Chapter 3

The Role of Three-Dimensional Endoanal Ultrasound in Preoperative Evaluation of Anorectal Diseases

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Additional information is available at the end of the chapter

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Abstract

Three-dimensional endoanal ultrasound (3D EAUS) has increased its application in coloproctology, both in pre- or in post-operative settings, since it provides more detailed information about anorectal anatomy and function. Perianal fistula complex, internal opening location and fistula tract relation with anal canal muscles are easily viewed on 3D EAUS. Moreover, hemorrhoidectomy, sphincterotomy and transanal rectal excisions hold potential in damaging anal sphincters and should be taken into account by the surgeon. Likewise, 3D EAUS has also a significant role in staging locoregional anal and rectal tumors with comparable accuracy to pelvic magnetic resonance imaging (MRI), particularly in regard to T staging in early lesions and tumor response after neoadjuvant therapy. Finally, patients with pelvic floor dysfunction or pelvic organ prolapse (POP) may benefit from 3D EAUS dynamic evaluation in order to rule out an occult sphincter defect or to unveil unsuspected anatomical multi-compartment dysfunction. Therefore, this review will address the current role of 3D EAUS as a valuable tool in modern colorectal surgical practice, highlighting its application in evaluating benign anorectal diseases, anal canal and rectal tumors and evacuation disorders, namely echodefecography.

Keywords: three-dimensional endoanal ultrasound, anorectal surgery, preoperative evaluation, anal physiology, rectal tumors

1. Introduction

Endoanal ultrasound was described for the first time almost 30 years ago [1]. Since then, we have witnessed its evolution and application in modern colorectal practice. There are now high-frequency probes (16 MHz) with excellent spatial resolution and automatic image acquisition, which, coupled with the development of recent software, are capable of generating high-quality two- or three-dimensional images.

3D images are generated by the coordinate movement of two crystals inside the transducer, creating automatic sequences of bi-dimensional captures without moving the probe [2]. The time spent is no longer than 55 s and the superposition of images creates a cube that enables the examiner to evaluate real time and as many as necessary, all details of anatomy in multiple planes.

The exam is performed with the patient in lateral decubitus, usually with no sedation. A previous rectal enema 2 h before the exam's scheduled time is recommended. The probe is inserted up to 6–7 or 15 cm depending on whether an anal scanning or a rectal scanning has to be undertaken.

External anal sphincter (EAS), a striated hyperechoic muscle, has very low water content while internal anal sphincter (IAS), a smooth hypoechoic muscle, has high water content. Due to these different tissue/echogenic proprieties, anorectal muscles are clearly viewed on endoanal ultrasound (**Figure 1**).

Regadas et al. have described the modern anatomy of anal canal on 3D EAUS in both genders. They pointed out anatomic misconcepts related to the sphincter disposition in the anal canal, that have been clarified when viewed in sagittal plane, and the same authors have further expanded these concepts to nulliparous and multiparous women [3, 4].

In sagittal plane, it is possible to measure the longitudinal length of anal canal, EAS, IAS and puborectalis muscle. In women, mainly who had vaginal deliveries, there is an anterior area devoid of muscle located in superior anal canal, prone to developing anorectocele. On the contrary, men have the same area covered anteriorly by the prostate, which prevents anorectal anterior wall from herniation (**Figure 2**).

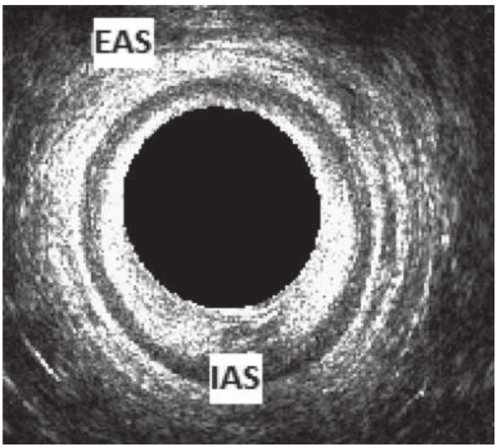

Figure 1. Detail in axial view of hyperechoic external anal sphincter (EAS) and hypoechoic internal anal sphincter (IAS). Note that they appear as two concentric rings with different echogenicity.

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Murad-Regadas et al. have suggested dividing the canal anal into three regions: superior anal canal that comprises the puborectalis muscle longitudinal extension; middle anal canal that comprises the longitudinal extension of the overlapping of EAS and IAS and the inferior anal canal that comprises only of the extension of EAS subcutaneous part.

A 3D EAUS scanning of rectal layers is a more challenging exam where the examiner does need some experience in undertaking a proper capture. It is recommended that at least 30 exams should be performed in order to obtain proficiency in rectal exams [5].

