Pathological physiology of the anorectal malformations with visible fistula. A review.

M.D. Levin, MD, PhD, DSc. Radiologist,

Department of Pediatric Radiology of the 1-st State Hospital, Minsk, Belarus.

Dorot-Netanya Geriatric Medical Center, Israel.

Amnon VeTamar, 1/2, Netanya, 42202, Israel.

nivel70@hotmail.com; michael.levin@dorot.health.gov.il

https://orcid.org/0000-0001-7830-1944

https://www.anorectalmalformations.com

Scopus Author ID: 7402571390

All information contained in this review has been repeatedly sent to leading pediatric surgeons, who have published their work on the diagnosis and treatment of anorectal malformations over the past 10 years. At the forum, which assumed an open discussion, there was not a single objection or attempt to correct my views on the pathological physiology of anorectal malformations with visible fistulas. The new view of the pathophysiology of ARM opens great opportunities for improving the surgical correction of this pathology.

Abstract

Until 1982, pediatric surgeons came to a consensus that in patients with anorectal malformations (ARM), the intestine that is located caudal to the pubococcygeal line is the anal canal and, in order to achieve the best functional result, it must be preserved during surgery. Simultaneously with the publication of posterior sagittal anorectoplasty (PSARP), it was stated that except for patients with rectal atresia and stenosis, patients with ARMs are born without an anal canal. It was believed that the rectal pouch or fistula should be removed, which was the rationale for the use of PSARP in all types of ARM. Purpose, analysis of the literature to study anatomy and physiology of ARM with visible fistulas. Results. Analysis of the literature indicates that all patients with ARM with visible fistulas (perineal and vestibular) have a functioning anal canal, which ensures normal fecal retention, and defecation. Unlike the normal anal canal, its outlet is displaced anteriorly and, as a rule, is represented by a narrow rigid ring. Therefore, when an infant has hard stools, the ectopic anus does not allow normal emptying of the rectum, resulting in stool retention, rectal distension (megarectum), and secondary damage to the pelvic floor muscles (descending perineum syndrome). The distal part of the anal canal is outside the ring of the subcutaneous portion of the external anal sphincter, which can cause gas leakage. From the point of view of the pathological anatomy of defects, these forms should be called anoperineal ectopy or anovestibular ectopy.

Keywords: anorectal malformations; anorectal fistula; anorectal physiology; anovestibular ectopy; anoperineal ectopy; pathophysiology anorectum.

Introduction

In 1953, Stephens proposed the concept of a pubococcygeal (P-C) line, which runs from the lower limit of the pubic bone to the distal coccygeal vertebra. He showed that this line corresponds to the location of the puborectalis muscle (PRM), which is located between the rectum and the anal canal. If the blind end of the intestine is located above this line, these cases are considered a high type of anorectal malformations (ARM), if at the level of this line it is an intermediate type, and low type if the intestine is located more caudally of this line [1]. This understanding of the pathological physiology of ARM was reflected in the Wingspread classification (1984). Since then, it was believed that if the gut is located below the P-C line, it means the patient has an anal canal that needs to be preserved during surgery [2]. Such a subdivision was of great practical importance. With high types of ARM pull-through surgery was performing, and with low types, perineal rectoplasty was performed. "The results in low deformities operated by perineal rectoplasty showed "good" clinical scores, good preservation of the rectoanal reflex, and good electrical activity of the external sphincter [3]. Low type anomalies were treated by neonatal perineoplasty, anal transplants, or cut-back. In patients with the vestibular ectopy, "the sling of the puborectalis muscle was well identified by causing contraction of the puborectalis muscle with an electric stimulator". Patients with low type had good results in 100% [4].

In 1982, deVries and Peña published their experience in the use of pull-through operation through the posterior sagittal approach proposed by Jean Zulema Amussat in 1835 [5,6]. The endearing feature of posterior sagittal anorectoplasty (PSARP) is that "in perineal and vestibular fistulas, the rectum is immediately visible" after separating the superficial portion of the external anal sphincter (EAS) from the coccyx, after the incision of muscle complex (which consists from the puborectalis muscle (PRM), deep and superficial portions of EAS) and

levator muscles in the midline" [7]. Two months after the first article [5], Peña publishes an article, exclusively based on materials from Mexico City, in which the following provisions are put forward without any justification. (A) PRM is not a sphincter, which means it is not involved in the fecal retention; (B) Most patients with ARM do not have an anal canal; (C) the rectum has a common wall with the bladder in females and with the urethra in males [6]. It is currently believed that "except for patients with rectal atresia and stenosis, patients with ARMs are born without an anal canal". The intestinal segment located caudal to the P-C line is called the rectum, rectal pouch, or fistula [7]. Therefore, the Krickenbeck classification (2005) was adopted, which is a listing of the main types of ARM without a division into high and low types [2].

In 1992, Okada et al. proposed the anterior sagittal anorectoplasty (ASARP) [9]. Laparoscopically assisted anorectal pull-through (LAARP) was first reported as a successful cure of high ARM by Georgeson et al. in 2000 [10]. All pediatric surgeons, regardless of access to the rectum, perform pull-through surgery and use the terms "rectum", "fistula" or "rectal pouch" in the name of the distal intestine, formally recognizing the absence of the anal canal.

The aim of the study was to analyze articles on the pathological anatomy and physiology of ARM with visible fistulas (perineal and vestibular).

Material and methods. The article analyzes 48 studies related to the anatomy and physiology of the pelvic floor and the pathological physiology of ARM, which indexed in PubMed, SCOPUS, and EBSCO.

