13 Endoanal Ultrasonographic Imaging of the Anorectal Region

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Learning Objective

The reader will learn the basic anatomy and the ultrasound instrumentation needed for visualization of anorectum pathologies.

Introduction

Anorectal diseases require imaging for proper case management. At present, endoanal ultrasonography (EAUS) and endorectal ultrasonography (ERUS) have become important parts of the diagnostic workup of patients with posterior compartment disorders (fecal incontinence, obstructed defecation, posterior vaginal wall prolapse, perianal fistulas, pelvic floor dyssynergy, and perianal pain) and provide sufficient information for clinical decision-making in many cases [1–3]. The advent of high-resolution three-dimensional (3D) ultrasound has further improved our understanding of the 2D technique [4]. The anatomic structures in the pelvis, the axial and longitudinal extension of anal sphincter defects, the anatomy of the fistulous tract in complex perianal sepsis, and the presence of anterior rectal wall prolapse may be imaged in greater detail. This additional information brings an improvement in both planning and conducting surgical procedures [5].

This chapter is devoted to discussing the methods for generating and using 3D-EAUS and 3D-ERUS, particularly with regard to the advantages of these techniques in the diagnostic imaging of posterior compartment disorders.

Ultrasonographic Techniques

EAUS may be performed with different transducers: multi-frequency (6–16 MHz), 360° rotational mechanical probe (BK 2052, BK Ultrasound, Analogic, Peabody, MA, USA) and multi-frequency (4–12 MHz), 65 mm linear array probe (BK 8838, BK Ultrasound, Analogic, Peabody, MA, USA) with built-in high-resolution 3D capabilities computer controlled; radial electronic probe (AR 54 AW, frequency: 5–10 MHz, Hitachi Medical Systems, Tokyo, Japan) with free-hand 3D acquisition [1]. The rotating probe has an internal automated motorized system that allows acquisition of 300 aligned transaxial 2D

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Fig. 13.1 High multi-frequency (6–16 MHz), 360° rotational mechanical probe, BK 2052 probe (BK Ultrasound, Analogic, Peabody, MA, USA)

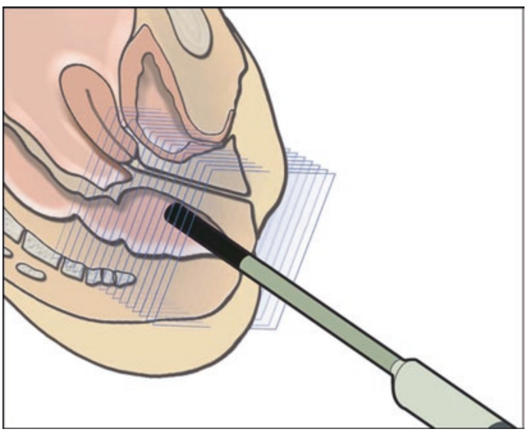

Fig. 13.2 Schematic illustration of 3D endoanal ultrasonography technique performed by BK 2052 probe

images over a distance of 60 mm in 60 s, without any movement of the probe within the tissue (Fig. 13.1). The set of 2D images is instantaneously reconstructed into a high resolution 3D image for real time manipulation (Fig. 13.2). As opposed to 2D static ultrasonography, 3D imaging allows volume measurements that may be displayed as either multiplanar images (usually as three orthogonal planes, namely coronal, sagittal, and axial) or rendered images that display the entire volume in a single image [5]. Furthermore, the images can be rotated and sliced to enable visualization from different angles. The 3D volume can also be archived for offline analysis on the ultrasonography system or on a PC with the help of dedicated software [5].

Before the probe is inserted into the anus, a digital rectal examination should be performed. If there is anal stenosis, the finger can check to determine whether it will allow easy passage of the probe. A gel-containing condom is placed over the probe, and a thin layer of water-soluble lubricant is placed on the exterior of the condom. Any air interface will cause a major interference pattern. The patient should be instructed before the examination that no pain should be experienced. Under no circumstances should force be used to advance the probe. During examination, the patient may be placed in the dorsal lithotomy, the left lateral, or the prone position. However, irrespective of the position, the transducer should be rotated so that the anterior aspect of the anal canal is superior (12 o'clock) on the screen, right lateral is left (9 o'clock), left lateral is right (3 o'clock), and posterior is inferior (6 o'clock). The length of recorded data should extend from the upper aspect of the "U"- shaped sling of the puborectalis (PR) to the anal verge.

Endosonographic Anatomy of the Normal Anal Canal

On ultrasound five hypoechoic and hyperechoic layers can be seen in the normal anal canal [6]. The ultrasonographer must have a clear understanding of what each of these five lines represents anatomically (Fig. 13.3):

- The *first* hyperechoic layer, from inner to outer, corresponds to the interface of the transducer with the anal mucosal surface
- The *second* layer represents the subepithelial tissues and appears moderately reflective. The mucosa as well as the level of dentate line is not visualized. The muscularis submucosae ani can be sonographically identified in the upper part of the anal canal as a low reflective band
- The *third* hypoechoic layer corresponds to the internal anal sphincter (IAS). The sphincter is not completely symmetric, either in thickness or termination. It can be traced superiorly into the circular muscle of the rectum, extending from the anorectal junction to approximately 1 cm below the dentate line. In older age groups, the IAS loses its uniform low echogenicity, which is characteristic of smooth muscle throughout the gut, to become more echogenic and inhomogeneous in texture
- The *fourth* hyperechoic layer represents the longitudinal muscle (LM). It presents a wide variability in thickness and is not always distinctly visible along the entire anal canal. The LM appears moderately echogenic, which is surprising, as it is mainly smooth muscle; however, an increased fibrous stroma may account for this. In the intersphincteric space the LM conjoins with striated muscular fibers from the levator ani, particularly the puboanalis, and a large fibroelastic element derived from the endopelvic fascia to form the *conjoined longitudinal layer* (CLL). Its fibroelastic component, permeating through the subcutaneous part of the external anal sphincter (EAS), terminates in the perianal skin
- The *fifth* mixed echogenic layer corresponds to the EAS. The EAS is made up of voluntary muscle that encompasses the anal canal. It is described as having three parts: (1) The deep part is integral with the PR. Posteriorly there is some ligamentous attachment. Anteriorly some fibers are circular and some decussate into the deep transverse perineii. (2) The superficial part has a very broad attachment to the underside of the coccyx via the anococcygeal ligament. Anteriorly there is a division into circular fibers and a decussation to the superficial transverse perineii. (3) The subcutaneous part lies below the internal anal sphincter

Ultrasound imaging of the anal canal be divided into three levels of assessment in the axial plane (upper, middle, and lower levels),

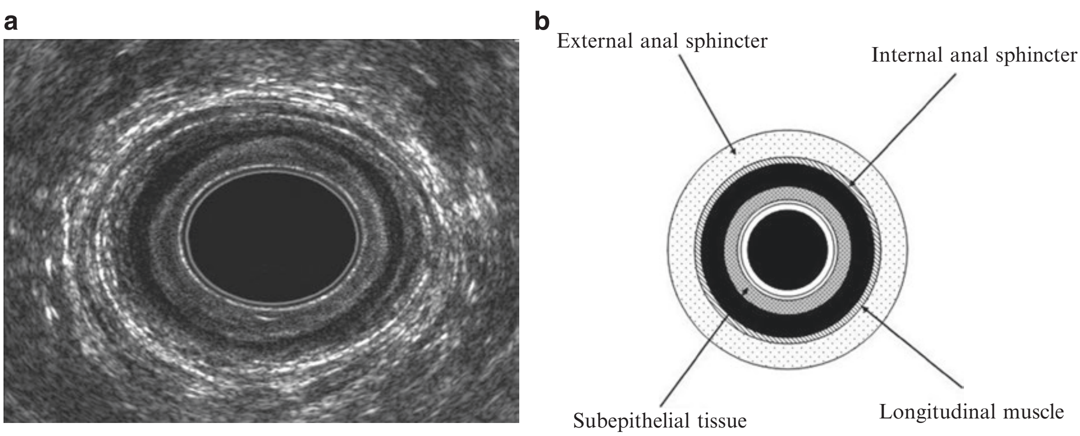

Fig. 13.3 (**a**) Normal ultrasonographic five-layer structure of the mid-anal canal. Axial image obtained by BK 2052 probe. (**b**) Schematic representation

referring to the following anatomical structures (Fig. 13.4) [6, 7]:

- *Upper Level:* the sling of the puborectalis (PR), the deep part of the EAS and the complete ring of IAS
- *Middle Level*: the superficial part of the EAS (complete ring), the CLL, the IAS (complete ring), the transverse perineii muscles
- *Lower Level:* the subcutaneous part of the EAS

The anal canal length is the distance measured between the proximal canal, where the PR is identified, and the lower border of the subcutaneous EAS. It is significantly longer in males than in females, as a result of a longer EAS, whereas there is no difference in PR length. The anterior part of the EAS differs between sexes, and anatomic studies showed that this difference is already present in fetal age. In males, the EAS is symmetrical at all levels; in females, it is shorter anteriorly, and there is no evidence of anterior ring high in the canal. In examining a female subject, the ultrasonographic differences between the natural gaps (hypoechoic areas with smooth, regular edges) and sphincter ruptures (mixed echogenicity, due to scarring, with irregular edges) occurring at the upper anterior part of the anal canal must be kept in mind. 3D longitudinal images are particularly useful to assess these anatomic characteristics of the EAS (see Fig. 13.4) [8–11]. Williams et al. [8] reported that the anterior EAS occupied 58% of the male anal canal compared with 38% of the female canal ($P < 0.01$). In females the PR occupied a significantly larger proportion of the canal than in males (61 versus 45%; $P = 0.02$). There was no difference in the length of the IAS between male and female (34.4 versus 33.2 mm) or the proportion of the anal canal that it occupied (67 versus 73%; $P = 0.12$).

Normal values for sphincter dimensions differ between techniques [6]. Defining the true values of sphincter muscle thickness is not very relevant, because the purpose of measuring anal sphincters is to distinguish a normal versus abnormal measurement, regardless of the absolute values. Measurement should be taken at the 3, 6, 9, and 12 o'clock positions in the midlevel of the anal canal. The thickness of IAS varies from 1.8 ± 0.5 mm and increases with age, owing to the presence of more fibrous tissue as the absolute amount of muscle decreases, measuring 2.4–2.7 mm < 55 years and 2.8–3.5 mm > 55 years. Any IAS>4 mm thick should be considered

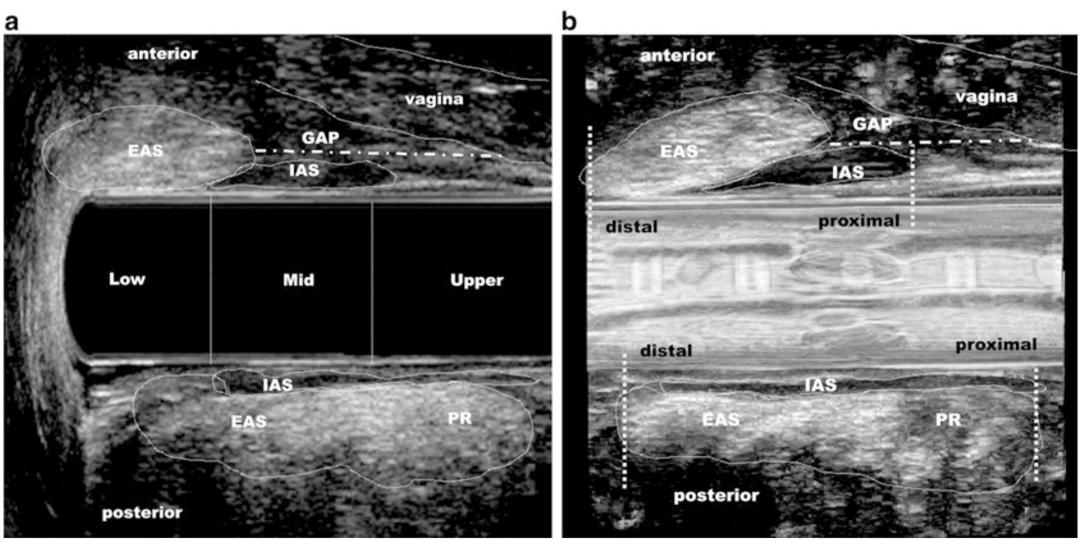

Fig. 13.4 (**a**) Three levels of assessment of the anal canal in the axial plane. Scan obtained by BK 2052 probe. External anal sphincter (EAS), internal anal sphincter (IAS), puborectalis (PR). (**b**) 3D reconstruction on the coronal plane

abnormal whatever the patient's age. Conversely, a sphincter of 2 mm is normal in a young patient, but abnormal in an elderly one. The LM is 2.5 ± 0.6 mm in males and 2.9 ± 0.6 mm in females. The average thickness of the EAS is 8.6 ± 1.1 mm in males and 7.7 ± 1.1 mm in females. However, endosonography largely overestimates the size of the EAS due to its failure to recognize and separate the LM. Frudinger et al. [12] reported a significant negative correlation between the patient's age and the EAS thickness at all anal canal levels. In particular, the anterior EAS part was found significantly thinner in older subjects.

