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ORIGINAL ARTICLE

Normal anorectal musculatures and changes in anorectal malformation

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Abstract

Purpose We investigated the anorectal musclulature in normal children and anorectal malformations (ARM) to evaluate its role in bowel control mechanism.

Methods Pelves of 50 neonates died of ARM-unrelated diseases and 16 patients with anorectal malformations (8 high, 5 intermediate, and 3 low ARMs) were dissected and analyzed.

Results Normal anorectal musculature was divided into three muscular tubes: the internal sphincter tube (IAST), longitudinal muscle tube (LMT) and transverse muscle tube (TMT). The LMT came from the outer longitudinal smooth muscle fiber of the rectum and the striated muscle fiber of the levator ani, and the TMT composed of the puborectalis and the external anal sphincter. However, in ARM, the IAST was absent and the LMT, the center of the sphincter muscle complex, was only from the levator ani and could be divided into the pelvic portion and the perineal portion. The former, from the upper rim of the puborectalis to the bulbar urethral, became narrowed and dislocated anteriorly near to the posterior urethra in high ARM and rectal pouch in intermediate ARM. The latter, below the bulbar urethra to the anal dimple, was fused to a column both in high and intermediate ARM. The columnar perineal LMT run downwards and then split, penetrated the superficial part of EAS and terminated at the deep aspect of the skin, to form the anal dimple, which represents the center of the perineal LMT from the perineal aspect. The length of the LMT was longer in high and intermediate ARM than the normal neonate. The columnar perineal LMT and narrowed pelvic LMT could be possibly identified by laparoscopic and perineal approaches retrospectively and widened to allow the passage of the rectum through.

Conclusions The anorectal musculature in ARM is composed of agenesic LMT and TMT and the narrowed LMT gives anatomical evidence of the center, where the neorectum should pull through.

Keywords Rectum · Anal sphincteres · Levator ani · Anorectal malformations · Surgical anatomy

Introduction

Understanding the anorectal musculatures is crucial for surgical correction of anorectal malformations (ARM). In 1953, based on the anatomical study on 29 ARM cavaders, Douglas Stephens [1] firstly described that the puborectalis constituted the only potential sphincter available for continence following pull-through operations, and proposed the sacral route for mobilization of the rectum, tunnel formation through the puborectalis sling behind the urethra and closure of the rectourethral fistula [2]. In 1982, Alberto Peña [3] highlighted the importance of muscle complex, which was defined by a vertical group of striated muscle fibers between the levator musclulature and the fibers about the anal dimple. According to this theory, he proposed the posterior sagittal

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anorectoplasty (PSARP) to visualize the complex by splitting in the sagittomidline with use of electrical stimulator, and ultimately approximating the complex surrounding the neorectum. Since then, for the last 3 decades, PSARP has become the mainstay of surgical technique for high and intermediate ARMs. The results of PSARP represent an improvement over the prior operations [4, 5]. However, the incidence of constipation was up to nearly 40% following the PSARP [6], which might possibly result from the muscle scarring after splitting and reconstructing the muscle complex. Despite the careful and deliberate technique of an experienced pediatric surgeon, functional outcomes after the anorectoplasties were far from perfect [7]. To accomplish a correction of high ARM without mid-sagittal division of any of the muscles of continence, in 1998 Willita firstly reported the laparoscopic-assisted anorectal pull-through (LAARP) [8] and Georgeson modified this procedure and got popularization in 2000 [9]. Since that time, many other centers had gained experience with this minimally invasive technique, and had confirmed the advantages of the approach to this complex malformation [10–16]. From the LAARP point of view, the details of anorectal musculature have not been fully described and subsequently hindered the progress of this technique and improvement of its outcomes. The aim of this study was to investigate the anorectal musclulature in normal and ARM to evaluate its role in bowel control mechanism and contribute to fully understanding of the surgical anatomy of the region.

Materials and methods

Pelves of 50 neonates died of ARM-unrelated diseases and 16 patients with anorectal malformations (8 high, 5 intermediate, and 3 low ARMs) were dissected and sectioned. Each pelvis was bisected along mid-sagittal plane. The hemipelves were fixed in 10% formalin. A block was frozen-sectioned at 30 pm thickness and were stained with HE, Van-Gieson and modified Bielschowsky [17] for histological studies. This anatomic description was based upon a comparison of the dissection with sagittal, parasagittal and coronal sections in the neonate and anorectal malformation.

Results

Normal anorectal musculature in neonate

The anal canal was surrounded by the anal sphincter complex, which was defined as the internal sphincter tube (IAST), longitudinal muscle tube (LMT), and transverse muscle tube (TMT). The TMT consisted of the puborectalis and the external anal sphincter (EAS). Even in neonate, each component could be clearly identified (Fig. 1a, b).