To understand the pathological physiology of ARM, it is necessary to use generally accepted anatomical designations and to know the normal anatomy and physiology of the anorectum.

1. Normal anatomy and physiology of the anorectum.

Stool accumulates in the rectum, where pressure on the intestinal wall stimulates reflexes, which play an important role in retaining feces and defecation. The anal canal, located distal to the pubococcygeal line, is constantly closed. Its length as a zone of high pressure in comparison with the pressure in the rectum increases from 1.7 cm in newborns to 4 cm in adults [11,12]. The same figures were obtained during barium enema, where the anal canal is defined as the distance from the rectum to the contrast marker at the anal dimple along the posterior contour of the enema tip (Figure 1, a). Table 1 shows the indicators of the length of the anal canal and the width of the rectum in children of different ages without pathology of the digestive tract [13, 14].

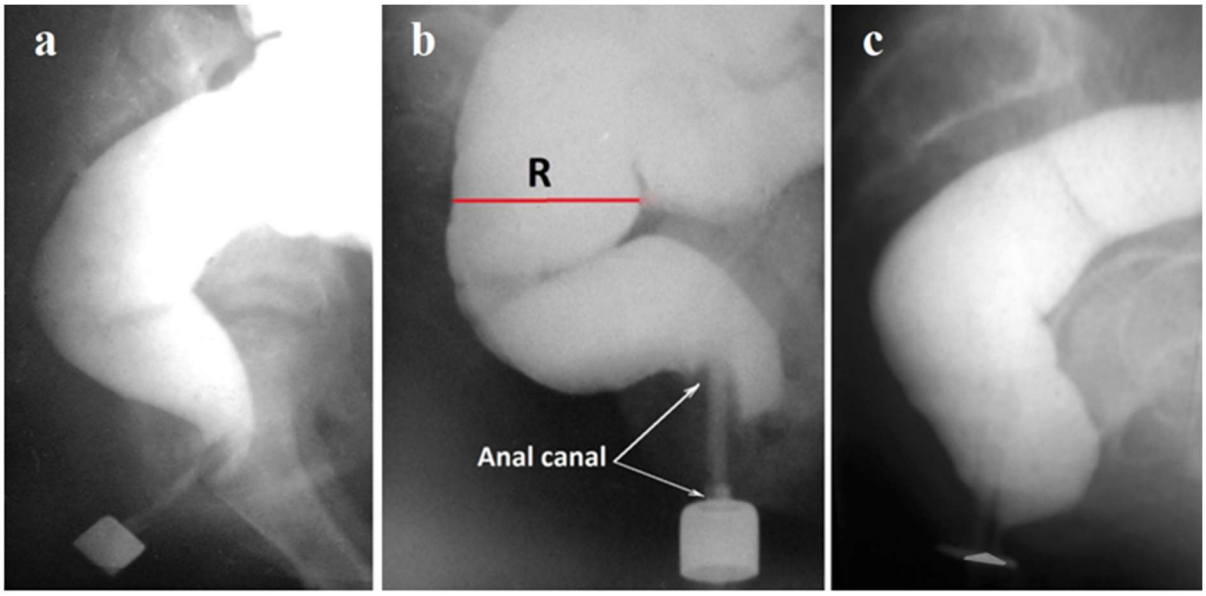

Figure 1. Lateral radiographs of anorectum in different patients without digestive system pathology. **(a).** In a 12-year-old patient, the length of the anal canal is 3.4 cm. As a result of the contraction of the PRM, the axis of the anal canal is displaced forward relative to the axis of the rectum with the formation of an acute rectoanal angle. **(b).** In a 9-year-old patient, the anal canal is 3.3 cm long. As a result of BAC relaxation, barium penetrated the upper part of the anal canal in front of the enema tip. The posterior wall in the upper part of the anal canal is pressed against the tip of the enema by contracted PRM. This is a picture of the rectoanal inhibitory reflex. Despite the relaxation of the IAS, barium (fecal) retention occurs because of the contraction of the PRM and EAS. **(c).** Under the influence of high pressure in the rectum, a wide opening of the anal canal occurred, which is due to the contraction of the levator plates. This attempt

defecation was prevented by voluntary contraction of the subcutaneous portion of the EAS.

Table 1. The normal size of the rectum and anal canal in different ages.

Ages	The width of the rectum (cm)	The length of the anal canal (cm)
5 days – 11 months	1.3 – 3.0 (2.24±0.09)	1.7 – 2.5 (2.21±0.15)
1 – 3 years	3.0 – 3.7 (3.21±0.11)	2.3 – 2.8 (2.55±0.10)
4 – 7 years	3.0 – 3.9 (3.43±0.14)	2.5– 3.6 (3.17±0.14)
8 – 10 years	3.2 – 4.1 (3.72±0.05)	2.6 – 3.7 (3.11±0.10)
11 – 15 years	3.6 – 4.6 (3.95±0.07)	3.1 – 3.9 (3.43±0.10)
23 – 64 years	3.5 – 4.8 (3.95±0.21)	3.4 – 4.2 (4.08±0.07)