A rectal scan always requires wall distention by using a balloon attached to the probe and frequently involves many insertions and lumen cleansing during the exam, in order to minimize artifacts' interference. Moreover, the probe must remain in a perpendicular axis related to the rectal lumen, throughout the image acquisition. As in anal scan, the five rectal layers are viewed on 3D EAUS as alternate layers with different echogenic properties, as depicted in **Figure 3**.

Due to these abovementioned properties and high spatial resolution, 3D EAUS has been used in modern colorectal practice to assess benign or malignant anorectal diseases both in pre- and postoperative settings. In recent years, the dynamic scan, namely echodefecography, has increased its role in routine work-up of patients with pelvic floor dysfunction, outperforming MRI defecography and conventional defecography, with better tolerance and not needing radiation.

We have been performing all 3D EAUS modalities over the last 10 years on a routine basis. The main indications still are anorectal fistula, fecal incontinence and preoperative local staging for rectal cancer. However, as the exam has evolved, the indications have evolved as well. The recent addition of transvaginal scan to ecodefecography has increased the 3D EAUS role in anorectal physiology, allowing a comprehensive evaluation of multi-compartment pelvic floor prolapse. **Table 1** shows the most common indications to 3D EAUS we have performed in over a thousand patients.

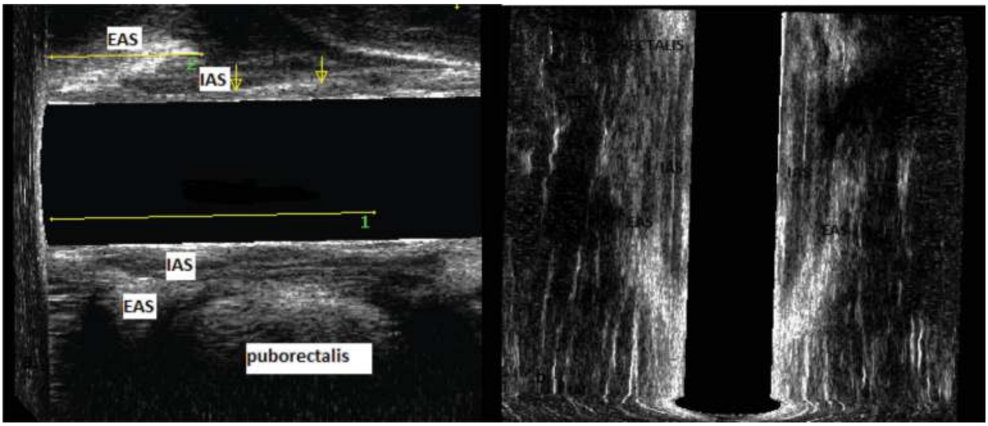

Figure 2. Multiple views of normal female anal canal. A. Sagittal view of anterior and posterior aspects of external anal sphincter (EAS), internal anal sphincter (IAS) and puborectalis muscle. B. Coronal view of right and left aspects of EAS, IAS and puborectalis muscle. Note the anterior area devoid of sphincter (arrows).

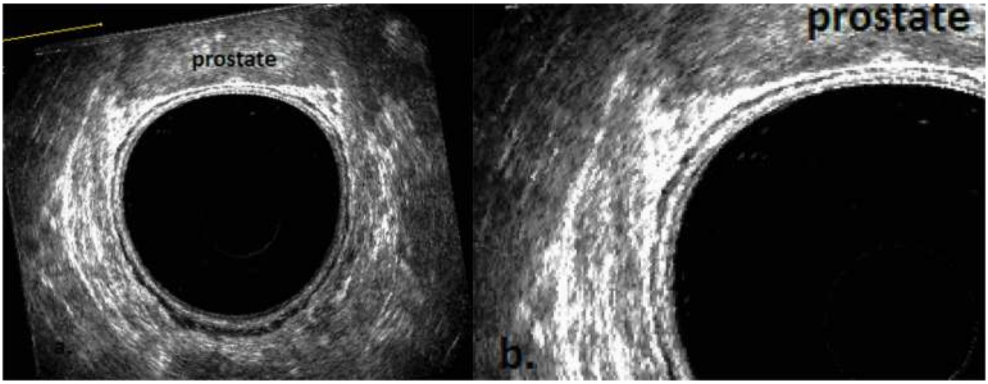

Figure 3. (a) Normal disposition of rectal layers after full balloon distension. (b) Detail of the rectal wall disposed as alternated hyper- and hypoechoic layers: mucous membrane (inner white), muscularis mucosa (next dark), submucosa (next white), muscularis propria (outer dark) and perirectal fat.