The IAST was a thickening and homogeneous in appearance of the inner circular muscle coat of the rectal wall. In the middle sagittal plane, the mean thickness of the posterior internal anal sphincter was 0.12 ± 0.05 cm and mean length of internal anal sphincter is 1.24 ± 0.25 cm (Table 1). The caudal parts of the IAST and the superficial external anal sphincte (EAS) were penetrated by the longitudinal muscle fibers which terminated in the anal mucosa and the perianal skin (Fig. 1b, c). No obvious organized sensory nerve ending in the IAST; however, a richul free sensory nerve endings in the anal mucosa below the anorectal line, where was the junction between the rectal columnar epithelium and the anal squamous epithelium.

The LMT was a vertical layer of muscular tissue interposed between the IAST and the TMT (Fig. 1a, b and c). The LMT in neonate consisted of smaller numbers of outer striated muscle fibers and predominantly inner smooth muscle fibers. The former came from the levator ani muscle and the latter from the longitudinal smooth muscular layer of the rectum (Fig. 1a, c). At the level of the pelvic floor, there was a plane of cleavage between the longitudinal striated muscles of the levator ani muscle and the longitudinal muscular coat of the rectum laterally and posteriorly. Predominantly below the level of the dentate line, both of the longitudinal fibers were fused together to penetrate the superficial part of the EAS and terminate the deep aspect of the dermis. The terminal LMT muscle split into recognizable an "eagle claw" fibers to connect the deep dermis with abundant nerve supply (Fig. 1d). The terminal fibers of this muscle also spread into the IAST and terminate at the submucosa of the anal canal. Thus, the LMT connected the visceral and somatic parts of the anal sphincter complex, rather than being a boundary.

In the middle sagittal plane, the mean thickness of the posterior LMT was 0.09 ± 0.06 cm and the mean length (from the upper rim of the puborectalis to the perianal skin) of the posterior LMT was 1.80 ± 0.28 cm. The perineal portion of the LMT (from the bulbar urethra to the perianal skin) was 1.02 ± 0.24 cm in length (Table 2). In the transverse sections, the LMT was identifiable and showed a circular shape, interposed between the IAS and EAS (Fig. 2a). There were abundant of sensory nerve endings, such as the Pacinian corpuscles among the fibro-elastic septa of longitudinal muscle fibers, which was the pressure sensory nerve endings responsible for creating the anal sensation to the brain when the internal anal sphincter relaxation or the feces in the anal canal.

TMT was comprised of the puborectalis and the EAS components. The puborectalis muscle arose from the back of the pubic bone. It was a sling-like ribbon of muscle that was anchored anteriorly to the inferior ramus of the pubic bone on both sides. The sling was set on an inclined