Fecal Retention. At rest, the IAS and striated muscles of the pelvis floor are in a state of tonic contraction. They help to support the pelvic organs and participate in the continuous retention of feces. When the fecal bolus penetrates from the sigmoid colon into the rectum, it stretches the wall of the rectum and rectal pressure increases. It causes a reflex relaxation of the IAS and contraction of the EAS and PRM (anorectal inhibitory reflex). The PRM pulls forward the upper part of the anal canal. In front, inside the PRM loop the anal pressure decrease because of the IAS relaxation. Between the rectum and anal canal, there is a narrow opening through which the gas and liquid feces can penetrate the upper part of the anal canal. In the mucosa at this level, there are sensors that allow distinguishing the liquid from the gas. During anorectal inhibitory reflex, the formed stool remains in the rectum due to the acute anorectal angle and the narrow hole between the rectum and anal canal. After a few seconds, the rectum adapts to the new rectal volume and relaxes. After entering the rectum of another bolus of feces this picture (anorectal inhibitory reflex) is repeated. This picture can be observed up to seven per hour. During IAS relaxation, its muscle fibers restore contraction ability. In this period, the fecal retention is performed by the

PRM and EAS contraction. During the rise of the intra-abdominal pressure (rise from the spot, cough, etc.), the reflex contraction of all sphincters occurs.

Defecation. When the need for a bowel movement coincides with the possibility of its implementation, a straining of the abdominal wall and diaphragm increases the rectal pressure to the threshold defecation pressure. A strong peristaltic wave of the rectum expels stool through the open anal canal. The wide opening of the anal canal is due to the relaxation of the IAS, PRM, and EAS, with a simultaneous contraction of the LAM. Any of the pressure levels depend not only on the volume of feces but also from the tone of the rectum. During the opening of the anal canal, its wall is stretched at the level of deep and superficial portions of the EAS. The subcutaneous portion is relaxed, but it is not connected with LAM and therefore does not stretch. Therefore, during the evacuation of soft feces, it forms a tape, the diameter of which depends on the viscosity of the feces [13,14].

II. Pathological anatomy and physiology of ARM with visible fistulas

Histological studies in ARM. In a study by Holschneider et al. it was shown that in patients with ARM "Classical aganglionosis was found in 31% of the rectal pouch specimens, hypoganglionosis in 38%, neuronal intestinal dysplasia (NID) type B in 14%, and dysganglionosis in 10%". In the authors' opinion, "...the recommendation to use the distal rectal pouch and parts of the fistula in the reconstruction of anorectal malformations should be reconsidered" [15]. These histological results were confirmed by other researchers, who believed that the histological structure of the rectal pouch should be consistent with the structure of the rectum [16,17]. Xiao et al., also concludes that the distal rectal pouch has distinct defects in the neuromusculature and need to be respected for better functional outcomes of the remaining gut [17]. First, like the previous authors, they compared the tissue specimens of the rectum, taken from 2 to 4 cm above the dentate line in the control group, with the tissue specimens, taken in the ARM group from 0.5 to 2.0 cm of the most distal part of the rectal pouch, i.e.

compared the samples from the anal canal with the rectal samples. Secondly, they did not consider that in the postnatal period there are changes in the terminal part of the intestine, associated with chronic constipation due to stenosis of the ectopic anus.

Alamovich et al. investigated the innervation of the normal IAS. This study shows that the internal sphincter itself has no autonomous innervation unlike the rest of the digestive tube [18]. Thus, the research of Holschneider and other authors proves that what they called the "rectal pouch" is the anal canal. Lambrecht and Lierse in neonatal pigs with ARM found that the proximal region of the fistulae in ARM has most features of a normal anal opening: (1) it is surrounded by an internal sphincter, (2) the rectal pouch in the region of the internal sphincter as well as the fistulae are hypoganglionotic, (3) the proximal fistula region is lined by transitional epithelium, and (4) it contains anal glands. They, therefore, consider that the fistula should be designated as an ectopic anal canal. The most important result was the demonstration of a normal internal sphincter even in high and intermediate types of ARM [19]. Rintala et al have shown that in anorectal malformations the distal rectal pouch with the fistulous connection is an anal canal ectopy [20]. Articles that use anatomical designations that are not accepted in scientific research, in which the conclusions are the same for defects of different levels, do not inspire confidence and therefore they are not given in this work.

X-ray examinations. In patients with perineal and vestibular fistulas, the distal intestine at rest is constantly in a closed state. Its length between the rectum and anal dimple in children without a serious megarectum is equal to the length of the normal anal canal (**Figure 2. a)**. During a bowel movement, the anal canal opens to the width of the rectum. At this point, the caudal wall of the anal canal is approaching the anal dimple. The distance between the wall of the anal canal and anal dimple varies from 2 to 5 mm, depending on the age. It is equal to the

thickness of the skin and subcutaneous tissue (**Figure 2. b**). During a barium enema, penetration of the contrast agent into the upper part of the anal canal in front of the enema tip can be seen intermittently. At this time, the posterior wall of the anal canal at this level is pressed against the tip of the enema by the contracted PRM. It is the radiological equivalent of the anorectal inhibitory reflex (**Figure 2.c**). Contrast retention and defecation are indistinguishable from normal anorectal function.