Multiplanar EAUS has enabled detailed longitudinal measurement of the components of the anal canal (Figs. 13.4, 13.5, and 13.6). Williams et al. [8] reported that the anterior EAS was significantly longer in men than in women (30.1 mm vs. 16.9 mm; $P < 0.001$). There was no difference in the length of the PR between men and women, indicating that the difference in anal canal length between the sexes is due solely to the longer male EAS. The IAS did not differ in length between males and females. Regadas et al. [9] demonstrated the asymmetrical shape of the anal canal and also confirmed that the anterior EAS was significantly shorter in the female. West et al. [13] reported similar results, with IAS and EAS volumes found larger in males than in females.

Regardless of the absolute values of the anal sphincter, the most relevant utility of EAUS applies to the detection of localized sphincter defects, where its benefit has been proved [14, 15]. It has been suggested that measuring sphincter thickness is important when EAUS cannot depict any sphincter damage to exclude diffuse structural sphincter changes associated with idiopathic fecal incontinence (FI), passive FI, or obstructive defecation disorders. A postulated association between manometric function of the sphincters and their sonographic appearance, however, remains controversial in the literature. Some authors have found no correlation between muscle thickness and muscle performance, neither resting nor squeeze pressure. Scanning anal sphincter muscle may allow for determination of their integrity, but not for their morphometric properties.

Endosonographic Anatomy of the Rectum

The normal rectum is 11–15 cm long and has a maximum diameter of 4 cm. It is continuous with the sigmoid colon superiorly at the level of the third sacral segment and courses inferiorly along the curve of the sacrum to pass through the pelvic diaphragm and become the anal canal. It is surrounded by fibrofatty tissue that contains blood vessels, nerves, lymphatics, and small lymph nodes. The superior one-third is covered anteriorly and laterally by the pelvic peritoneum. The middle one-third is covered with peritoneum only anteriorly, where it curves anteriorly onto the bladder in the male and onto the uterus in the female. The lower one-third of the rectum is below the peritoneal reflection and is related anteriorly to the bladder base, ureters, seminal vesicles, and prostate in the male and to the lower uterus, cervix, and vagina in the female.

The rectal wall consists of five layers surrounded by perirectal fat or serosa [16]. On ultrasound the normal rectal wall is 2–3 mm thick and is composed of a five-layer structure. Good visualization depends on maintaining the probe in the center lumen of the rectum and having adequate distension of a water-filled latex balloon covering the transducer to achieve good acoustic contact with the rectal wall. It is important to eliminate all bubbles within the balloon to avoid artifacts that limit the overall utility of the study. The rectum can be of varying diameters, and therefore the volume of water in the balloon may have to be adjusted intermittently. The five layers represent (Fig. 13.7):

- The *first* hyperechoic layer: the interface of the balloon with the rectal mucosal surface
- The *second* hypoechoic layer: the mucosa and muscularis mucosae
- The *third* hyperechoic layer: the submucosa
- The *fourth* hypoechoic layer: the muscularis propria (in rare cases seen as two layers: inner circular and outer longitudinal layer)
- The *fifth* hyperechoic layer: the serosa or the interface with the fibrofatty tissue surrounding the rectum (mesorectum). The mesorectum

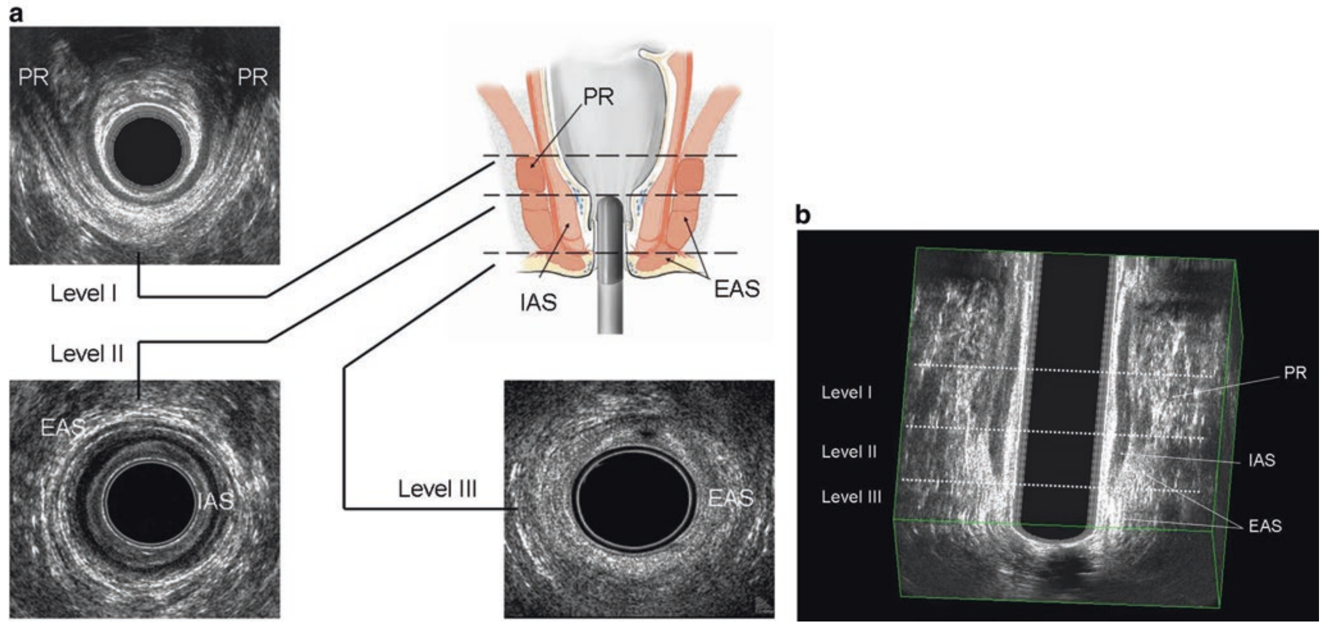

Fig. 13.5 (**a**) Female anal canal anatomic configuration. 3D reconstruction on the sagittal plane shows the asymmetrical shape of the anal canal and the positions of anal sphincters. The anterior anal canal (external and internal anal sphincters, EAS/IAS) starts and ends more distally, and the posterior anal canal (puborectalis-EAS and IAS starts) starts and ends more proximally. Puborectalis muscle (PR); the GAP is the area in the anterior quadrant without striated muscle, measured from the proximal edge of the posterior PR to the proximal edge of the anterior EAS. (**b**) Render mode

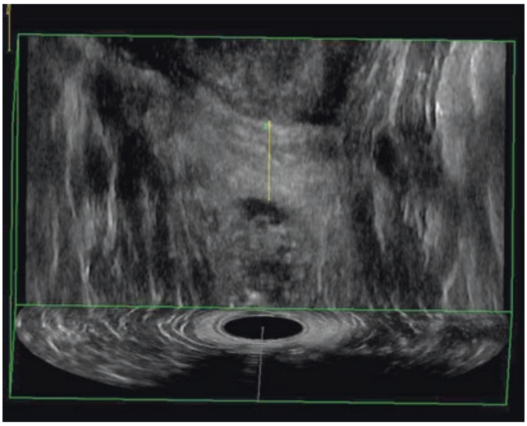

Fig. 13.6 3D endoanal ultrasonography performed by BK 2052 probe. Measurement of anterior length of the external sphincter in the coronal plane

contains blood vessels, nerves, and lymphatics and has an inhomogeneous echo pattern. Very small, round to oval, hypoechoic lymph nodes should be distinguished from blood vessels, which also appear as circular hypoechoic structures

ERUS allows an accurate visualization of all pelvic organs adjacent to the rectum: the bladder, seminal vesicles, and prostate in the male and the uterus, cervix, vagina, and urethra in the female. Intestinal loops can also easily be identified as elongated structures.

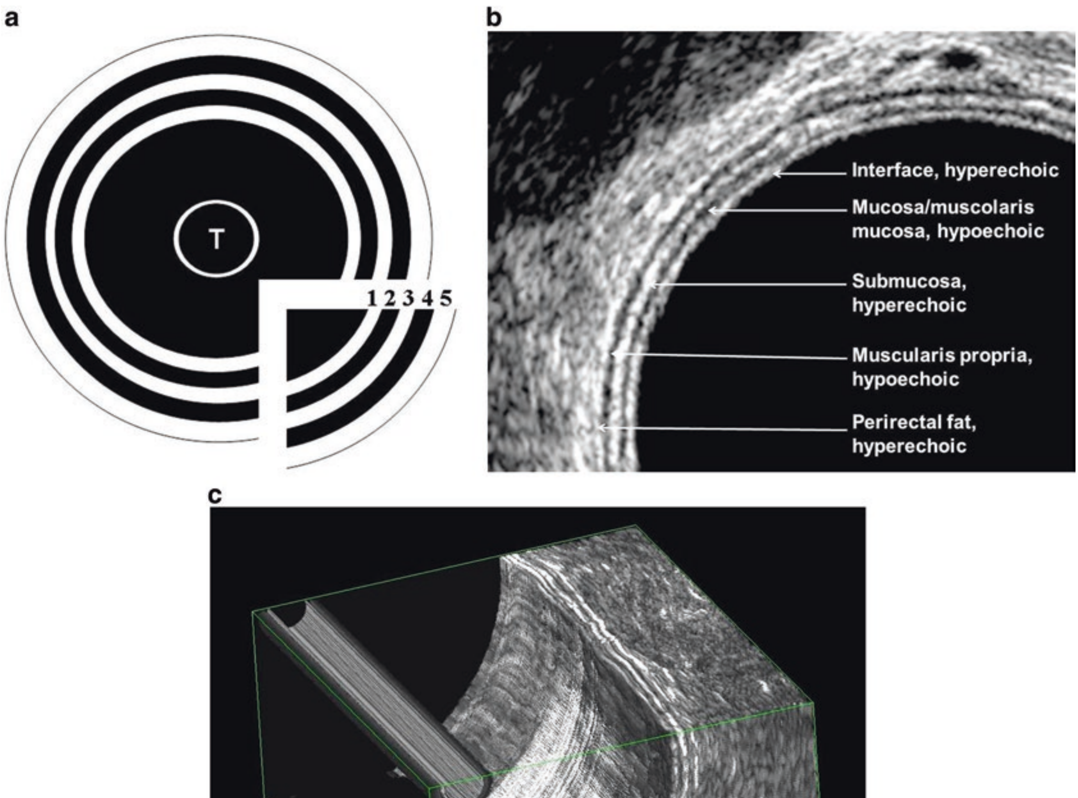

Fig. 13.7 (**a**) Schematic ultrasound representation of the rectal wall. Transducer (T). (**b**) The five layers in the axial plane. (**c**) 3D reconstruction of the rectal wall in the coronal plane. Scans obtained by BK 2052 probe

Clinical Application of 3D Endoanal/Endorectal Ultrasound

Clinical applications of pelvic floor ultrasonography [1] for both anatomical assessment and evaluation of function in posterior compartment disorders are reported in detail below.

Fecal Incontinence

Fecal incontinence is defined as the involuntary loss of feces (liquid or solid stool), and anal incontinence is defined as the complaint of involuntary loss of flatus or feces [14]. A meta-analysis revealed a rate of 11–15% in the general population, although it may perhaps be underestimated [17]. Intact musculature, including the PR, IAS, and EAS, is a prerequisite for fecal control, as is a functioning nerve supply to these muscles. Other factors contributing to FI include stool consistency, rectal sensitivity and capacity, and the anorectal angle (ARA). Any impairment to one or more of these factors may result in FI. Anal sphincter defects and pudendal nerve injury can occur during vaginal delivery and are by far the most common causes of FI, consequently making this problem more prevalent in women [17].