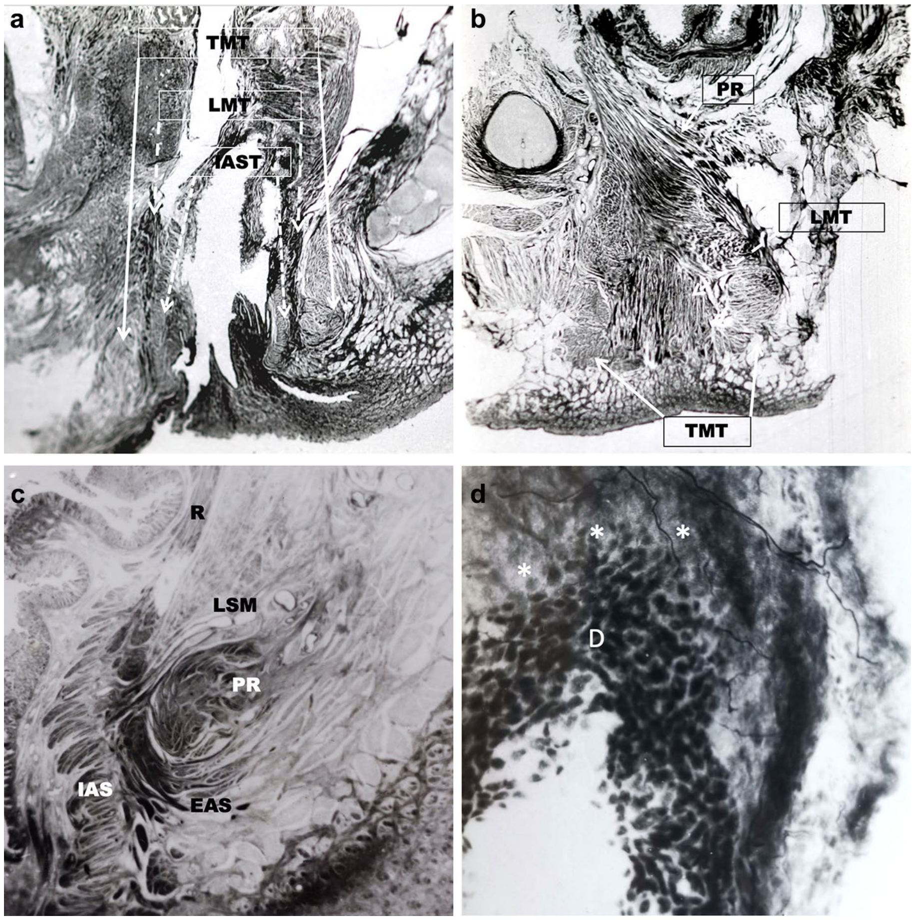

Fig. 1 **a** Middle sagittal section of the pelvis in neonate, showing the longitudinal anal muscle (LMT) between the internal anal sphincter Tube (IAST) and the transverse muscle tube (TMT), modified Bielshowsky staining, original magnification × 4. **b** Lateral sagittal section of the pelvic in neonate, showing the puborectalis (PR), the external anal sphincter (EAS) and the longitudinal muscle fibers (LMF) which terminates with the perianal skin modified Bielshowsky staining, original magnification × 4. **c** Magnification of the sagittal section of the lower part of posterior wall of the anal canal, showing the fusion of the predominantly longitudinal smooth muscle layer of the rectum (R) with the longitudinal striated muscle (LSM) from the pelvic floor to form the conjoint longitudinal muscle, which penetrated the superficial part the external anal sphincter (EAS) and terminates to the deep part of the dermis of the perianal skin, PR, puborectalis; IAS, internal anal sphincter. Van-Gieson staining, original magnification × 10. **d** Magnification of the perinal skin, showing the terminal LMT fiber becomes split into "eagle claw" manner (*) to connect the deep dermis (D) with rich nerve supply (modified Bielshowsky staining, original magnification × 400

Table 1 The thickness and length of the internal anal sphincter in neonates

	Neonate
Thickness of posterior internal anal sphincter (cm)	0.12 ± 0.05
Length of internal anal sphincter (cm)	1.24 ± 0.25

Data are presented as the mean ± SD

plane from the pubis to the back of the longitudinal muscle tube, it hugged the back and the sides of the LMT and terminal rectum. The mean length of the puborectalis was 2.29 ± 0.22 cm in neonates.

Table 2 The thickness and length of longitudinal muscle tube (LMT) in neonates

	Neonate
Thickness of posterior LMT (cm)	0.09 ± 0.06
Length of the posterior LMT† (cm)	1.80 ± 0.28
Length of the perineal portion of LMT†† (cm)	1.02 ± 0.24

Data are presented as the mean ± SD

† From the upper rim of the puborectalis to the perianal skin

†† From the bulbar urethra to the perianal skin

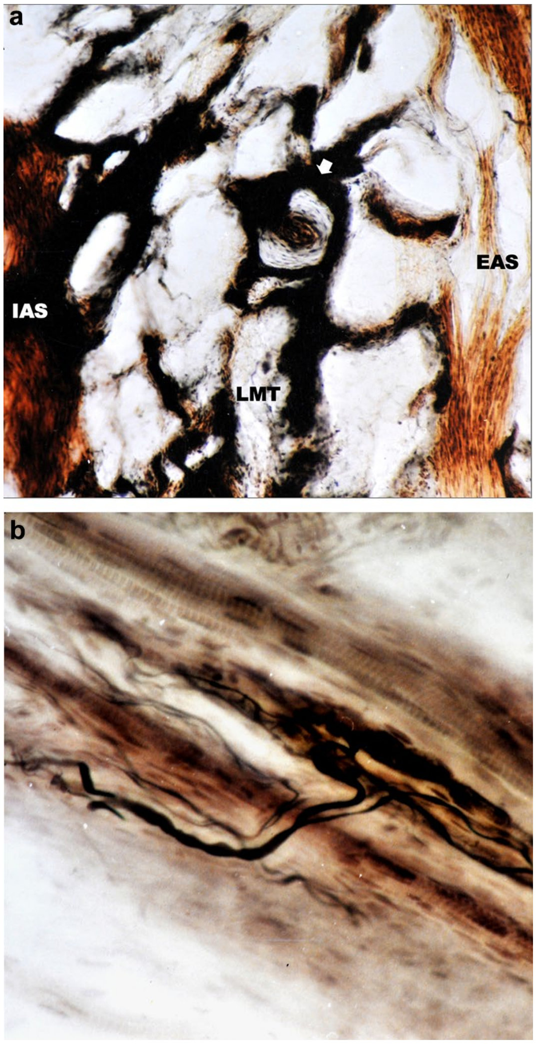

Fig. 2 **a** Pacinian corpuscle (arrow) in the longitudinal muscle layer (LMT) between the internal anal sphincter (IAS) and the external anal sphincter (EAS), modified Bielshowsky staining, ×150. **b** Muscle spindle in the puborectalis in neonate, modified Bieishowsky staining, ×400