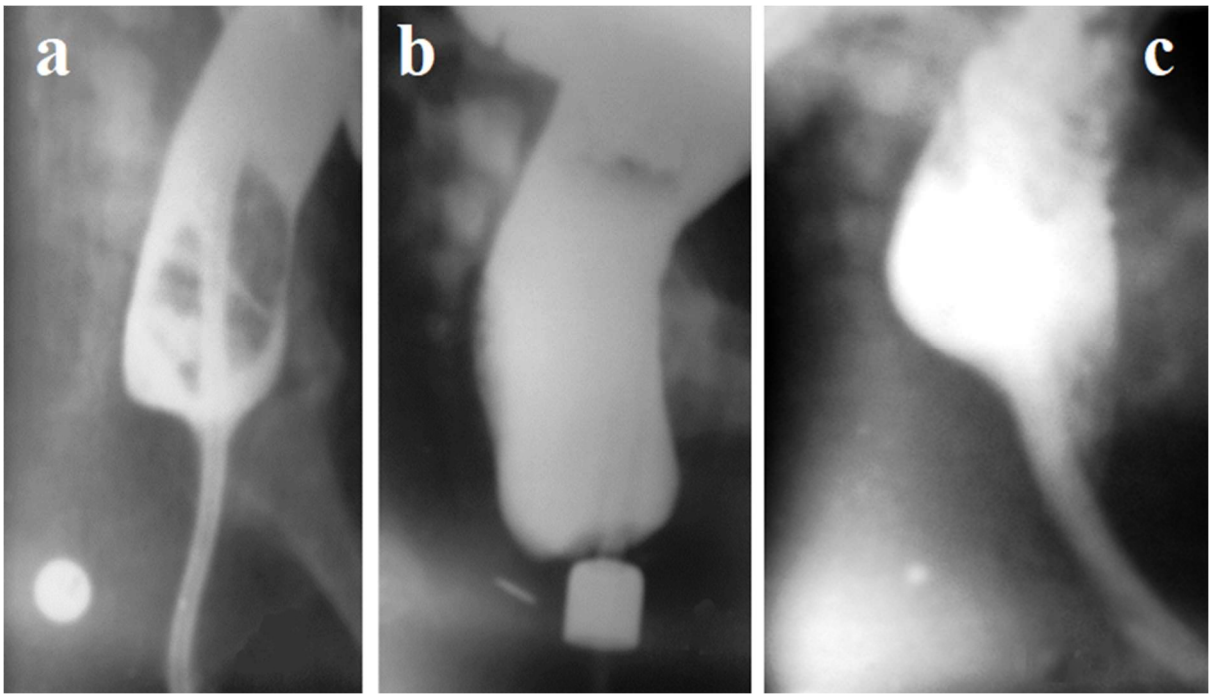

Figure 2. (a-b) The radiographs of the same girl with vestibular fistula performed at different ages. **(a).** At the age of 3 months, the rectum was filled with barium through the catheter, conducted through the fistula. A pushpin is located near anal dimple. The distal intestine, with a length equal to the length of the normal anal canal, constantly contracted around the catheter, preventing leakage of barium. **(b)** At the age of 9 months, during a barium enema, the wide opening of the anal canal occurred. The distance from the pushpin to the distal wall of the open anal canal equals 4 mm. Barium does not penetrate outward, since the tip of the enema occluded the narrow and rigid ectopic anus. The true diameter of the marker on the enema tip is 1.6 cm. The width of the rectum is 4.3 cm at the maximum rate for children under 1 year is 3 cm. Conclusion: ano-vestibular ectopy, megarectum. The diastasis between the anal canal and anal dimple is (4 mm), which corresponds to the thickness of the skin and subcutaneous tissue. **(c)** Barium was injected into the rectum through an intubation tube (№ 8), passed through the vestibular fistula. The penetration of barium into the upper part of the

anal canal in front of the intubation tube is determined. The posterior wall of the anal canal is pressed against the tube of the contracted PRM. The PRM and EAS provide normal liquid barium retention.

Ectopic anus of the perineal and vestibular fistulas, as a rule, are represented by a rigid ring with varying degrees of narrowing compared to the normal anus. While the baby has liquid feces, the narrow opening does not prevent normal rectal emptying. When hard stool appears, it does not completely pass through the ectopic anus. Stool accumulates in the rectum causing it to expand (megarectum). The fact that the ectopic anus is usually narrow is beyond doubt. Because of this, in patients with visible fistula, there were no manometric examinations because it was impossible to pass a rectal balloon. Kyrklund et al performed cutback anoplasty, or dilatations, in boys with perineal fistula [21]. De la Torre-Mondragón et al found megarectum in 60% of patients with visible fistulas during a preoperative study [22]. This figure is clearly underestimated, since the assessment was made by eye, without comparison with the normal range. This information turned out to be unexpected for the authors since the literature does not describe the relationship between megarectum and the narrowness of the fistulous opening. Sharma et al showed that the wider the rectum before PSARP, the more severe the constipation after surgery [23]. In another study, 48 (87%) of 55 patients with visible fistulas aged 1 day to 12 years had chronic constipation before surgery. Each of them on X-ray examination had rectum wider than the maximum age limit. The degree of megacolon depended on the width of the fistula and the age of the patient. Only in 3 out of 7 patients under the age of 3 months without complaints of constipation, the width of the rectum was within the age norm. Four patients had fecal incontinence. The length of the ectopic anal canal was measured in 21 patients under one year of age. It ranged from 1.7 cm to 3.2 cm (average 2.44 ± 0.08 cm). Only in one case, it was shorter than the age norm. In 18 patients older one year, the length of the anal canal ranged from 1.3 cm to 3.6 cm (average 2.38 ± 0.17 cm, which is

significantly less than in children under one year old ($p < 0.001$). Only in 8 (44%) of 18 patients, the length of the anal canal was within the age norm. In 10 (56%) patients, the length of the ectopic anal canal was shorter than the minimum age norm. In four cases, an X-ray examination was performed twice before surgery (**Figure 3**) [24].