In patients with FI, therefore, it is fundamental to establish the underlying pathophysiology in order to choose the appropriate therapy (dietary or medications, biofeedback, sphincter repair, artificial bowel sphincter, graciloplasty, sacral nerve stimulation, injection of bulking agents). EAUS has become the gold standard for the morphological assessment of the anal canal [14, 15]. The International Consultation on Incontinence (ICI) has recommended EAUS as the first-line imaging investigation for FI to differentiate between those with intact anal sphincters and those with sphincter lesions (defects, scarring, thinning, thickening and atrophy) [18]. Tears are defined by an interruption of the circumferential fibrillar echo texture. Scarring is characterized by loss of normal architecture, with an area of amorphous texture that usually has low reflectivity. The operator should identify if there is a combined lesion of the IAS and EAS or if the lesion involves just one muscle. The number and circumferential (radial angle in degrees or in hours of the clock site) and longitudinal (proximal, distal or full length) extension of the defects should also be reported. In addition, 3D-EAUS allows measurement of the length, thickness, area of sphincter defect in the sagittal and coronal planes and volume of sphincter damage (Figs. 13.8, 13.9, 13.10, and 13.11) [5].

Using multiplanar EAUS, two scoring systems have been proposed to define the severity of the sphincter damage. Starck et al. [19] intro-

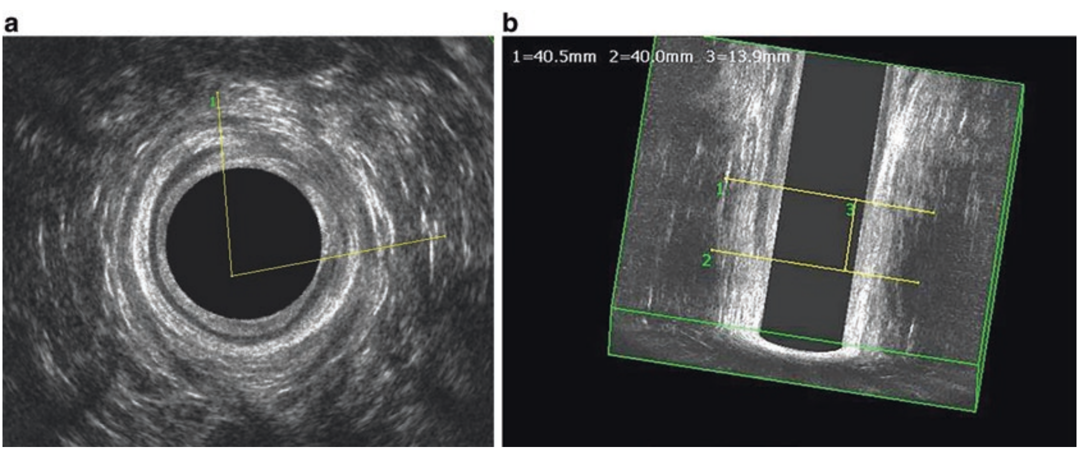

Fig. 13.8 (**a**) Internal anal sphincter lesion between 12 o'clock and 3 o'clock position following a left lateral internal sphincterotomy for fissure; (**b**) Measurement of the internal anal sphincter damage on the coronal plane after 3D reconstruction. Scans obtained by BK 2052 probe

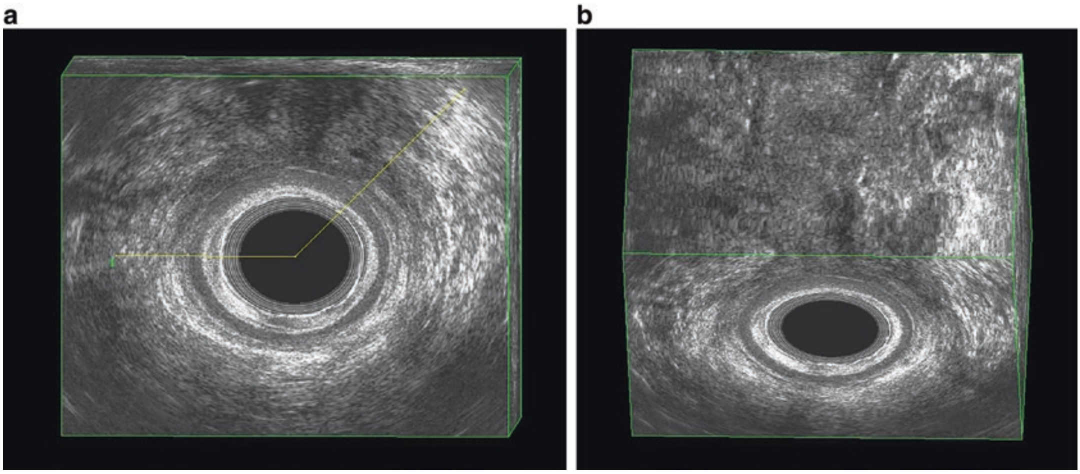

Fig. 13.9 (**a**) External sphincter lesion between 9 o'clock and 1 o'clock position due to obstetric trauma. (**b**) Anterior external anal sphincter damage demonstrated with 3D reconstruction in the coronal plane. Scans obtained by BK 2052 probe

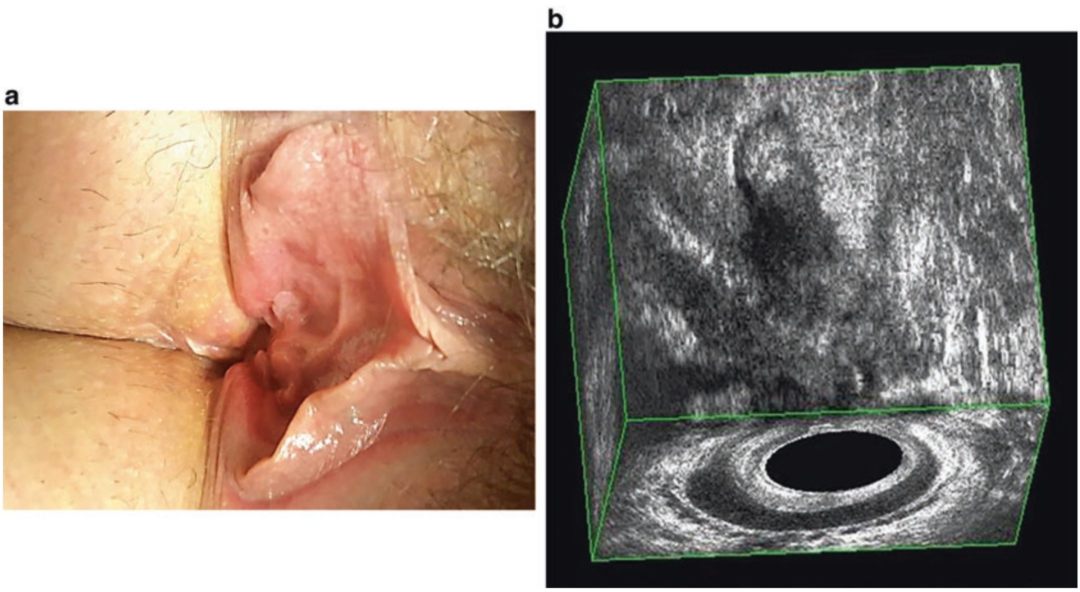

Fig. 13.10 (**a**) Fourth degree anal sphincter lesion due to obstetric trauma. (**b**) 3D reconstruction demonstrates combined anterior damage of the internal and external anal sphincters in the coronal and axial planes. Scans obtained by BK 2052 probe

duced a specific score, with 0 indicating no defect and 16 corresponding to a defect >180° involving the whole length and depth of the sphincters. Recently, Noderval et al. [20] reported a simplified system for analyzing defects, including fewer categories than the Starck score and not recording partial defects of the IAS. A maximal score of 7 denotes defects in both the EAS and the IAS exceeding 90° in the axial plane and involving more than half of the sphincter length. Both systems showed good intraobserver and interobserver agreement in classifying anal sphincter defects. The presence of a sphincter defect, however, does not necessarily mean that it

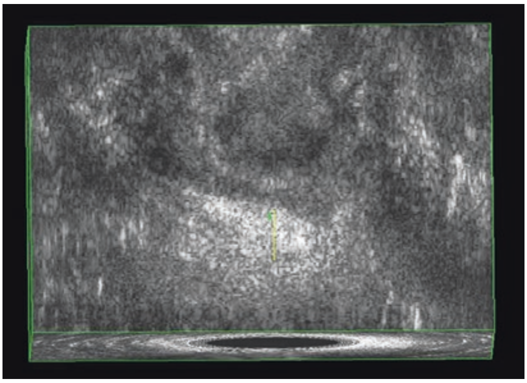

Fig. 13.11 External anal sphincter atrophy. 3D reconstruction in the coronal plane demonstrates a short anterior length (6.6 mm) of the external sphincter. Scans obtained by BK 2052 probe

is the cause of FI, as many people have sphincter lesions without having symptoms of incontinence [21]. On the other hand, patients with FI and an apparent intact sphincter can have muscle degeneration, atrophy, or pudendal neuropathy.

EAUS has an important role in detecting clinically occult anal sphincter injuries after a vaginal delivery [22]. In a meta-analysis of 717 vaginal deliveries, Oberwalder et al. [23] found an incidence of occult sphincter damage of 26.9% among a sample of 462 primiparous women and a rate of 8.5% new defects in the group of 255 multiparas. In one-third of these (29.7%), postpartum sphincter damage was symptomatic. As shown in this meta-analysis, the probability that postpartum FI will be associated with anal sphincter defect is 77–83%. This analysis included five studies in which EAUS was the only imaging technique used. In another study, Oberwalder et al. [24] reported that FI related to sphincter lesions is likely to occur even in an elderly population of women who experienced vaginal deliveries earlier in life. They found that 71% of women with late-onset FI (median age 61.5 years) had occult sphincter defects on EAUS. Obstetric anal sphincter injury (OASIS) is a term used to define trauma to the perineum during vaginal childbirth that includes third- (injury to perineum involving the anal sphincter complex—EAS and IAS) and fourth-degree tears (injury to perineum involving the anal sphincter complex and anal epithelium). When the diagnosis of OASIS is obtained from EAUS evaluation within 2 months of delivery, the incidence of any degree of anal sphincter defect in primiparous women is reported to be as high as 27–35%, and between 4 and 8.5% of multiparous women have a new sphincter defect [25]. When women sustain an OASIS, they are at increased risk of developing FI either immediately following birth or later in life. The true prevalence of FI related to OASIS may be underestimated. The reported rates of FI following the primary repair of OASIS range between 15 and 61%, with a mean of 39% [25]. There is some evidence to suggest that EAUS performed after vaginal birth and before the tear has been repaired could lead to improved primary repair of the IAS and EAS resulting in reduced rates of FI and improved quality of life for women. One trial randomized 752 primiparous women. Compared with clinical examination (routine care), the use of EAUS prior to perineal repair was associated with a reduction in the rate of severe FI at greater than 6 months postpartum (risk ratio RR 0.48) (Level of Evidence 2, Recommendation Grade B) [26]. More high quality randomized controlled trials are needed before the routine use of EAUS on the labor ward can be supported. Cost and training required to implement EAUS should be considered. Data are controversial for asymptomatic patients. There are no cost-benefit studies of EAUS in this setting, or of whether or not asymptomatic patients could benefit from it. Currently, there is no recommendation about screening women later after vaginal delivery for occult sphincter defects.

EAUS may also have a role after perineal repair in the evaluation of residual injury and in the management of subsequent pregnancies [27]. There are no systematic reviews or randomized controlled trials to suggest the best method of follow-up after OASIS. Studies show a high frequency of endosonographic sphincter defects after primary repairs, ranging from 54 to 93% of women [28, 29]. These data emphasize the importance of adequate repair of OASIS and demonstrate that repair can be difficult or underestimated. The current guidelines of the Royal

College of Obstetricians and Gynecologists (RCOG) do not make recommendations about using EAUS for confirming a complete primary repair [30]. According to this guideline, if a woman is experiencing FI at follow-up after repair, referral to EAUS should be considered. A persistent ultrasound-detected defect in the anal sphincter muscles after OASIS is associated with FI [31]. Reconstruction of the entire length of the EAS is crucial. Incontinence after primary repair of OASIS is related to relative length of reconstructed EAS and to the extent of the ultrasonographic defects demonstrated by 3D–EAUS (Level of Evidence 3, Recommendation Grade C) [32]. In a prospective study that assessed at long term the function and morphology of the anal sphincters and the pelvic floor after primary repair of OASIS, women who experienced deterioration of continence over time following repair had a significantly shorter anterior EAS at 3D-EAUS. EAS length correlated with increased severity of FI [33].

