our study shows that the LAM receives fibres from the medial part of the pubococcygeus and puborectalis muscles, and that it consisted predominantly of striated muscle fibers, with a few smooth muscle fibres, probably deriving from the longitudinal muscle of the rectum. It is interesting to note that the smooth fibres are located sparcely in the context of the muscle, whereas Shafik [6] smooth muscle fibres located predominantly in the inner part of the, named medial longitudinal muscle, representing the prolongation of the longitudinal muscle coat of the rectum. It may be hypothesised that the fibres deriving from the levator ani, with those deriving from the longitudinal muscle of the anus, and that the fibres from the pubococcygeus and puborectalis run obliquely, also reaching the inner aspect of the LAM. However, the contribution of the levator ani prevales over that of the longitudinal muscle of the rectum, also determining a close link between the LAM are subdivided in three layers: upper, middle and lower. The middle layer corresponds to the LAM, described as a striated muscle not attached to the rectum, which connects the upper and lower muscle layers.[8] The LAM, with its vertical course, creates a downward force for bladder neck closure during effort and stretches the outflow tract open during micturition. A similar mechanism has also been proposed for the ano-rectal function, in which the LAM angulates the tip of the levator ani downwards, creating the ano-rectal angle.[8] Shafik [6] also attributed to the LAM a role in defecation, during which the rectum and the pubococcygeus contract, with consequent contraction of the LAM. Due to its attachments, contraction of the LAM shortens and widens the anal canal, the direction of contraction being upward and lateral because of the longitudinal extension of the pubococcygeus muscle. The anal and perianal skin is everted, and the anal orifice is opened. Shafik suggests calling the LAM the "evertor ani muscle". Since in the present study we documented the double contribution to the LAM from the levator ani, wider action of the LAM may be suggested. Due to its characteristic attachment, in the first phase the fixed point may be represented by the inferior, fibro-elastic attachment of the LAM: when the latter contracts, there is a downward force, with shortening and widening of the diameter of the anal canal, which becomes more linear. In the second phase, the fixed point is represented by the upper portion: contraction of the puborectal sling and consequently of the LMA creates an upward force and restoration of the ano-rectal angle of continence.

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Correspondence to:
Prof. RAFFAELE DE CARO, MD
Section of Anatomy, Dept. of Human Anatomy and Physiology
School of Medicine, University of Padova
Via A. Gabelli 65, 35127 Padova, Italy
Tel. +39 049 8272327 - Fax +39 049 8272319
E-mail: rdecaro@unipd.it