The EAS stretched from the lower border of the puborectalis cranially to the caudal termination of the anal canal. The EAS attached anteriorly to the perineal muscles, and posteriorly to the anococcygeal raphe and coccyx, whereas its striated muscle fibers tranversely surrounded the perineal LMT. In the neonate, the puborectalis and EAS could not be clearly separated and there was no constant plain of cleavage between these two muscles (Fig. 1b). The most distal part of the EAS, so called superficial or subcutaneous EAS, was penetrated and divided by the end of the longitudinal muscle fibers, which terminated in the perianal dermis (Fig. 1c, d).

Even in neonates, there were plenty of the muscle spindles in the puborectalis and the EAS (Fig. 2b). The muscle spindles in this region were morphologically extremely complicated.

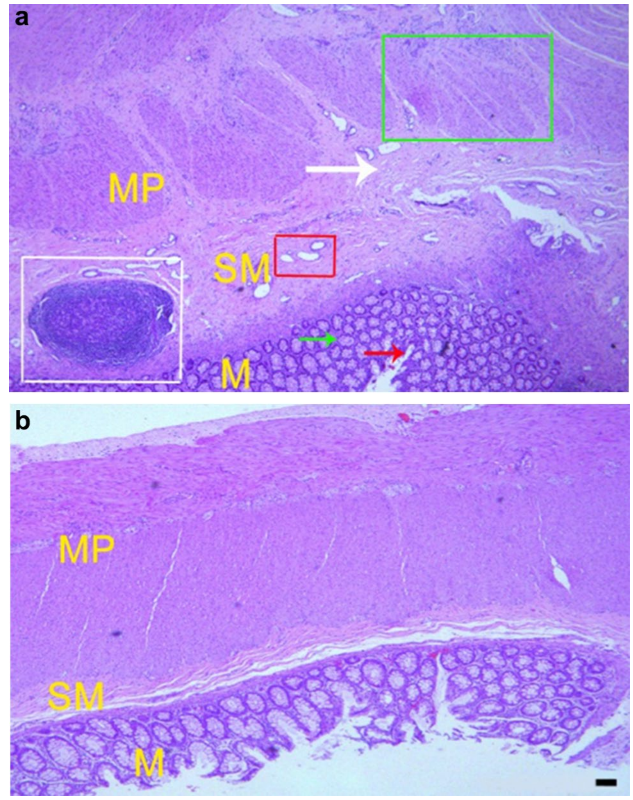

Fig. 3 Fibrosis exists more predominantly at the submucosa and between the smooth bundles of the rectum in anorectal malformation (**a**) than in neonate (**b**), *M* mucosa, *SM* submucosa, *MP* musclularis propria, *HE* staining, ×100

Anorectal musculature in ARM

In ARM, the terminal part of the rectum was abnormally placed above (partially or completely) the LMT. The longitudinal smooth muscle from the rectum did not fuse with the longitudinal striated muscle fibers from the levator ani muscle both in high and intermediate type of malformations, but it extended along the rectal wall and continued with the wall of the rectourethral fistula. Dilatation of the distal rectum was evident in high and intermediate ARM specimens. The circular smooth muscle became thickened and hypertrophic, especially at the junction with the fistula. Histologically, the fibrosis tissue predominantly existed at the submucosa and between the bundles of the smooth muscle fibers in the rectum (Fig. 3). Hypoganglionosis in the terminal dilated rectal wall was a characteristic change in the wall of dilated rectum. Moreover, it was found that there were plenty of autonomic nerve plexus (nerves and ganglia) surrounding the walls of the rectoprostatic or rectovesical fistula and the terminal rectum in high ARM (Fig. 4), these plexus contributed to supply the bladder and penis.

In ARM, the LMT only came from the striated muscle fibers of the levator ani muscle and its route was nonlinear.

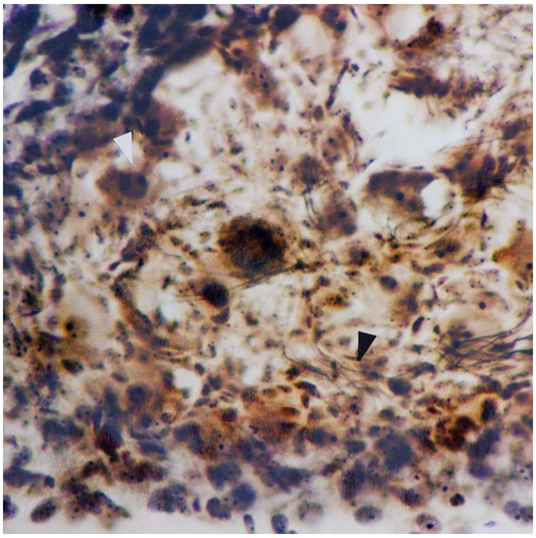

Fig. 4 Autonomic nerve plexu (nerves and ganglia) surrounding the wall of the rectoprostatic fistula in a hige anorectal malformation patient, modified Bielshowsky, ×400