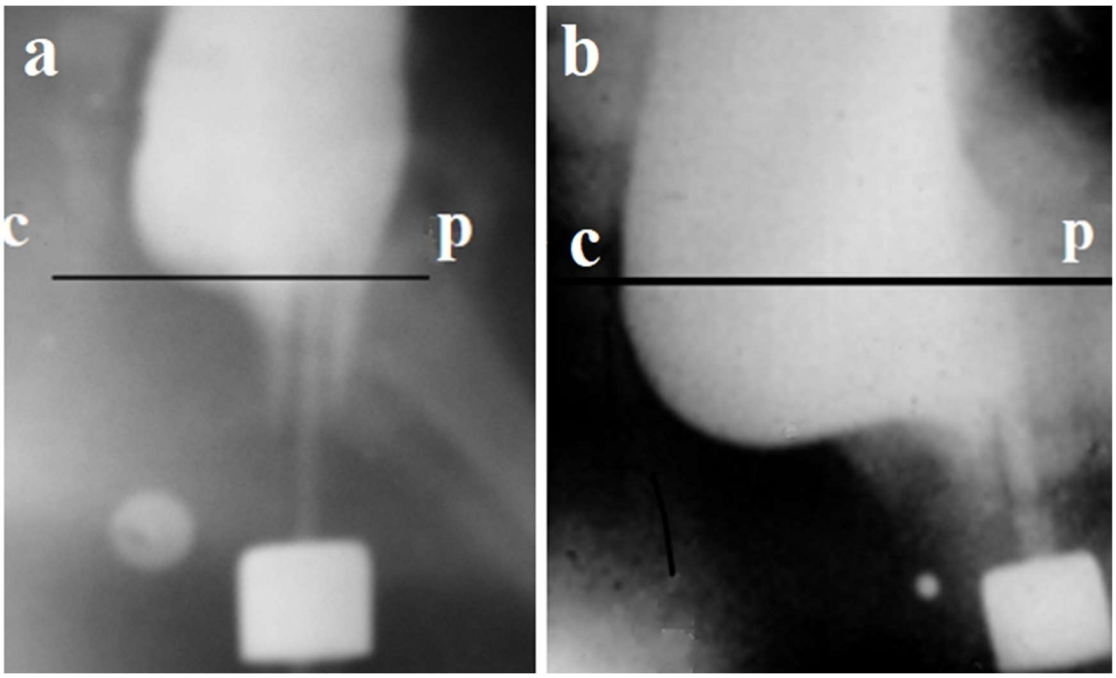

Figure 3. Lateral radiographs of the anorectum made in the same girl with a vestibular fistula at different ages. P-C is the pubococcygeal line. The true diameter of the contrast marker strung on the tip of the enema is 1.6 cm. It is located near the fistula. (a). At the age of 8 months. Permanent contraction of the ectopic anal canal was observed during the barium enema. Its length is 2.5 cm, which corresponds to the anal canal age norm. The width of the rectum is 3.4 cm, which is greater than the maximum normal limit (3 cm) (megarectum). Barium penetrates the anal canal behind the tip of the enema. This shows the weakness of the PRM, which does not pull of the posterior wall of the anal canal forward. (b). At the age of 1.5 years, she had a severe constipation and soiling. The width of the rectum is 5.5 cm, which significantly exceeds the maximum limit of the norm for this age (3.7 cm). A megarectum is combined with a significant shortening of the anal canal. Its length is 1.9 cm (minimal limit is 2.3 cm). Conclusion. ARM with vestibular ectopy, megarectum, and descending perineum syndrome.

Excessive abdominal straining during bowel movements has been identified as the cause of progressive perineal descent: The recurrent straining against outlet

obstruction impairs pelvic floor muscle tone until it disappears completely. The whole pelvic floor descends, due to high intra-abdominal pressure, and becomes funnel-shaped due to stretching of the puborectalis muscle [25]. Defecography images clarify the pathophysiology. During defecography, a descent of the rectum relative to the pubococcygeal line is determined. The descending perineum is first mobile when the pelvic floor is in the normal position at rest, and then, it descends > 3 cm during straining and bowel evacuation and afterward returns to its initial position. The descending perineum becomes fixed if defecography at rest shows a pelvic floor descent > 3 cm which increases several centimeters during straining and evacuative maneuvers and returns slowly or not returning to the starting line [26]. The use of a contrast marker near the anal fossa allows us to determine the descent perineum during a barium enema by shortening the distance from the rectum to the anal fossa. Fixed descending perineum is determined when shortening the anal canal at the beginning of the filling of the intestine with barium, and mobile descending perineum, when shortening of the anal canal occurred at the end of the filling of the large intestine, that is, at high pressure [27,28]. Thus, the shortening of the ectopic anal canal in ARM with visible fistula indicates severe damage (distension) of the PRM and levator plates.

MRI studies. In 3D reconstruction images (MRI) in "5 patients, the rectal atresia passed through puborectalis completely and was diagnosed as low ARM". In them, the puborectalis and external anal sphincter were almost normal except 1 patient who showed a little asymmetric puborectalis" [29]. The assertion of some authors that MRI could clearly reveal fistula anatomy and associated anomalies of ARMs [30] is not consistent with research results. First, the authors consider surgical conclusions as the criterion of accuracy. Meanwhile, it is known that PSARP does not usually detect BAC and it is cut off from the rectum. Therefore, operational diagnosis cannot be used to assess "the distal end of the rectum" (IAS). Second, the distal end of the rectum was correctly identified only at 75% (18/24). Thirdly, the anal canal at rest is in a closed state and it cannot be detected without abdominal compression. In some

cases, the authors of the article call it a fistula, and in others, the rectum. Fourth, the research on anomalies of the spine is irrelevant, as the results do not affect treatment tactics. The accuracy of diagnostics of anomalies of the genital and urinary systems by the ultrasound study is not inferior to that of MRI.