Decision about the mode of delivery of pregnancy after OASIS based on symptoms, anal manometry, and EAUS helps in preserving the anal sphincter function and avoiding unnecessary cesarean sections (Level of Evidence 2, Recommendation Grade B) [34]. In a descriptive study on a cohort of women who had OASIS from 2006 to 2013, vaginal delivery was recommended to asymptomatic women with normal investigations (EAUS and anal manometry) and elective cesarean section was recommended to women with fecal symptoms, anal sphincter defects of more than 30°, or low resting or incremental anal pressures. Cesarean section was done in 22 women, and 28 women delivered vaginally. Worsening of fecal symptoms and reduction in anal pressures were not observed in planned vaginal delivery or elective cesarean section groups. There were no new sphincter defects or recurrent OASIS in any of the women in the study group.

EUAS can be useful to select patients with FI that could benefit from rehabilitation. Therapy may be less effective in patients with sphincter lesions, and there is a linear relationship between post-rehabilitative FI scores and severity of sphincter defects [35].

Currently, there is no evidence to support the use of real time elastography in FI evaluation. There was an absence of a correlation of elastogram color distributions of the IAS and EAS with major clinical and functional parameters. So elastography does not seem to provide additional information in the diagnostic workup of FI [36].

Hemorrhoidectomy, fistulectomy or fistulotomy, anal dilatation, or internal lateral sphincterotomy can be a cause of FI, due to anal sphincter injury. Clinical severity of FI after anorectal surgery is related with EAUS features. More frequently, in patients with higher clinical severity score the IAS is always affected and thicker (Level of Evidence 3, Recommendation Grade C) [37]. EAUS has been used to select the surgical options in patients with FI and to assess the clinical efficacy of the treatment. Using 3D-EAUS, de la Portilla et al. [38] demonstrated that all the implants of silicone to treat FI were properly located in the intersphincteric space 3 months after injection (Fig. 13.12). At 24 months, 75% of implants were still properly located. They found that the continence deterioration suffered by most patients after the first year from the injection was not related to the localization and number of implants the patient had. In a multicenter observational study on the implantation of prostheses in patients with FI, EAUS was used preoperatively to select cases (either intact sphincters or IAS lesions extending for less than 60° of the anal circumference) intraoperatively to perform the implants into the intersphincteric space and postoperatively to evaluate the results of surgery and complications (prostheses dislodgement) [39].

Obstructed Defecation and Posterior Vaginal Wall Prolapse

Anorectal outlet obstruction, also known as obstruction defecation syndrome (ODS), is a pathological condition due to a variety of causes and is characterized by an impaired expulsion of the bolus after calling to defecate [14]. Patients complain of different symptoms, including incomplete evacuation with or without painful

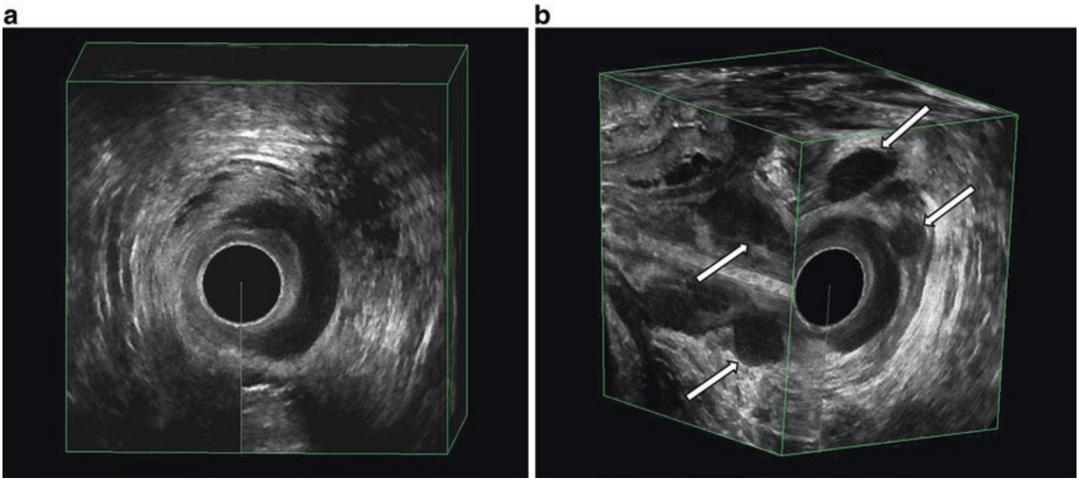

Fig. 13.12 (**a**) Internal anal sphincter damage in the right quadrants of the anal canal (from 6 to 12 o'clock position). (**b**) Implant of prostheses (*arrows*) in the intersphincteric space. Scans obtained by BK 8838 probe

effort, unsuccessful attempts with long periods spent in the bathroom, return visit to the toilet, use of perineal support, manual assistance (insertion of finger into the vagina or anal canal), straining, and dependence on enema and/or laxatives. Other symptoms are pain at defecation; extreme straining to defecate; extended time at the toilet; perineal pain/discomfort when standing; feeling of incomplete evacuation; fragmented defecation; vaginal, perineal, or rectal digitation; and use of laxatives or enemas, FI [14]. These symptoms often lead to poor quality of life. Prevalence of the entire spectrum of constipation, of which ODS is part, accounts for 14.7% in the United States adult population while the true prevalence of ODS among the population is unknown and probably underestimated.

After ruling out pelvic and rectal tumor, the main distinction in the pathogenesis of ODS is between functional and mechanical causes. Failure to release the anal sphincters or paradoxical contraction of the PR muscle are considered the main and most frequent functional causes of ODS. In these patients, biofeedback can achieve reactivation of the inhibitory capacity of all pelvic floor muscles involved in defecation, with an improvement in symptoms of 50%. The most relevant mechanical causes of ODS are rectocele, rectal intussusception, enterocele, genital prolapse, and descending perineum. It is fundamental to distinguish between rectal causes (rectocele and intussusception) and extrarectal causes enterocele, genital prolapse, and descending perineum.

In recent years, alternatives to defecography, such as dynamic magnetic resonance imaging (MRI) and dynamic ultrasonography, have been developed for the evaluation of pelvic floor dysfunctions, with good correlation and the advantage of showing the entire pelvis [40–50]. Studies using dynamic ultrasound with different types of transducers (convex, endfire, biplanar probes) and different techniques (translabial, transperineal, introital ultrasound) have produced findings consistent with defecography to assess patients with ODS [1, 43–50]. Murad-Regadas et al. [47–50] developed echodefecography, a 3D dynamic anorectal ultrasonography technique using a 360° transducer, automatic scanning, and high frequencies for high-resolution images to evaluate evacuation disorders affecting the posterior compartment (rectocele, intussusception, anismus) and the middle compartment (grade II or III sigmoidocele/enterocele). The technique is standardized; the parameters and values of echodefecography make the method reproducible [48–50]. Echodefecography was shown to correlate well with conventional defecography and was validated in a prospective multicenter study [48–50].

Echodefecography is performed with a 3D ultrasound endoprobe (BK 2052 Anorectal 3D Transducer, BK Ultrasound, Analogic, Peabody, MA, USA) with proximal-to-distal 6.0 cm automatic scans. By moving two crystals on the extremity of the transducer, axial and longitudinal images are merged into a single cube image, recorded, and analyzed in multiple planes. Following rectal enema, the patient is examined in the left lateral position. Images are acquired by four automatic scans and analyzed in the axial, sagittal and, if necessary, in the oblique plane. The result of the exam depends on the degree of cooperation obtained from the patient: scans 1, 2, and 4 use a slice width of 0.25 mm and last 50 s each; scan 3 lasts 30 s with a slice width of 0.35 mm:

- *Scan 1* (at rest position without gel): The transducer is positioned at 5.0–6.0 cm from the anal margin. It is performed to visualize the anatomic integrity of the anal sphincter musculature and to evaluate the position of the PR muscles and the EAS at rest. The angle formed between a line traced along the internal border of the EAS/PR muscles (1.5 cm) and a line traced perpendicular to the axis of the anal canal is measured
- *Scan 2* (at rest-straining/at rest without gel): The transducer is positioned at 6.0 cm from the anal verge. The patient is requested to rest for 15 seconds, strain maximally for 20 s, then relax again, with the transducer following the movement. The purpose of the scan is to evaluate the movement of the PR and the EAS during straining, identifying normal relaxation, non-relaxation or paradoxical contraction (anismus). The resulting EAS/PR muscle positions (represented by the angle size) are compared between scans 1 and 2. Normal relaxation is recorded if the angle increased by a minimum of one degree, whereas paradoxical contraction is recorded if the angle decreased by a minimum of one degree. Non-relaxation is recorded if the angle changed less than one degree (Figs. 13.13 and 13.14)
- *Scan 3:* The transducer is positioned proximally to the PR (anorectal junction). The scan starts with the patient at rest (3.0 s), followed by maximum straining with the transducer in fixed position (the transducer does not follow the descending muscles of the pelvic floor). When the PR becomes visible distally, the scan is stopped. Perineal descent is quantified by measuring the distance between the position of the proximal border of the PR at rest and the point to which it has been displaced by maximum straining (PR descent). Straining time is directly proportional to the distance of perineal descent (Fig. 13.15). Even with patients in the lateral position, displacement of the PR is easily visualized and quantified. On echodefecography, normal perineal descent during straining is defined as a difference in PR position of ≤2.5 cm, and perineal descent >2.5 cm. The normal range values were established by comparing echodefecography findings with defecography
- *Scan 4:* Following injection of 120–180 ml ultrasound gel into the rectal ampulla, the transducer is positioned at 7.0 cm from the anal verge. The scanning sequence is the same as in Scan 2 (at rest for15 s, strain maximally for 20 s, then relax again, with the transducer following the movement). The purpose of the scan is to visualize and quantify all anatomical structures and functional changes associated with voiding (rectocele, intussusception, Grade II or III sigmoidocele/enterocele). In normal patients, the posterior vaginal wall displaces the lower rectum and upper anal canal inferiorly and posteriorly, but maintains a straight horizontal position during defecatory effort. If rectocele is identified, it is classified as Grade I (< 6.0 mm), grade II (6.0–13.0 mm), or Grade III (>13.0 mm) (Fig. 13.16). Measurements are calculated by first drawing two parallel horizontal lines along the posterior vaginal wall, with one line placed in the initial straining position, and the other line drawn at the point of maximal straining. The distance between the two vaginal wall positions determines the size of the rectocele. Intussusception is clearly identified by observing the rectal wall layers protruding through

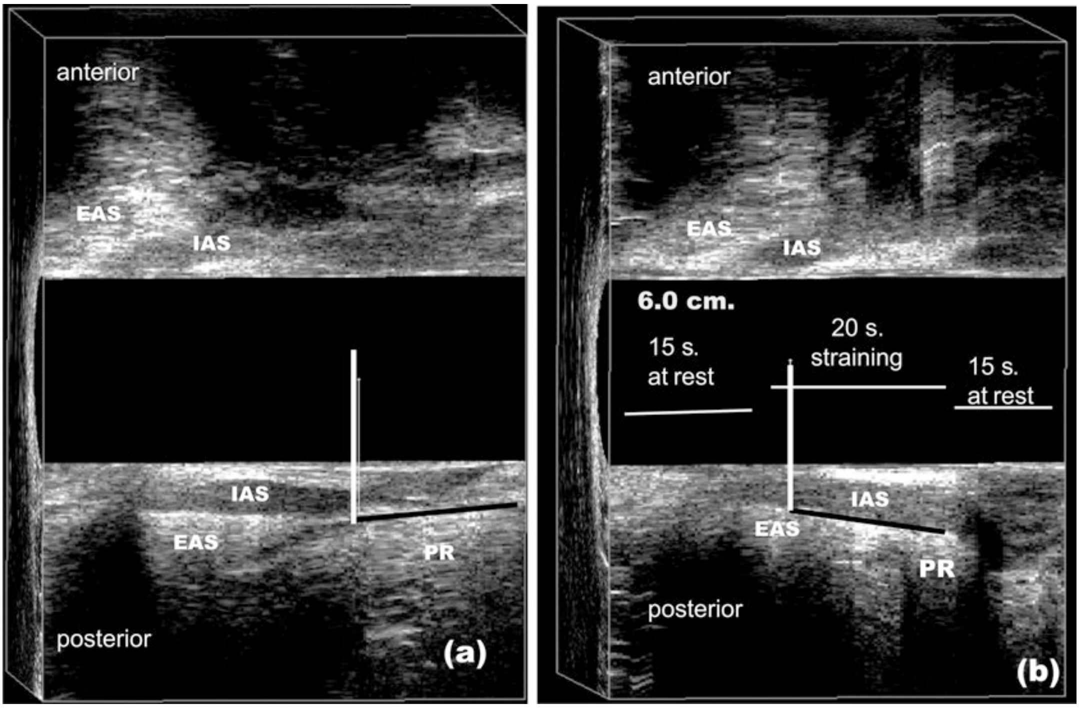

Fig. 13.13 (**a**) Angle measured at rest position in the sagittal plane (*lines*). (**b**) Increased angle (normal relaxation) during straining (*lines*). External anal sphincter (EAS), internal anal sphincter (IAS), puborectalis (PR). Scans obtained by BK 2052 probe