Because the rectal pouch located above the pelvic floor in high ARM, the pelvic LMT was displaced upwards and anteriorly just behind the posterior urethra (Fig. 5a, b). In the intermediate ARM, the rectal pouch extended alone the posterior urethral down into the levator ani muscle, so the pelvic LMT surrounded bilaterally the posterior wall of the rectal pouch and the urethral fistula. Both in high and intermediate ARMs, below the level of the bulbar urethra, the bilateral and posterior longitudinal muscle fibers concentrated and fused to form a column, named the perineal LMT, which run downwards and penetrated the superficial part of the EAS and terminated at the deep aspect of the skin, to form the "anal dimple". The anal dimple represented the center of the sphincter muscle complex from the perineal aspect (Fig. 6). In the middle saggital plane, the mean length (from the upper rim of the puborectalis to the perianal skin) of the LMT was 2.66 ± 0.37 cm in high ARM and 2.33 ± 0.54 cm in intermediate ARM, respectively. The mean length of the perineal LMT (from the bulbar urethra to the perianal skin) was 2.07 ± 0.51 cm in high ARM and 1.22 ± 0.17 cm in intermediate ARM (Table 3). The number of the longitudinal muscle fiber was fewer especially in some high type ARM than the normal neonate. No sensory nerve ending was found in the LMT in ARM. In the case with good developed LMT, the dimple was deeper and surrounded by the circular superficial EAS. In some cases with well-developed LMT, the