Manometric study. In 1877, Gowers discovered a decrease in pressure in the anal canal after insufflation air into the rectum [31]. In the middle of the 20th century, it was found that this reflex is not evoked in Hirschsprung's disease. Numerous studies have found that a sharp increase in pressure in the rectum causes a decrease in pressure in the upper anal canal as a result of relaxation of the IAS and a simultaneous increase in pressure in the lower anal canal as a result of contraction of the PRM and EAS [32,33,34]. This reflex was called the anorectal inhibitory reflex since the contraction of the striated muscles inhibited defecation during the relaxation of the IAS. To graduate the rectal pressure, the use of a rectal balloon has been proposed. Although it was found that the insufflation of more than 70 cm^3 of air into the rectal balloon, the IAS response does not change, the use of a rectal balloon has become a mandatory element of this technique. Since the IAS reaction was sufficient for the diagnosis of Hirschsprung's disease, the study of the EAS reaction was stopped.

The rejection of the rectal balloon made it possible to perform a manometric study in ARM with visible fistulas. To create a high pressure in the rectum, sharply injected 50 cm^3 of air into the rectum was produced. Anorectal inhibitory reflex was found in all patients in whom it was possible to carry out a measuring device (endotracheal tube) to the rectum. Basal pressure in the anal canal was within the normal range [13]. Ruttenstock et al produced preoperative rectal manometry of rectoperineal or rectovestibular fistula. The manometric device was introduced from the colostomy. It showed the presence of functional anal structures within the fistula in all patients. Complete transposition of the fistula was achieved in all patients. All patients had voluntary bowel movements, with no incontinence or soiling. They

speculated that fistula-preserving surgery in patients with anorectal malformations is associated with improved bowel function outcomes [35].

Anorectal function before and after ARM treatment

After the correction of ARM, "a large proportion of the patients have persistent fecal incontinence, constipation, and sexual problem [36]. Study Hashish et al "showed that stooling patterns are perceived to worsen with age" [37]. The pediatric surgeons consider such results as good, explaining that they could not be better since these patients have not had an anal canal since birth [7,8,11].

Late diagnosis. Because chronic constipation can be the only symptom of mild ARM, it often requires more time to diagnose than severe forms. Many women are, therefore, diagnoses with ARM at an older age, or they may go undiagnosed altogether [38]. If the ectopic foramen does not provide for normal bowel emptying, then the delay in diagnosis leads to the development of megarectum and megacolons, which is accompanied by chronic constipation and fecal incontinence [39,40]. In rare cases, when the ectopic orifice allows normal bowel movement, the patients remain asymptomatic [41,42,43]. They consulted a doctor due to marital issues [42] or because cosmetics [43]. In adult patients with adequate width of the vestibular fistula, fecal retention and defecation were normal. In one case a leakage of flatus was observed [43].

As shown in a study by Kyrklund et al, "All males treated for low ARMs (rectoperineal fistula) with cutback anoplasty, incision of anocutaneous membrane, or dilatations had voluntary bowel movements; 98% of patients were socially continent (p = NS); 67% of patients and 64% of controls were totally continent (p = NS)". Constipation amongst patients (33 vs 3% in controls; $p < 0.0001$) declined significantly with age. Outcomes by bowel function scores were good at 85% and satisfactory in 15%" [21]. Thus, the long-term results of operations and procedures that fully preserve the anal canal indicate normal function fecal retention. Constipation amongst 33% of patients can be explained by the fact that these

children were operated on after they developed a megarectum. The results of this tactic are far superior to all types of pull-through surgery.

It is believed that low-type lesions have a better functional prognosis than intermediate and high lesions. However, Daher et al no significant differences were found between the results of the surgical treatment of patients with perineal fistula after the perineal approach and after PSARP in patients with intermediate and high lesions [44]. The PSARP adepts do not distinguish between high and low ARM. In any case, PSARP is executed. The more extensive the dissection of perineal tissue, the worse the results are [45, 46]. Analysis of the literature indicates that for normal anorectum function it is not enough to preserve all the sphincters and pelvic floor muscles. Intersection of the neural connections between the rectum and muscles cancels the reflexes of fecal retention and defecation [47, 48], which inevitably leads to chronic constipation and fecal incontinence.

Conclusion

Analysis of the literature indicates that all patients with ARM with visible fistulas (perineal and vestibular) have a functioning anal canal, which ensures normal fecal retention, and defecation. Unlike the normal anal canal, its outlet is displaced anteriorly and, as a rule, is represented by a narrow rigid ring. Therefore, when an infant has hard stools, the ectopic anus does not allow normal emptying of the rectum, resulting in stool retention, rectal distension (megarectum), and secondary damage to the pelvic floor muscles (descending perineum syndrome). The distal part of the anal canal is outside the ring of the subcutaneous portion of the external anal sphincter, which can cause gas leakage. From the point of view of the pathological anatomy of defects, these forms should be called anoperineal ectopy or anovestibular ectopy.