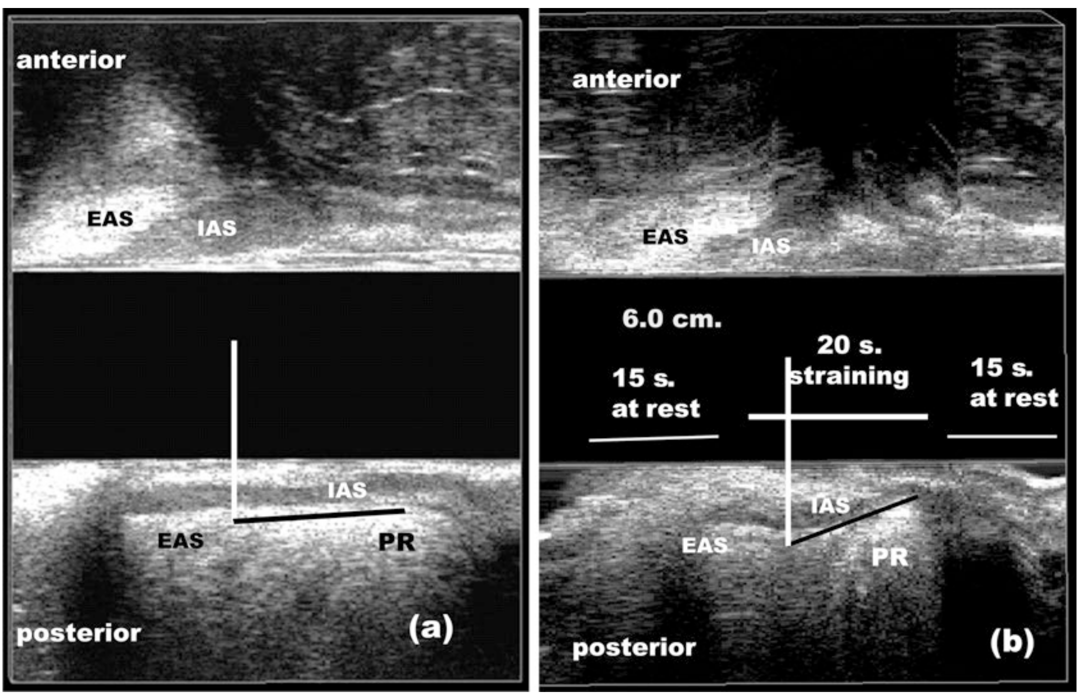

Fig. 13.14 (**a**) Angle measured at rest position in the sagittal plane (*lines*). (**b**) Decreased angle (anismus) during straining (*lines*). External anal sphincter (EAS), internal anal sphincter (IAS), puborectalis (PR). Scans obtained by BK 2052 probe

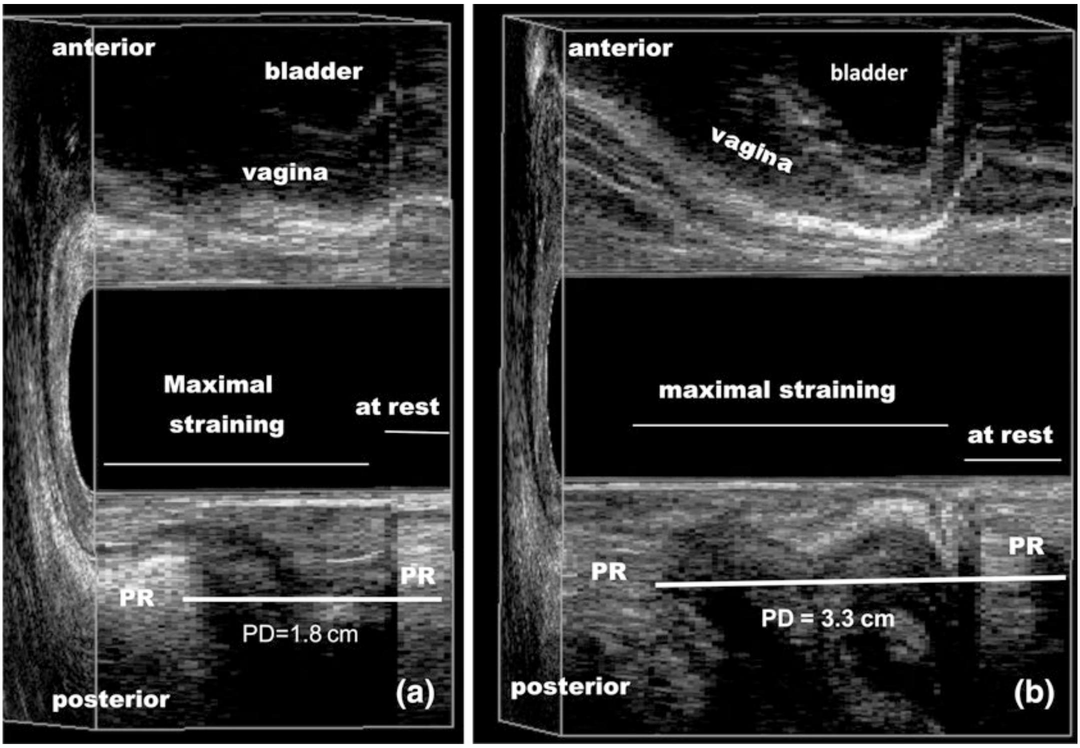

Fig. 13.15 Puborectal descent (PD) measured in the sagittal plane. (**a**) Normal perineal descent ≤2.5 cm. (**b**) Pathologic perineal descent >2.5 cm. Puborectalis (PR). Scans obtained by BK 2052

the rectal lumen. No classification is used to quantify intussusceptions (Fig. 13.17). Grade II or III sigmoidocele/enterocele is recognized when the bowel is positioned below the pubococcygeal line (on the projection of the lower rectum and upper anal canal).

Dynamic ultrasound scanning is a helpful tool in the evaluation of patients with ODS, as it clearly shows the anatomical structures and mechanisms involved in defecation. It also demonstrates anatomical integrity of the anal canal and is able to detect sphincter injury with high spatial resolution. In addition, the cube image acquired during the automatic scan is recorded in real-time for subsequent analysis as may be necessary in many cases. It is fast, relatively low-cost, and well tolerated by patients without exposure to radiation.

Perianal Abscesses and Fistulas

The pathogenesis of anorectal abscesses and fistulae is generally attributed to an infection of the anal glands, usually located in the subepithelial position, the intersphincteric space, or the external sphincter, with ducts that enter at the base of the anal crypts of Morgagni at the dentate line level [51]. Infection of the glands can result in an abscess that can spread in a number of directions, usually along the path of least resistance, and can lead to subsequent development of anal fistula. Five presentations of anorectal abscess have been described [51]:

1. *Perianal abscess*, which is the most common type of anorectal abscess, occurring in 40–45% of cases and is identified as a superficial, tender mass outside the anal verge. Physical

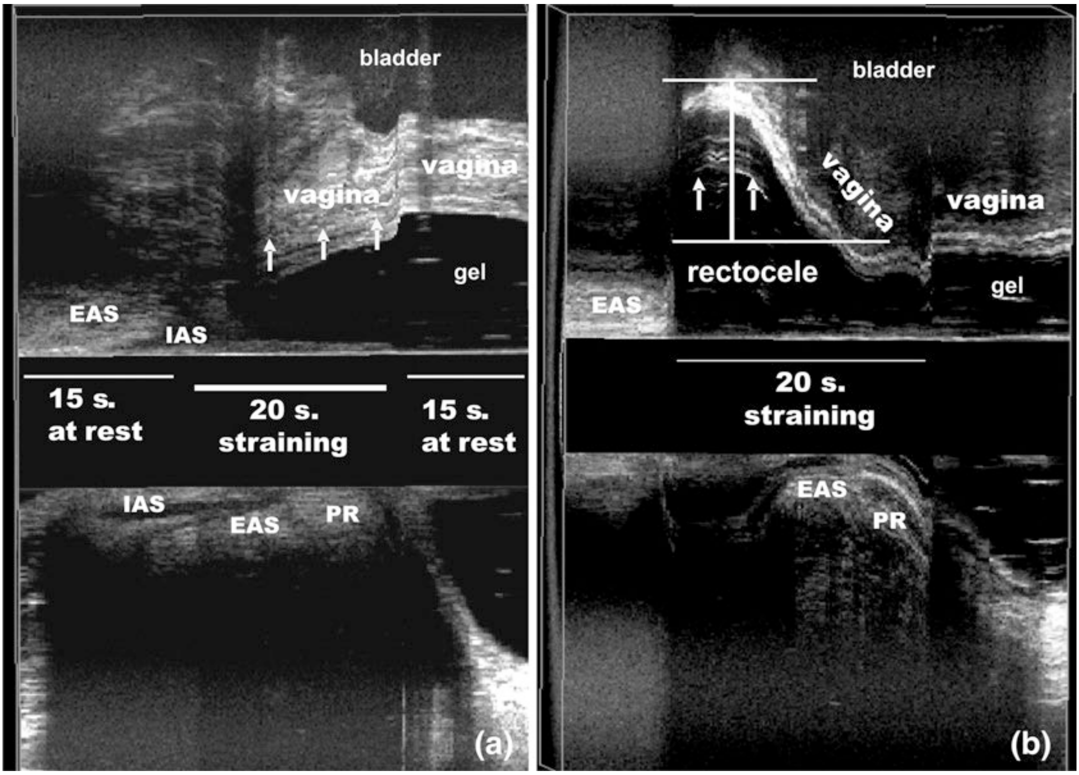

Fig. 13.16 (**a**) Patient without rectocele (*arrows*). Sagittal plane. Using gel in the rectum. (**b**) Grade III rectocele (*arrows*). External anal sphincter (EAS), internal anal sphincter (IAS), puborectalis (PR). Scans obtained by BK 2052 probe

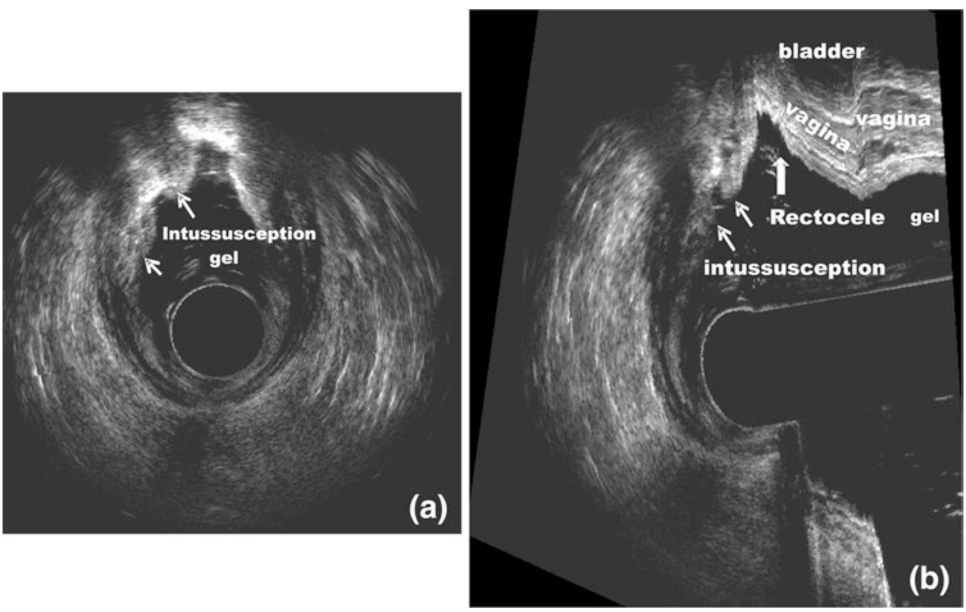

Fig. 13.17 (**a**) Anterior intussusception (*arrows*). Axial plane. Using gel into the rectum. (**b**) Grade III rectocele and anterior intussusceptions (*arrows*). Sagittal with coronal plane. Scans obtained by BK 2052 probe

examination reveals an area of erythema, induration, or fluctuance, and anoscopic examination can demonstrate pus exuding at the base of a crypt
2. *Submucosal abscess,* which arises from an infected crypt in the anal canal and is located under the mucosa. Rectal examination may reveal a tender submucosal mass, which may not be readily apparent by anoscopy
3. *Intersphincteric abscess,* which represents between 2 and 5% of anorectal abscesses. In this condition the infection dissects in the intersphincteric plane and can spread cephalad (high type) or caudal (low type)
4. *Ischioanal abscess,* which is seen in 20–25% of patients and may present as a large, erythematous, indurated, tender mass of the buttock or may be virtually inapparent, the patient complaining only of severe pain or fever
5. *Supralevator and pelvirectal abscesses,* which are relatively rare, comprising less than 2.5% of anorectal abscesses. They may occur as a cephalad extension of an intersphincteric or trans-sphincteric abscess, or may be associated with a pelvic inflammatory condition (Crohn disease, diverticulitis, salpingitis) or pelvic surgery