Indications	Cases (%)
Benign anorectal diseases	421 (37.75%)
Anorectal abscess	18
Perianal fistula	350
Preoperative anorectal surgery	22
Postoperative fistulotomy/sphincterotomy or sphincteroplasty	31
Malignant anorectal diseases	207 (18.56%)
Rectal tumor preoperative	143
Post neoadjuvant Rdt/Chem	52
Anal canal tumor	12
Fecal incontinence	187 (16.77%)
Obstructed defecation	212 (19%)
Pelvic organ prolapse(POP)- preoperative/ postoperative	45 (4.12%)
Other	43 (3.8%)

Rdt, radiotherapy; Chem, chemotherapy.

Table 1. 3D EAUS indications in author's personal cases.

With the basic initials concepts in mind, this review will outline the multiple applications of 3D EAUS in coloproctology, focusing as pre-operative and post-operative settings. Its role in evaluating surgical cases of benign anorectal diseases, malignant anorectal diseases and finally echodefecography, the dynamic technique assessment used in pelvic floor functional diseases, is discussed.

2. 3D EAUS in benign anorectal diseases

2.1. Perianal sepsis

Perianal sepsis refers both to anorectal abscesses (acute phase) and to anorectal fistulas (chronic phase), as different forms of the same disease [6].

Anorectal abscesses are easy to diagnose with self-evident signs and symptoms presented by patients, which prompt urgent treatment, usually by surgical drainage. However, some patients may present with fever, pelvic pain or anorectal discomfort, without overt signs in the perianal region. Due to local pain, digital rectal examination is not feasible or when possible, it is performed under difficult conditions, not capable of ruling out a deep occult pelvirectal abscess.

In this situation, 3D EAUS is a suitable imaging technique that shows location, in relation to the sphincter muscles/rectal wall, extension of cavity and sometimes the internal opening what helps guide the surgeon to the best treatment approach [7]. Usually, the exam is performed under minimal sedation with duration no longer than 1–2 min. A typical ischiorectal abscess image is easily seen and appears as a heterogeneous hypoechoic image due to some debris inside the cavity (**Figure 4**).

Irrespective of spontaneous or surgical drainage, over half of abscesses become chronic inflammatory anorectal fistula tracts [6]. 3D EAUS has played a pivotal role in evaluating anorectal fistulas tracts in the pre-operative routine work-up [7].

When the external opening is patent, it is possible to inject through this opening, first under normal pressure and then at high pressure, 0.1–0.5 ml of H_2O_2 whose bubbles will increase the fistula tract's echogenicity, showing clearly its relation to anorectal muscles, the location of internal opening (IO), accessories tracts and occult cavities [7, 8] (**Figure 5**).

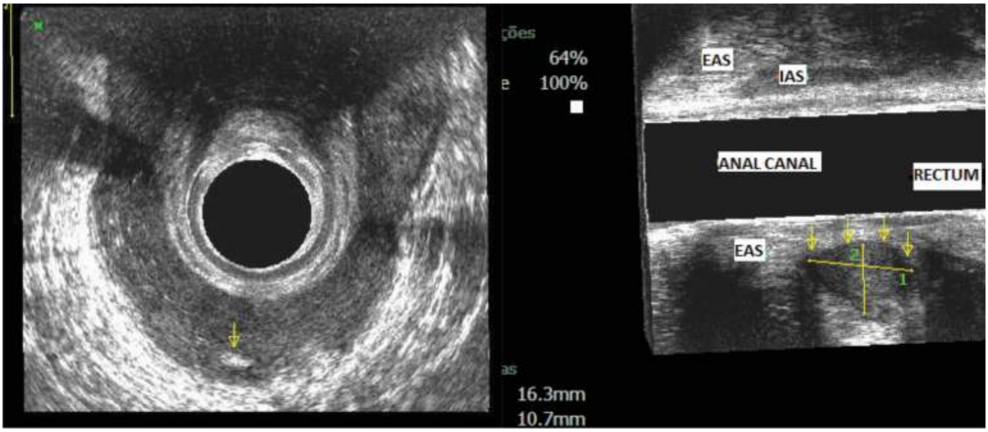

Figure 4. Left. Voluminous horseshoe ischiorectal abscess in axial view. Arrow: detail of debris seen inside the cavity. Right. Aspect in sagittal view depicting precise cavity measurements and location related to anal canal and rectum (arrows).

3D EAUS is able to drive more accurate surgical decisions by revealing accessory tracts or defining the exact location of IO not detected intraoperatively. Defining the internal opening location is not an easy task and many recurrences occur once IO or accessory tracts are overlooked during the surgical procedure [6].