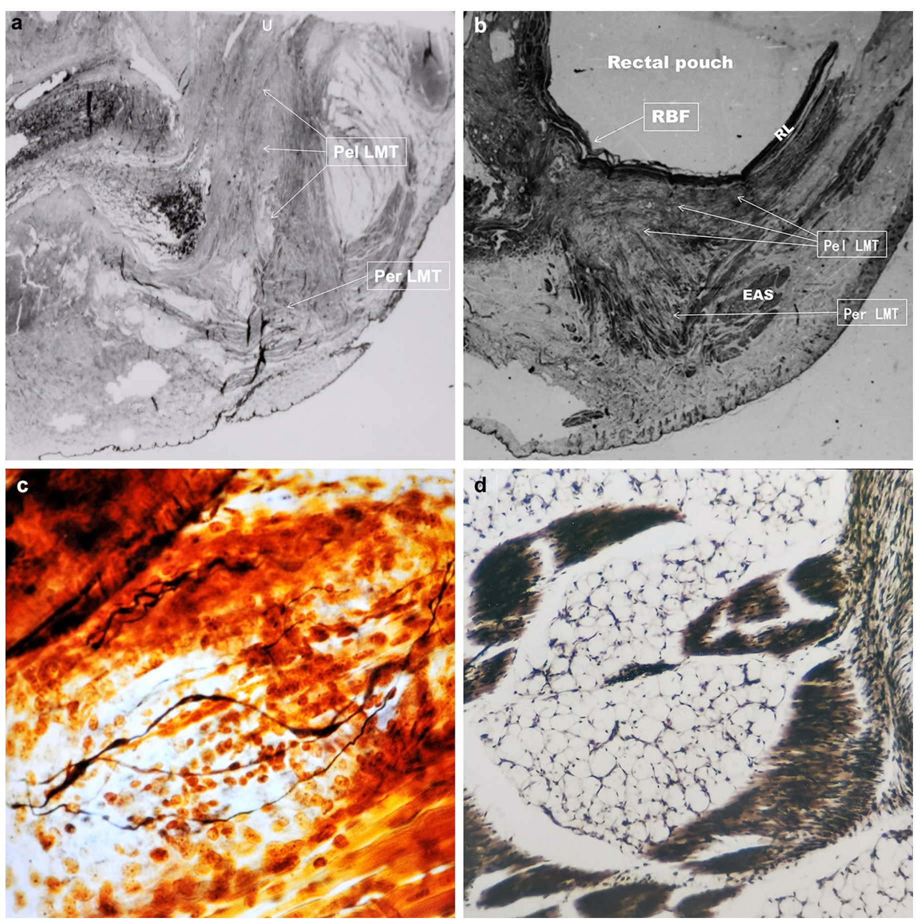

Fig. 5 **a** Middle sagittal section of the pelvis in rectal bladder neck fistula, showing the longitudinal muscle tube (LMT) comes from the longitudinal striated muscle fibers of the levator ani muscle. The pelvic LMT (Pel LMT) is displaced anteriorly behind the posterior urethra. HE staining, original magnification × 4. **b** Middle sagittal section of the pelvis in rectal bulbar fistula (RBF), the rectal pouch is dilated and its longitudinal rectal coat (RL) extends to the fistula. The pelvic LMT (Pel LMT) surrounds the wall of the rectal pouch and the urethral fistula. The perineal longitudinal muscle tube (Per LMT) fuse to form a column which run downwards the anal dimple. HE staining, original magnification × 4. **c** External anal sphincter is filled with the fat tissue in high anorectal malformation with the rectal prostatic fistula, modified Bielshowsky staining, × 100. **d** Muscle spindle in the puborectalis in rectal prostatic fistula, modified Bieishowsky staining, × 400

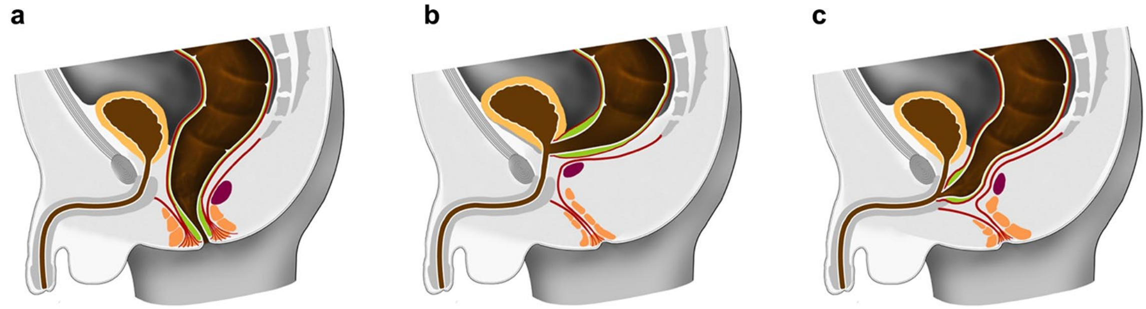

Fig. 6 Diagrams of the anorectal musclature in normal neonate (**a**), rectobladerneck fistula (**b**) and rectobbulbar fistula (**c**). **a** showing that the longitudinal muscle tube (LMT) comes from the longitudinal smooth muscle of the rectum and longitudinal striated muscle of the levator ani muscle. **b** showing the LMT comes from the levator ani muscle and is displaced upwards and anteriorly just behind the posterior urethra. **c** showing the LMT comes from the levator ani muscle, the pelvic LMT is widened by the rectal pouch and the perineal LMT is fused to form a column

Table 3 The length of puborectalis and longitudinal muscle tube (LMT) in neonates and anorectal malformation (ARM)

	Neonate	High ARM	Intermediate ARM
Length of Puborectalis (cm)	2.29 ± 0.22 (2.00–3.00)	1.41 ± 0.46* (1.10–2.10)	2.02 ± 0.33* (1.80–2.50)
Length of LMT (cm)	1.79 ± 0.27 (1.40–2.60)	2.66 ± 0.31 (3.00–2.20)	2.33 ± 0.54 (1.70–2.80)
Length of Perineal LMT (cm)	0.97 ± 0.23 (0.50–1.50)	2.07 ± 0.51 (1.50–2.70)	1.22 ± 0.17 (1.00–1.40)

Data are presented as the mean ± SD (range)

*The lengths of the puborectalis in high ARM were significantly shorter than that in intermediate ARM ($p < 0.05$)

terminal portion of the longitudinal muscle fibers radially split and penetrated the circular EAS to connect the peri-dimple skin.

The TMT in ARM was comprised of the puborectalis and the EAS subdivisions and surrounded the LMT. In the high type ARM, the puborectalis muscle sling narrowed and upward anteriorly dislocated; however, in the intermediate ARM, the sling was wider to fit the size rectal pouch and the rectobulbar fistula than in high ARM. The length of the puborectalis in high ARM was significantly shorter than that in intermediate ARM (1.41 ± 0.46 cm vs. 2.02 ± 0.33 cm, $p < 0.05$). In ARM, the EAS dominantly underdeveloped and shrunk, the volume of the muscle fiber was fewer than in normal neonate. The fat-filled muscle was apparently observed in the EAS in high ARM (Fig. 5c). The muscle spindle in the puborectalis was the only sensory nerve endings observed (Fig. 5d) in anal region and no obvious sensory nerve endings found in the EAS in ARM. The number of the muscle spindle in the high and intermediate ARMs was significantly fewer than in normal with $p < 0.05$ [18].