Anorectal fistula represents a communication between two epithelial surfaces: the perianal skin and the anal canal or rectal mucosa [51]. Any fistula is characterized by an internal opening, a primary tract, and an external or perineal opening. Occasionally, the primary tract can present a secondary extension, or a fistula is without a perineal opening. Parks et al. [51] classified the main tract of the fistula in relation to the sphincters into four types:

1. *Intersphincteric tract* (incidence between 55 and 70%). An intersphincteric fistula passes through the internal sphincter and through the intersphincteric plane to the skin. Only the most superficial portions of the tract pass through the subcutaneous external sphincter. Secondary extension may be observed to proceed cephalad in the intersphincteric plane (high blind tract)
2. *Trans-sphincteric tract* (incidence between 55 and 70%). A trans-sphincteric fistula passes through both the internal and external sphincters, into the ischioanal fossa and to the skin. The level of the tract determines three types of trans-sphincteric fistula: high (traversing the upper two-thirds of the external sphincter), mid, and low. The height of the internal opening, however, does not always reflect the level at which a trans-sphincteric fistula crosses the external anal sphincter [52]
3. *Suprasphincteric tract* (incidence between 1 and 3%). A suprasphincteric fistula courses above the puborectalis muscle and below the levator after initially passing cephalad as an intersphincteric fistula. It then transverses downward through the ischioanal fossa to the skin
4. *Extrasphincteric tract* (incidence between 2 and 3%). An extrasphincteric fistula is described by a direct communication between the perineum and rectum with no anal canal involvement

Submucosal fistulae are those in which the tract is subsphincteric and does not involve or pass the sphincter complex. Anovaginal fistulae have an extension toward the vaginal introitus. Secondary tracts may develop in any part of the anal canal or may extend circumferentially in the intersphincteric, ischioanal, or supralevator spaces (horseshoe extensions). The term "complex" fistula is a modification of the Park's classification, which describes fistulae whose treatment poses a higher risk for impairment of continence. According to the American Society of Colon and Rectal Surgeons (ASCRS) classification, an anal fistula may be termed "complex" when the tract crosses more than 30–50% of the external sphincter (high trans-sphincteric, suprasphincteric, and extrasphincteric), is anterior in a female, has multiple tracts, is recurrent, or the patient has pre-existing incontinence, local irradiation, or Crohn disease.

The configuration of perianal sepsis and the relationship of abscesses or fistulae with internal and external sphincters are the most important factors influencing the results of surgical management. Preoperative identification of all loculate purulent areas and definition of the anatomy of the primary fistulous tract, secondary extensions, and internal opening play an important role in adequately planning the operative approach in order to ensure complete drainage of abscesses, to prevent early recurrence after surgical treatment, and to minimize iatrogenic damage of sphincters and the risk of minor or major degrees of incontinence.

EAUS has been demonstrated to be a very helpful diagnostic tool in accurately assessing all fistula or abscess characteristics. It can be easily repeated while following patients with perianal sepsis to choose the optimal timing and modality of surgical treatment, to evaluate the integrity of or damage to sphincters after operation, and to identify recurrence of fistula. It also provides information on the anal sphincters, which is valuable in performing successful fistula surgery. A fistula tract affecting minimal muscle can be safely excised, but where the bulk of external sphincter muscle is affected, it is best treated by seton drainage or mucosal advancement flap. In a prospective, consecutive study, a strong correlation was found between preoperative 3D-EAUS measurements of fistula height with intraoperative and postoperative 3D-EAUS measurements of IAS and EAS division. Fistulotomy limited to the lower two-thirds of the EAS is associated with excellent continence and cure rates (Level of Evidence 3, Recommendation Grade C) [53].

Ultrasonography examination is generally started using 10–13 MHz, changing to 7 or 5 MHz to optimize visualization of the deeper structures external to the anal sphincters. The PR muscle, EAS, CLL, and IAS should always be identified and used as reference structures for the spatial orientation of the fistula or abscess. An anal abscess appears as a hypoechoic dyshomogeneous area, sometimes with hyperechoic spots within it, possibly in connection with a fistulous tract directed through the anal canal lumen. Abscesses are classified as superficial, intersphincteric, ischioanal, supralevator, pelvirectal, and horseshoe (Fig. 13.18).

An anal fistula appears as a hypoechoic tract, which is followed along its crossing of the subepithelium, internal or external sphincters, and through the perianal spaces. With regard to the anal sphincters, according to Park's classification [51], the fistulous primary tract can be classified into four types:

- *Intersphincteric tract,* which is presented as a band of poor reflectivity within the longitudinal layer, causing widening and distortion of an otherwise narrow intersphincteric plane. The tract goes through the intersphincteric space without traversing the external sphincter fibers (Fig. 13.19)
- *Trans-sphincteric tract*, appearing as a poorly reflective tract running out through

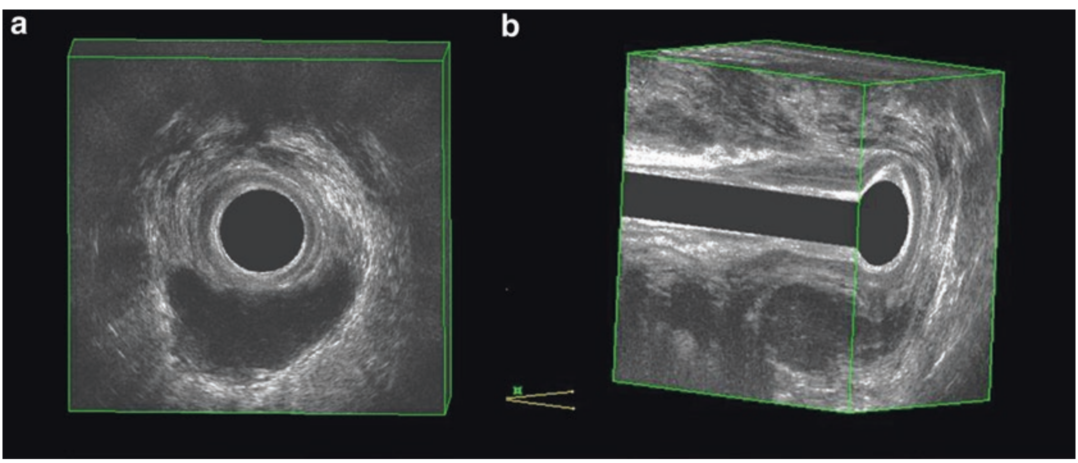

Fig. 13.18 3D endoanal ultrasound with BK 2052. (**a**, **b**) Acute abscess in the posterior intersphincteric space presenting as an area of low reflectivity

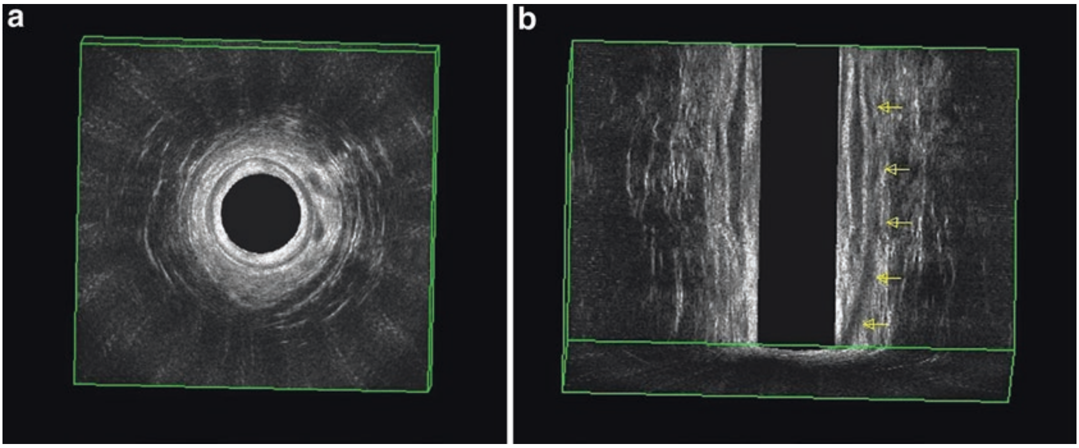

Fig. 13.19 3D endoanal ultrasound with BK 2052. (**a**) A hypoechoic area is present in the left intersphincteric space (3 o'clock). (**b**) Reconstruction in the coronal plane confirms an intersphincteric tract, appearing as a band of poor reflectivity. The tract (*arrows*) extends through the intersphincteric space without traversing the external anal sphincter

the external sphincter and disrupting its normal architecture. The point at which the main tract of the fistula traverses the sphincters defines the fistula level. The trans-sphincteric fistulae are divided into high, medium, or low, corresponding to the ultrasound level of the anal canal [52]. The low trans-sphincteric tract traverses only the distal external sphincter third at the lower portion of the medium anal canal. The medium trans-sphincteric tract traverses both sphincters, external and internal, in the middle part of the medium anal canal. The high trans-sphincteric tract traverses both sphincters in the higher part of the medium anal canal, in the space below the puborectalis (Fig. 13.20)

- S*uprasphincteric tract*, which goes above or through the PR level. It can be very difficult to determine a suprasphincteric extension because EAUS is not able to visualize the precise position of the levator plate that lies in the same plane as the ultrasound beam
- *Extrasphincteric tract,* which may be seen close to but more laterally placed around the external sphincter

Differentiation between granulated tracts and scars is sometimes difficult. Straight tracts are easily identified, but smaller and oblique tracts are more difficult to image. Secondary tracts, when present, are related to the main one and are classified as intersphincteric, trans-sphincteric, suprasphincteric, or extrasphincteric. Similarly, horseshoe tracts, when identified, are categorized as intersphincteric, suprasphincteric, or extrasphincteric. The exact location (radial site and anal canal level) of the internal opening can be difficult to define, as the dentate line cannot be identified as a discrete anatomical entity on EAUS. It is assumed to lie at approximately mid-anal canal level, which is midway between the superior border of the PR muscle and the most caudal extent of the subcutaneous EAS. According to this, the site of the internal opening is categorized as being above, at, or below the dentate line, or in the rectal ampulla. In addition, the site can also be characterized by the clock position, being classified from 1 o'clock to 12 o'clock. The internal opening can be identified as hypoechoic (when acute inflammation is present) or hyperechoic area (when chronically inflamed).