References

1. Stephens FD. Imperforate rectum. A new surgical technique. Med J Australia. 1953;**1**:202.

2. Holschneider A, Hutson J, Peña A et al. Preliminary report on the International Conference for the Development of Standards for the Treatment of Anorectal Malformations. J Pediatr Surg. 2005;40(10):1521–1526. doi: 10.1016/j.jpedsurg.2005.08.002.
3. Ito Y, Yokoyama J, Hayashi A, Ihara N, Katsumata K. Reappraisal of endorectal pull-through procedure. I. Anorectal malformations. J Pediatr Surg. 1981 Aug;16(4):476-83.
4. Iwai N[1], Yanagihara J, Tokiwa K, et al. Results of surgical correction of anorectal malformations. A 10-30 year follow-up. Ann Surg. 1988 Feb;207(2):219-22.
5. deVries PA, Peña A Posterior sagittal anorectoplasty. J Pediatr Surg. 1982 Oct;17(5):638-43.
6. Peña A, Devries PA. Posterior sagittal anorectoplasty: important technical considerations and new applications. J Pediatr Surg. 1982 Dec;17(6):796-811.
7. Wood RJ and Levitt MA. Anorectal Malformations. Clin Colon Rectal Surg. 2018 Mar; 31(2): 61–70. doi: 10.1055/s-0037-1609020.
8. Danielson J, Karlbom U, Graf W, Wester T. Outcome in adults with anorectal malformations in relation to modern classification - Which patients do we need to follow beyond childhood? J Pediatr Surg. 2017 Mar;52(3):463-468. doi: 10.1016/j.jpedsurg.2016.10.051.
9. Okada A, Kamata S, Imura K, et al. Anterior sagittal anorectoplasty for rectovestibular and anovestibular fistula. J Pediatr Surg. 1992 Jan;27(1):85-8. doi: 10.1016/0022-3468(92)90113-l.
10. Georgeson KE, Inge TH, Albanese CT. Laparoscopically assisted anorectal pull-through for high imperforate anus--a new technique. J Pediatr Surg. 2000 Jun;35(6):927-30; discussion 930-1. doi: 10.1053/jpsu.2000.6925.
11. Li ZH, Dong M, Wang ZF. Functional constipation in children: investigation and management of anorectal motility. World J Pediatr. 2008 Feb;4(1):45-8. doi: 10.1007/s12519-008-0009-7.
12. Knowles AM, Knowles CH, Scott SM, Lunniss PJ. Effects of age and gender on three-dimensional endoanal ultrasonography measurements: development of normal ranges. Tech Coloproctol. 2008 Dec;12(4):323-9. doi: 10.1007/s10151-008-0443-5
13. Levin MD. The pathological physiology of the anorectal defects, from the new concept to the new treatment. Eksp Klin Gastroenterol. 2013; (11):38-48.
14. Levin MD. The role of the external anal sphincter in the physiology of the pelvic floor. Pelviperineolohy. 2017; 36(4):108-112. (Open access).

15. Holschneider AM[1], Ure BM, Pfrommer W, Meier-Ruge W. Innervation patterns of the rectal pouch and fistula in anorectal malformations: a preliminary report. J Pediatr Surg. 1996 Mar;31(3):357-62.
16. Gangopadhyay AN[1], Upadhyaya VD, Gupta DK, et al.Histology of the terminal end of the distal rectal pouch and fistula region in anorectal malformations. Asian J Surg. 2008 Oct;31(4):211-5. doi: 10.1016/S1015-9584(08)60089-5.
17. Xiao H[1,2], Huang R[3], Cui DX[3], et al. Histopathologic and immunohistochemical findings in congenital anorectal malformations. Medicine (Baltimore). 2018 Aug;97(31):e11675. doi: 10.1097/MD.0000000000011675.
18. Duhamel B. Physio-pathology of the internal anal sphincter. Arch Dis Child. 1969 Jun;44(235):377-81.
19. Lambrecht W[1], Lierse W. The internal sphincter in anorectal malformations: morphologic investigations in neonatal pigs. J Pediatr Surg. 1987 Dec;22(12):1160-8.
20. Rintala R[1], Lindahl H, Sariola H, et al. The rectourogenital connection in anorectal malformations is an ectopic anal canal. J Pediatr Surg. 1990 Jun;25(6):665-8.
21. Kyrklund K, Pakarinen MP, Taskinen S, Rintala RJ. Bowel function and lower urinary tract symptoms in males with low anorectal malformations: an update of controlled, long-term outcomes. Int J Colorectal Dis. 2015 Feb;30(2):221-8. doi: 10.1007/s00384-014-2074-9.
22. De la Torre-Mondragón L, Bañuelos-Castañeda C, Santos-Jasso K, Ruiz-Montañez A.Unexpected megarectum: A potential hidden source of complications in patients with anorectal malformation. J Pediatr Surg. 2015 Sep;50(9):1560-2. doi: 10.1016/j.jpedsurg.2015.05.004.
23. Sharma N, Pratap A, Bajpai M. Rectal pouch index: a prognostic indicator for constipation after surgery for high and intermediate anorectal malformations. Eur J Pediatr Surg. 2014 Aug;24(4):332-6. doi: 10.1055/s-0033-1347296.
24. Levin MD. [Roentgeno-functional studies in ectopia of the anal canal in children]. Vestn Rentgenol Radiol. Sep-Oct 1989;(5):10-6. [Article in Russian]. PubMed.
25. Henry MM, Parks AG, Swash M. The pelvic floor musculature in the descending perineum syndrome. Br J Surg. 1982 Aug;69(8):470-2. doi: 10.1002/bjs.1800690813.
26. Pucciani F. Descending perineum syndrome: new perspectives. Tech Coloproctol. 2015 Aug;19(8):443-8. doi: 10.1007/s10151-015-1321-6.