Discussion

The anal canal, defined from the upper rim of the puborectalis sling to the anal orifice, is the most important part for bowel control. The canal consists of two muscular systems, the internal anal sphincter, the terminal portion of the inner circular smooth muscle layer of the rectum, and the surrounding striated muscle components. Although the literatures on the anatomy of the anal canal revealed a great variability in descriptions of the anorectal musclulature in human, in this study we classify the normal anal sphincter complex into three muscular tubes: IAST, LMT and TMT. ARMs are not a simply covered anus, but considered to be a caudal dysplasia syndrome with maldeveloped sphincter muscle complex and rectum. The association of the ARM with urinary, bony sacral and neurological abnormalities has been well recognized [19–22]. Our study shows that the IAS in neonate is morphologically identified as a thickness circular muscle structure, with an extension of the muscular wall of the rectum. While fecal retention, the internal anal sphincter contracts to maintain the resting pressure gradient in the anal canal and the rectum relaxes and performs a cumulative role. During bowel movements, the rectum strongly contracts and the IAS relaxes to facilatate evacuation of the stool through the open anal canal. The functions of the rectum and IAS could not controlled consciously.

In high and intermediate ARMs, the terminal rectum does not pass through the pelvic floor to the perineal skin, the connections of the IAST with the LMT and TMT does not developed. Because the outlet of the rectum is narrowed in early fetal stage, the rectum is obstructed during the development before birth in ARM Our study shows that the rectal pouch in ARM is dilated with predominant thickened circular smooth muscle and fibrosis tissue. This finding supports the hypothesis that fetal colonic peristalsis and defecation is a normal physiological process [23]. These distinct defects in the neuro-musculature changes are the sign of the intrinsic damages of the smooth muscle and innervation in the rectal pouch, and may be responsible to the rectal dysfunction in association with the postoperative constipation and megarectum. It is reasonable to believe that the distal dilated rectal pouch needs to be resected for better functional outcomes of the remaining gut.

Urinary retention is one of the common complications after anorectoplasty for the rectoprostatic or rectovesical fistula [24]. It was thought to result from the damage of the autonomic pelvic nerve plexus during the surgery. In this study, it is found that a plenty of autonomic nerve plexus exists closely surrounding the walls of the fistula in high ARM. These plexus may contribute to supply the bladder and penis. Because the external dissection and ligation of the fistulous wall in surgery may injury these plexus and result in postoperative urinary retention. It is advisable to close the fistular by internally removing the fistulous mucosa and keeping the muscular cuff and the peripheral nerve plexus intact [25].

Our study demonstrates that the LMT in neonate is fully developed from the outer striated muscle of the levator ani and the inner longitudinal smooth muscle of the rectum between the IAST and the TMT. The LMT provides an anatomical evidence of a functional connection between the IAST of the smooth muscle system and the TMT of the striated muscle system, suggesting a pivotal role for the LMT in the dynamics of pelvic floor function and dysfunction. The longitudinal course of the LMT between the IAST and the TMT contributes to shortening of the anal canal during sphincter contraction and deepening position of the perianal skin. The LMT plays a role in anchoring the anal canal, preventing prolapse, closing the anal canal, and bridging the IAST and the TMT [26, 27].

The study by Shafik demonstrated that the levator ani muscles behave as one muscle: they contract or relax en masse [28]. The portion of the LMT from the longitudinal striated muscle and the TMT are belonging to the levator ani muscle. During these muscles contract en mass, the anal canal is shorten by the LMT, angulated by the puborectalis sling and closed by the TMT. While the bowel movement, the levator ani muscle relaxes, with the strong peristaltic contraction of the rectum, the contraction of the longitudinal smooth muscle of the LMT makes the anal canal straight and open, leading the stool expeled out.

The present study shows that abundant organized nerve endings, such as the Pacinian corpuscles and muscle spindles, are encountered in the LMT and TMT, indicating that the LMT and TMT are not only the motor but also the sensory organs. When the rectum is dilated by the stool or gas, the IAST will relax to stimulate the Pacinian corpuscles in the LMT and the muscle spindles in the TMT, to induce the reflex of the external sphincter contraction and create the bowel sensation.

Our study finds that in ARM, the LMT only comes from the longitudinal striated muscle of the levator ani. The LMT is the landmark of the center of the sphincter muscle complex, and can be divided into two parts; the pelvic LMT and the perineal LMT. However, the LMT is curve rather than a straight passage. The pelvic LMT displaces upwards and anteriorly just behind the posterior urethra in high ARM and behind the rectal pouch in intermediate ARM. The length of the puborectalis is shorter in high ARM than in intermediate ARM. The perineal LMT fuses to form a column both in high and intermediate ARM, runs downwards from the posterior urethra to the deep dermis of the anal dimple. The lengths of the LMT associated with ARM are increased, this correlates inversely with the degree of anorectal agenesis. They ranges from 2.2 to 3.0 cm in high ARM and 1.7 to 2.8 cm in intermediate ARM and 1.4 to 2.6 cm in neonate. The lengths of perineal LMT ranges from 1.5 to 2.7 cm in high ARM and 1.0 to 1.4 cm in intermediate ARM. These data are important for tunnel formation in laparoscopic assistant anorectoplasty from the perineal approach. The topography of the LMT and TMT in ARM could be possible to be defined and evaluated by a phase array MRI technique or computed tomography scanning before and after surgery [29–31]. The aim of the anorectoplasty should pull the neorectum through the LMT to make the longitudinal smooth muscle and the longitudinal striated muscle together to establish the normal LMT. We speculate that if the LMT is maldeveloped as in the flat bottom, damaged by the surgery or missed to surrounding the rectum in its center, the anus would be slack, prolapse, or asymmetrical after the anorectoplasty and poor anorectal continence would developed.