Initial experiences with EAUS reported a good accuracy for the selective identification of fistula (91.7%) and abscess (75%) configurations. However, a significant number of the internal openings (33.3%) were not detected [54]. Worse results in the identification of the internal opening were reported by Poen et al. [55] (5.3%

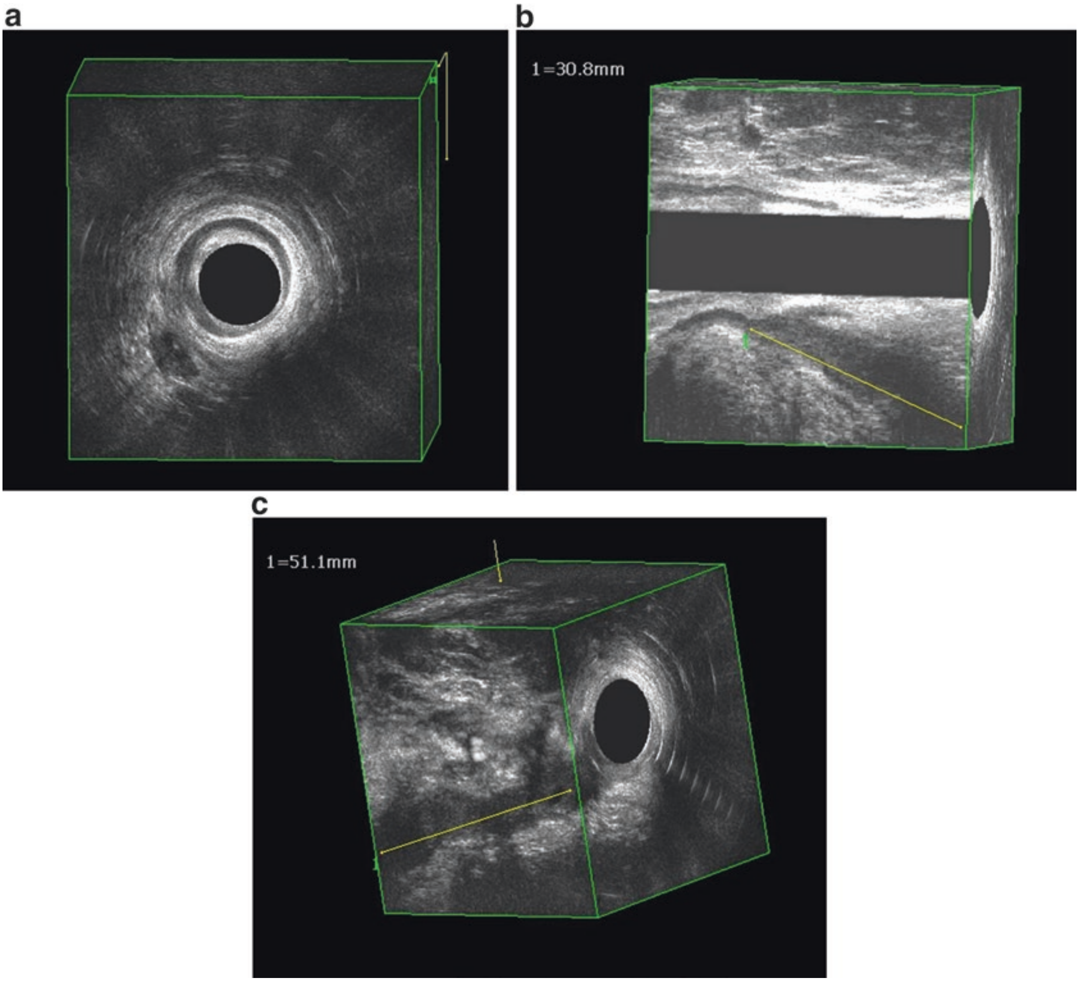

Fig. 13.20 3D endoanal ultrasound with BK 2052 probe. (**a**) A hypoechoic tract is traversing posteriorly the external anal sphincter. (**b**, **c**) Reconstructions in the sagittal plane confirm a posterior transsphincteric fistula

accuracy) and Deen et al. [56] (11% accuracy). The most probable reason for the poor results in the identification of internal openings by EAUS is the ultrasonographic criteria used. Cho [57] proposed the following endosonographic criteria to define the site of the internal opening: Criterion 1: Appearance of a root-like budding formed by the intersphincteric tract, which contacts the internal sphincter. Criterion 2: Appearance of a root-like budding with an internal sphincter defect. Criterion 3: A subepithelial breach connected to the intersphincteric tract through an internal sphincter defect. Using a combination of these three criteria, the author reported 94% sensitivity, 87% specificity, and 81 and 96% positive and negative predictive values.

The majority of problems while investigating primary tracts with EAUS occur because of the structural alterations of the anal canal and perianal muscles and tissues, which can overstage the fistula, or poor definition of the tract when filled with inflammatory tissue, which can downstage the fistula [58]. The disappointing results of EAUS in diagnosing the extrasphincteric fistulae could be due to the echogenicity of the fistulae, especially those with a narrow lumen, which is practically identical to the fat tissue in the ischioanal fossa, and to the short focal length of the transducer, which prevents imaging of fistula that are located at large distance from the anal canal. For this reason, performing ultrasonography after injecting 1.0–2.0 ml of 3% hydrogen peroxide

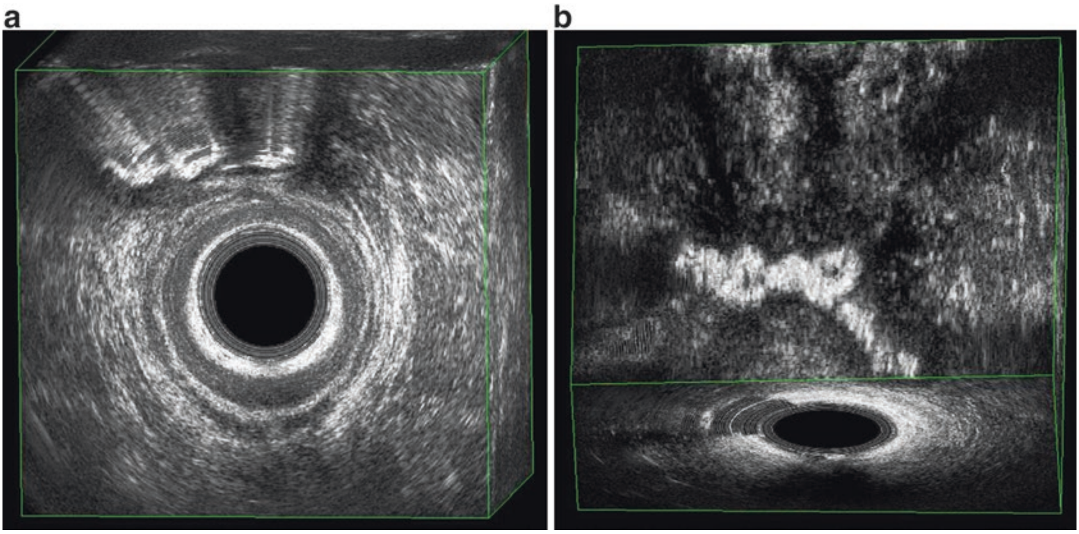

Fig. 13.21 3D endoanal ultrasound with BK 2052 probe. (**a**) After injection of hydrogen peroxide, the fistulous tract appears hyperechoic. (**b**) Reconstruction in the coronal plane

(HPUS) through the external opening of the fistula appears to be particularly useful [58]. This technique allows identification of tracts whose presence has not been definitively established, or distinction of an active fistulous tract from post-surgical or post-trauma scar tissue (Fig. 13.21). Gas is a strong ultrasound reflector, and after injection, fistula tracts become hyperechoic and the internal opening is identified as an echogenic breach at the submucosa. Because the injected HP often results in bubbling into the anal canal, which then acts as a barrier to the ultrasound wave, injection should be performed in two phases: an initial injection of a small amount of HP, and a further injection at a greater pressure. A disadvantage inherent to HP injection is the very strong reflection that occurs at a gas/tissue interface, which blanks out any detail deep to this interface. The bubbles produced by HP induce acoustic shadowing deep to the tract, so all information deep to the inner surface of the tract is lost. The reported diagnostic accuracy of HPUS ranges from 71 to 95% for primary tracts, and from 63 to 96.1% for secondary tracts; while that of standard EAUS ranges from 50 to 91.7% for the primary tract, and from 60 to 68% for secondary tracts [59, 60]. The highest concordance is usually reported for primary trans-sphincteric fistulae, while the major diagnostic difficulty is still the adequate identification of primary supra- and extrasphincteric fistulae. Injection can also contribute to a more accurate identification of the internal opening (HPUS accuracy ranging from 48 to 96.6% vs. EAUS accuracy ranging from 5.3 to 93.5%) [61].

The availability of 3D imaging has further improved the accuracy of EAUS [5]. With this technique, the operator can follow the pathway of the fistulous tract along all the desired planes (axial, coronal, sagittal, oblique). In addition, *volume render mode* can facilitate depiction of a tortuous fistula tract after HP injection, due to the transparency and depth information [5]. Buchanan et al. [62] reported a good accuracy of 3D-EAUS in detecting primary tracts (81%), secondary tracts (68%), and internal openings (90%) in 19 patients with recurrent or complex fistulae. The addition of HP did not improve these features (accuracies of 71%, 63%, and 86%, respectively). Using 3D imaging, Ratto et al. [60] reported an accuracy of 98.5% for primary tracts, 98.5% for secondary tracts, and 96.4% for internal openings, compared with 89.4%, 83.3%, and 87.9%, respectively, when the 2D system was used. Our experience [61] on 57 patients with perianal fistulae confirmed that 3D reconstructions improved the accuracy of EAUS in the identification of internal opening compared to 2D-EAUS (89.5% vs. 66.7%; P = 0.0033). Primary tracts, secondary tracts, and abscesses were similarly evaluated by both procedures.

EAUS has some clear advantages related to the fact that it is relatively cheap and simple to perform, is rapid and well tolerated by patients, and, unlike MRI, can be performed easily in the outpatient clinic or even on the ward since the machines are easily portable. It is vastly superior to digital examination and is therefore well worth performing. The major advantage of MRI over EAUS is the facility with which it can image extensions that would otherwise be missed since they can travel several centimeters from the primary tract. It is especially important to search for supralevator extensions, since these are not only difficult to detect but pose specific difficulties with treatment. Complex extensions are especially common in patients with recurrent fistulae or in those with Crohn disease. It should also be borne in mind that MRI and EAUS provide complementary and additive information, and there are no disadvantages to performing both procedures in the same patient where local circumstances, availability, and economics allow [63].

References

1. Santoro GA, Wieczorek AP, Dietz HP, Mellgren A, Sultan AH, Shobeiri SA, et al. State of the art: an integrated approach to pelvic floor ultrasonography. Ultrasound Obstet Gynecol. 2011;37(4):381–96.
2. Groenendijk AG, Birnie E, Boeckxstaens GE, Roovens JP, Bonsel GJ. Anorectal function testing and anal endosonography in the diagnostic work-up of patients with primary pelvic organ prolapse. Gynecol Obstet Investig. 2009;67(3):187–94.
3. Groenendijk AG, Birnie E, de Blok S, Adriaanse AH, Ankum WM, Roovens JP, Bonsel GJ. Clinical-decision taking in primary pelvic organ prolapse; the effects of diagnostic tests on treatment selection in comparison with a consensus meeting. Int Urogynecol J. 2009;20(6):711–9.
4. Abdool Z, Sultan AH, Thankar R. Ultrasound imaging of the anal sphincter complex: a review. Br J Radiol. 2012;85(1015):865–75.
5. Santoro GA, Fortling B. The advantages of volume rendering in three-dimensional endosonography of the anorectum. Dis Colon Rectum. 2007;50(3):359–68.
6. Santoro GA, Di Falco G. Endoanal and endorectal ultrasonography: methodology and normal pelvic floor anatomy. In: Santoro GA, Wieczorek AP, Bartram C, editors. Pelvic floor disorders imaging and a multidisciplinary approach to management. Milan: Springer Verlag Italia; 2010. p. 91–102.
7. Santoro GA, Sultan AH. Pelvic floor anatomy and imaging. Semin Colon Rectal Surg. 2016;27(1):5–14.
8. Williams AB, Cheetham MJ, Bartram CI, Halligan S, Kamm MA, Nicholls RJ, Kmiot WA. Gender differences in the longitudinal pressure profile of the anal canal related to anatomical structure as demonstrated on three-dimensional anal endosonography. Br J Surg. 2000;87(12):1674–9.
9. Regadas FS, Murad-Regadas SM, Lima DM, Silva FR, Barreto RG, Souza MH, Regadas Filho FS. Anal canal anatomy showed by three-dimensional anorectal ultrasonography. Surg Endosc. 2007;21(12):2207–11.
10. Bollard RC, Gardiner A, Lindow S, Phillips K, Duthie GS. Normal female anal sphincter: difficulties in interpretation explained. Dis Colon Rectum. 2002;45(2):171–5.
11. Gold DM, Bartram CI, Halligan S, Humphries KN, Kamm MA, Kmiot WA. Three-dimensional endoanal sonography in assessing anal canal injury. Br J Surg. 1999;86(3):365–70.
12. Frudinger A, Halligan S, Bartram CI, Price AB, Kamm MA, Winter R. Female anal sphincter: age-related differences in asymptomatic volunteers with high-frequency endoanal US. Radiology. 2002;224(2):417–23.
13. West RL, Felt-Bersma RJF, Hansen BE, Schouten WR, Kuipers EJ. Volume measurements of the anal sphincter complex in healthy controls and fecal-incontinent patients with a three-dimensional reconstruction of endoanal ultrasonography images. Dis Colon Rectum. 2005;48(3):540–8.
14. Haylen BT, de Ridder D, Freeman RM, Swift SE, Berghmans B, Lee J, et al. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction. Int Urogynecol J. 2010;21(1):5–26.
15. Santoro GA. Which method is best for imaging of anal sphincter defects? Dis Colon Rectum. 2012;55(6):625–7.
16. Santoro GA, Di Falco G. Endosonographic anatomy of the normal rectum. In: Santoro GA, Di Falco G, editors. Benign anorectal diseases. Diagnosis with endoanal and endorectal ultrasonography and new treatment options. Milan: Springer Italy; 2006 p. 55–60.
17. Macmillan AK, Merrie AE, Marshall RJ, Parry BR. The prevalence of fecal incontinence in community-dwelling adults: a systematic review of the literature. Dis Colon Rectum. 2004;47(8):1341–9.
18. Bliss DZ, Mellgren A, Whitehead WE, Chiarioni G, Emmanuel A, Santoro GA, et al. Assessment and conservative management of faecal incontinence and quality of life in adults. In: Abrams P, Cardozo L, Khoury S, Wein A, editors. Incontinence. 5th