27. Levin MD. [Descending perineum syndrome in children: Pathophysiology and diagnosis]. Vestn Rentgenol Radiol. Sep-Oct 2015;(5):27-35.[Article in Russian] (PubMed).
28. Levin MD. Pathophysiology and diagnosis of descending perineum syndrome in children. (2018) Pelviperineology. 37(2):52-56. (Open access).
29. Tang ST, Cao GQ, Yong-Zhong Mao YZ, et al. Clinical value of pelvic 3-dimensional magnetic resonance image reconstruction in anorectal malformations. Pediatr Surg. 2009 Dec;44(12):2369-74. doi: 10.1016/j.jpedsurg.2009.07.074.
30. Zhan Y, Wang J, Guo WL. Comparative effectiveness of imaging modalities for preoperative assessment of anorectal malformation in the pediatric population. J Pediatr Surg. 2019 Dec;54(12):2550-2553. doi: 10.1016/j.jpedsurg.2019.08.037.
31. Gowers WR. The autonomic action of the sphincter ani. Proceedings of the Royal Society (London). 1877;26:77-81.
32. Tobon F, Schuster MM. Megacolon: special diagnostic and therapeutic features. Johns Hopkins Med J. 1974 Aug;135(2):91-105.
33. Bharucha AE. Pelvic floor: anatomy and function. Neurogastroenterol Motil. 2006 Jul;18(7):507-19. doi: 10.1111/j.1365-2982.2006.00803.x.
34. Palit S, Lunniss P, Scott SM. The physiology of human refecation. Dig Dis Sci. 2012 Jun;57(6):1445-64. doi: 10.1007/s10620-012-2071-1.
35. Ruttenstock EM[1], Zani A, Huber-Zeyringer A, Höllwarth ME. Pre- and postoperative rectal manometric assessment of patients with anorectal malformations: should we preserve the fistula? Dis Colon Rectum. 2013 Apr;56(4):499-504. doi: 10.1097/DCR.0b013e31826e4a38.
36. Danielson J, Karlbom U, Graf W, Wester T. Outcome in adults with anorectal malformations in relation to modern classification - Which patients do we need to follow beyond childhood? J Pediatr Surg. 2017 Mar;52(3):463-468. doi: 10.1016/j.jpedsurg.2016.10.051.
37. Hashish MS, Dawoud HH, Hirschl RB, et al. Long-term functional outcome and quality of life in patients with high imperforate anus. J Pediatr Surg. 2010 Jan;45(1):224-30. doi:10.1016/j.jpedsurg.2009.10.041.
38. Jonker JE, Trzpis M, Broens PMA.Underdiagnosis of Mild Congenital Anorectal Malformations. J Pediatr. 2017 Jul;186:101-104.e1. doi: 10.1016/j.jpeds.2017.03.054.
39. de Blaauw I, Midrio P, Breech L, et al. Treatment of adults with unrecognized or inadequately repaired anorectal malformations: 17 cases of rectovestibular and rectoperineal fistulas. J Pediatr Adolesc Gynecol.

2013 Jun;26(3):156-60. doi: 10.1016/j.jpag.2012.12.003. Epub 2013 Mar 16.
40. Sharma S, Gupta DK. Delayed presentation of anorectal malformation for definitive surgery. Pediatr Surg Int. 2012 Aug;28(8):831-4. doi: 10.1007/s00383-012-3128-0.
41. Chakravartty S, Maity K, Ghosh D, et al. Successful management in neglected cases of adult anorectal malformation. Singapore Med J. 2009 Aug;50(8):e280-2.
42. Pandey A, Gupta V, Singh SP, Verma R. Female anorectal malformation in a woman. BMJ Case Rep. 2015 Jul 22;2015: bcr2015211456. doi: 10.1136/bcr-2015-211456.
43. Bokhari I, Ali SU, Farooq AR, Khan A. Late presentation of a patient with an anorectal malformation (ARM). J Coll Physicians Surg Pak. 2010 Dec;20(12):825-7.
44. Daher P, Daher R, Riachy E, Zeidan S. Do low-type anorectal malformations have a better prognosis than the intermediate and high types? A preliminary report using the Krickenbeck score. Eur J Pediatr Surg. 2007 Oct;17(5):340-3. doi: 10.1055/s-2007-965462.
45. Levitt MA, Kant A, Peña A. The morbidity of constipation in patients with anorectal malformations. J Pediatr Surg. 2010 Jun;45(6):1228-33. doi: 10.1016/j.jpedsurg.2010.02.096.
46. Lombardi L, Bruder E, Caravaggi F, Del Rossi C, Martucciello G. Abnormalities in "low" anorectal malformations (ARMs) and functional results resecting the distal 3 cm. J Pediatr Surg. 2013 Jun;48(6):1294-300. doi: 10.1016/j.jpedsurg.2013.03.026.
47. Bertrand MM, Alsaid B, Droupy S, et al. Anatomical basis of the coordination between smooth and striated urethral and anal sphincters: loops of regulation between inferior hypogastric plexus and pudendal nerve. Immuno-histological study with 3D reconstruction. Surg Radiol Anat. 2016 Oct;38(8):963-72. doi: 10.1007/s00276-016-1655-4.
48. Essential Anatomy of the Anorectum for Colorectal Surgeons Lee JM, Kim NK. Focused on the Gross Anatomy and Histologic Findings. Ann Coloproctol. 2018 Apr;34(2):59-71. doi: 10.3393/ac.2017.12.15.