Because it is found in this study that in some cases with well-developed LMT, the distal fibers of the perineal LMT spreads and penetrates in the circular subcutaneous EAS to terminate at the deep dermis surrounding the anal dimple, the center of the distal perineal LMT in ARM is opened below the skin at the center of the dimple. The anal dimple marks the center of the distal perineal LMT. Because the depth of the dimple represents the LMT development, the deeper the dimple is, the better the LMT is developed. Topographically, the LMT in ARM is considered as an hourglass in shape with a longer tunnel between the two smaller funnels. As an electrical stimulator elicits the contraction of the superficial EAS and the LMT muscle from the perineal aspect, the potential tunnel in the LMT center could be possibly identified and dilated to widen from perineal and pelvic approaches under the guidances of the electrical stimulator and laparoscopy.

The puborectalis muscle and the EAS act as a common functional unit [28]. The puborectalis angulates the tip of the LMT upwards, creating the anorectal angle, in this way, the rectum and the LMT become closed with consequent the TMT contraction. The muscle spindle in TMT may create the proprioceptive reflex mechanism to maintain the persistent tonic contraction of these muscles and the sensory afferent messages from the muscles to the brain [32, 33], which may be translated as the anal sensation.

It is found in this study that the puborectalis muscle sling in the high type ARM narrows and dislocates upward anteriorly; however, in the intermediate ARM, the sling is wider to fit the size rectal pouch and the rectobulbar fistula than in high ARM. The length of the puborectalis in high ARM is significantly shorter than that in intermediate ARM. This musculature feature explains the reason that bowel control is better in intermediate ARM than in high ARM after the anorectoplasty [34], because it is more possible to put the rectum into the wider pelvic LMT in intermediate ARM than through the narrower pelvic LMT in high ARM.

The muscles in the TMT in ARM are maldeveloped and the number of the muscle spindle in ARMs is significantly fewer than in normal, which are responsible for poor anal sensation and bowel control after anorectoplasty in some ARM patients. Minimal trauma and maximal usages of the LMT and the TMT are crucial for achieving the good anorectal continence [18].

Pena proposes the theory of the muscle complex [3, 7, 35], which is defined by a vertical group of striated muscle fibers between the levator musclulature and the fibers about the anal dimple. According to this theory, after the middle of the muscle complex is splited, the center of the complex is identified by contraction of the vertical fibers and elevation of the anal dimple under electrical stimulation. The crossing of the muscle complex fibers with the parasagittal muscle structures defines the anterior and posterior limits of the new anus. Because the study by Shafik [18] demonstrated that the levator ani muscles behave as one muscle: they contract or relax en masse, by the electric stimulation described by Pena, it is impossible to distinguish the LMT from the TMT by electric stimulation. To compare with our observation, the extent of the muscle complex present by Pena is beyond the limitation of the LMT in high and intermediate ARM and the neorectum in PSARP is surrounded by the TMT rather than by the LMT.

In conclusion, our findings show that in the region of the anal canal, three muscular tubes can be identified: the IAST, the TMT which consists of puborectalis and EAS, and the LMT which is interposed between the IASM and TMT. The LMT extends vertically from the levator ani muscle to the perianal dermis, consisting of outer striated muscle fibers from the levator ani and inner smooth muscle fibers from the rectum. In ARM, the IAST and the inner longitudinal muscular fibers of the rectum is absent, the LMT only consists of the longitudinal striated muscle from the levator ani muscle. The LMT in ARM can be divided into the pelvic LMT and the perineal LMT. The pelvic LMT is displaced anteriorly just posterior to the neck of bladder and posterior urethra in high ARM or to the terminal rectal pouch and rectobulbar fistula in intermediate ARM. The perineal LMT is fused to form a vertical column in both high and intermediate ARM. In ARM, the LMT is a closed muscular tube, which could be possibly dilated to widen leading the rectum pull-through to establish the normal anorectal function.

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Compliance with ethical standards

Conflict of interest The authors have no conflict of interest to disclose.

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