International Consultation on Incontinence. Paris: ICUD-EAU; 2013. p. 1443–86.
19. Starck M, Bohe M, Valentin L. Results of endosonographic imaging of the anal sphincter 2–7 days after primary repair of third or fourth-degree obstetric sphincter tears. Ultrasound Obstet Gynecol. 2003;22(6):609–15.
20. Norderval S, Dehli T, Vonen B. Three-dimensional endoanal ultrasonography: intraobserver and interobserver agreement using scoring systems for classification of anal sphincter defects. Ultrasound Obstet Gynecol. 2009;33(3):337–43.
21. Voyvodic F, Rieger NA, Skinner S, Schloithe AC, Saccone GT, Sage MR, Wattchow DA. Endosonographic imaging of anal sphincter injury. Does the size of the tear correlate with the degree of dysfunction? Dis Colon Rectum. 2003;46(6):735–41.
22. Sultan AH, Kamm MA, Hudson CN, Thomas JM, Bartram CI. Anal sphincter disruption during vaginal delivery. N Engl J Med. 1993;329(26):1905–11.
23. Oberwalder M, Connor J, Wexner SD. Meta-analysis to determine the incidence of obstetric anal sphincter damage. Br J Surg. 2003;90(11):1333–7.
24. Oberwalder M, Dinnewitzer A, Baig MK, Thaler K, Cotman K, Nogueras JJ, et al. The association between late-onset fecal incontinence and obstetric anal sphincter defects. Arch Surg. 2004;139(4):429–32.
25. Harvey MA, Pierce M, Alter JE, Chou Q, Diamond P, Epp A, et al. Society of obstetricians and gynaecologists of Canada. Obstetrical Anal Sphincter Injuries (OASIS): prevention, recognition, and repair. J Obstet Gynaecol Can. 2015;37(12):1131–48.
26. Walsh KA, Grivell RM. Use of endoanal ultrasound for reducing the risk of complications related to anal sphincter injury after vaginal birth. Cochrane Datab Syst Rev. 2015;29(10):CD010826. doi:10.1002/14651858.CD010826.pub2.
27. Fitzpatrick M, Cassidy M, Barassaud ML, Hehir MP, Hanly AM, O'Connell PR, O'Herlihy C. Does anal sphincter injury preclude subsequent vaginal delivery? Eur J Obstet Gynecol Reprod Biol. 2016;198:30–4.
28. Oude Lohuis EJ, Everhardt E. Outcome of obstetric anal sphincter injuries in terms of persisting endoanal ultrasonographic defects and defecatory symptoms. Int J Gynaecol Obstet. 2014;126(1):70–3.
29. Reid AJ, Beggs AD, Sultan AH, Roos AM, Thakar R. Outcome of repair of obstetric anal sphincter injuries after three years. Int J Gynaecol Obstet. 2014;127(1):47–50.
30. Royal College of Obstetricians and Gynecologists (RCOG). The management of third- and fourth-degree perineal tears (Green-top Guideline No. 29). 3rd ed. London UK: RCOG Press; 2015; p. 1–19.
31. Laine K, Skjeldestad FE, Sanda B, Horne H, Spydslaug A, Staff AC. Prevalence and risk factors for anal incontinence after obstetric anal sphincter rupture. Acta Obstet Gynecol Scand. 2011;90(4):319–24.
32. Norderval S, Røssaak K, Markskog A, Vonen B. Incontinence after primary repair of obstetric anal sphincter tears is related to relative length of reconstructed external sphincter: a case-control study. Ultrasound Obstet Gynecol. 2012;40(2):207–14.
33. Soerensen MM, Pedersen BG, Santoro GA, Buntzen S, Bek K, Laurberg S. Long-term function and morphology of the anal sphincters and the pelvic floor after primary repair of obstetric anal sphincter injury. Color Dis. 2014;16(10):O347–55.
34. Karmarkar R, Bhide A, Digesu A, Khullar V, Fernando R. Mode of delivery after obstetric anal sphincter injury. Eur J Obstet Gynecol Reprod Biol. 2015;194:7–10.
35. Pucciani F, Raggioli M, Gattai R. Rehabilitation of fecal incontinence: what is the influence of anal sphincter lesions? Tech Coloproctol. 2013;17(3):299–306.
36. Allgayer H, Ignee A, Zipse S, Crispin A, Dietrich CF. Endorectal ultrasound and real-time elastography in patients with fecal incontinence following anorectal surgery: a prospective comparison evaluating short- and long-term outcomes in irradiated and non-irradiated patients. Z Gastroenterol. 2012;50(12):1281–6.
37. Albuquerque A, Macedo G. Clinical severity of fecal incontinence after anorectal surgery and its relationship with endoanal ultrasound features. Int J Color Dis. 2016;31(7):1395–6.
38. de la Portilla F, Vega J, Rada R, Segovia-Gonzáles MM, Cisneros N, Maldonado VH, Espinosa E. Evaluation by three-dimensional anal endosonography of injectable silicone biomaterial (PTQ) implants to treat fecal incontinence: long-term localization and relation with the deterioration of the continence. Tech Coloproctol. 2009;13(3):195–9.
39. Ratto C, Buntzen S, Aigner F, Altomare DF, Heydari A, Donisi L, et al. Multicentre observational study of the Gatekeepe for faecal incontinence. Br J Surg. 2016;103(3):290–9.
40. Lienemann A, Anthuber C, Baron A, Kohz P, Reiser M. Dynamic MR colpocystorectography assessing pelvic floor descent. Eur Radiol. 1997;7(8):1309–17.
41. Kaufman HS, Buller JL, Thompson JR, Pannu HK, DeMeester SL, Genadry RR, et al. Dynamic pelvic magnetic resonance imaging and cystocolpoproctography alter surgical management of pelvic floor disorders. Dis Colon Rectum. 2001;44(11):1575–83.
42. Dvorkin LS, Hetzer F, Scott SM, Williams NS, Gedroyc W, Lunniss PJ. Open-magnet MR defaecography compared with evacuation proctography in the diagnosis and management of patients with rectal intussusception. Color Dis. 2004;6(1):45–53.
43. Barthet M, Portier F, Heyries L, Orsoni P, Bouvier M, Houtin D, et al. Dynamic anal endosonography may challenge defecography for assessing dynamic anorectal disorders: Results of a prospective pilot study. Endoscopy. 2000;32(4):300–5.

44. Van Outryve SM, Van Outryve MJ, De Winter BY, Pelckmans PA. Is anorectal endosonography valuable in dyschesia? Gut. 2002;51(5):695–700.
45. Beer-Gabel M, Teshler M, Schechtman E, Zbar AP. Dynamic transperineal ultrasound vs. defecography in patients with evacuatory difficulty: a pilot study. Int J Color Dis. 2004;19(1):60–7.
46. Dietz HP, Steensma AB. Posterior compartment prolapse on two-dimensional and three-dimensional pelvic floor ultrasound: the distinction between true rectocele, perineal hypermobility and enterocele. Ultrasound Obstet Gynecol. 2005;26(1):73–7.
47. Murad-Regadas SM, Regadas FS, Rodrigues LV, Souza MH, Lima DM, Silva FRS, Filho FS. A novel procedure to assess anismus using three-dimensional dynamic ultrasonography. Color Dis. 2007;9(2):159–65.
48. Murad-Regadas SM, Regadas FS, Rodrigues LV, Silva FR, Soares FA, Escalante RD. A novel three-dimensional dynamic anorectal ultrasonography technique (echodefecography) to assess obstructed defecation, a comparison with defecography. Surg Endosc. 2008;22(4):974–9.
49. Regadas FS, Haas EM, Abbas MA, Marcio Jorge J, Habr-Gama A, Sands D, et al. Prospective multicenter trial comparing echodefecography with defecography in the assessment of anorectal dysfunctions in patients with obstructed defecation. Dis Colon Rectum. 2011;54(6):686–92.
50. Murad-Regadas SM, dos Santos SG, Regadas FS, Rodrigues LV, Buchen G, et al. A novel three-dimensional dynamic anorectal ultrasonography technique for the assessment of perineal descent, compared with defaecography. Color Dis. 2012;14(6):740–7.
51. Parks AG, Gordon PH, Hardcastle JD. A classification of fistula-in-ano. Br J Surg. 1976;63(1):61–2.
52. Buchanan GN, Williams AB, Bartram CI, Halligan S, Nicholls RJ, Cohen RJ. Potential clinical implications of direction of a trans-sphincteric anal fistula track. Br J Surg. 2003;90(10):1250–5.
53. Garcés-Albir M, García-Botello SA, Esclapez-Valero P, Sanahuja-Santafé A, Raga-Vázquez J, Espi-Macías A, Ortega-Serrano J. Quantifying the extent of fistulotomy. How much sphincter can we safely divide? A three-dimensional endosonographic study. Int J Color Dis. 2012;27(8):1109–16.
54. Law PJ, Talbot RW, Bartram CI, Northover JMA. Anal endosonography in the evaluation of perianal sepsis and fistula in ano. Br J Surg. 1989;76(7):752–5.
55. Poen AC, Felt-Bersma RJF, Eijsbouts QA, Cuesta MA, Neuwissen SG. Hydrogen peroxide-enhanced transanal ultrasound in the assessment of fistula-in-ano. Dis Colon Rectum. 1998;41(9):1147–52.
56. Deen KI, Williams JG, Hutchinson R, Keighley MR, Kumar D. Fistulas in ano: endoanal ultrasonographic assessment assists decision making for surgery. Gut. 1994;35(3):391–4.
57. Cho DY. Endosonographic criteria for an internal opening of fistola-in-ano. Dis Colon Rectum. 1999;42(4):515–8.
58. Santoro GA, Ratto C. Accuracy and reliability of endoanal ultrasonography in the evaluation of perianal abscesses and fistula-in-ano. In: Santoro GA, Di Falco G, editors. Benign anorectal diseases. Milan: Springer-Verlag Italia; 2006. p. 141–57.
59. West RL, Dwarkasing S, Felt-Bersma RJ, Schouten WR, Hop WC, Hussain SM, Kuipers EJ. Hydrogen peroxide-enhanced three-dimensional endoanal ultrasonography and endoanal magnetic resonance imaging in evaluating perianal fistulas: agreement and patient preference. Eur J Gastroenterol Hepat. 2004;16(12):1319–24.
60. Ratto C, Grillo E, Parello A, Costamagna G, Doglietto GB. Endoanal ultrasound-guided surgery for anal fistula. Endoscopy. 2005;37(8):1–7.
61. Santoro GA, Ratto C, Di Falco G. Three-dimensional reconstructions improve the accuracy of endoanal ultrasonography in the identification of internal openings of anal fistulas. Color Dis. 2004;6(Suppl 2):214.
62. Buchanan GN, Halligan S, Bartram CI, Williams AB, Tarroni D, Cohen CR. Clinical examination, endosonographym and MR imaging in preoperative assessment of fistula in ano: comparison with outcome-based reference standard. Radiology. 2004;233(3):674–81.
63. Siddiqui MR, Ashrafian H, Tozer P, Daulatzai N, Burling D, Hart A, et al. A diagnostic accuracy meta-analysis of endoanal ultrasound and MRI for perianal fistula assessment. Dis Colon Rectum. 2012;55(5):576–85.