Toyonaga et al. analyze a prospective series of 400 patients and were able to demonstrate that 3D EAUS was superior to intraoperative findings in identifying fistula tract (88.8 vs. 85.0%, $p = 0.0287$) and on localizing IO (85.5 vs. 69.1%, $p < 0.0001$) with lesser recurrence in cases evaluated pre-operatively with ultrasound [9].

With one acquisition, 3D EAUS allows real-time, multiple views of the fistula complex revealing precisely its relation to sphincter muscles, an invaluable information in complex fistulas, namely supra-sphincteric or extra-sphincteric fistulas.

These tracts involve sometimes the whole-sphincter longitudinal extension precluding a lay open technique, when incontinence is to be avoided. Options such as endorectal advancement flaps, cutting seton, fibrin glue or ligation of intersphincteric fistula tact (LIFT) should be considered, although they are all defined pre-operatively [10]. 3D EAUS allows surgeons not just to locate IO before operation but also to measure the exact distance from anal verge and determine how much muscle is involved by the main tract, therefore, defining which is the best surgical option (**Figure 6**).

In these complex cases, it is necessary to acquire images on the rectal mode in order to diagnose IO sometimes located on the rectal wall. These cases must be suspected when external openings are distant from anal verge (>3 cm) or when no palpable tract is identified in the physical exam.

We believe almost every patient with a diagnosis of perianal fistula should have their fistula tract evaluated by imaging. Nonetheless, we recommend that women with external opening located in anterior perineum, fistula with multiple external openings, recurrent fistulas and those from Crohn's disease must have obligatory imaging examination in order to avoid incontinence or fistula recurrence.

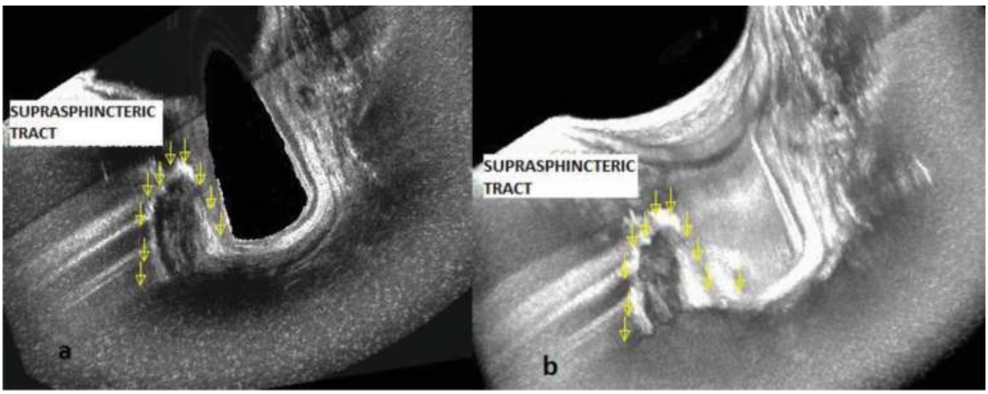

Figure 5. (a) Multiple axial and coronal views. Suprasphincteric fistula in real time 3D visualization (arrows). (b) Volume rendered mode revealing main tract orientation related to anorectal junction.

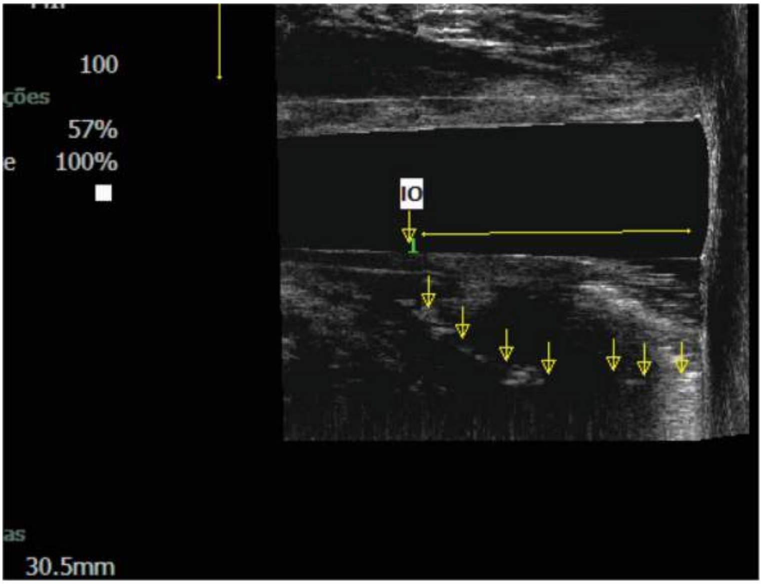

Figure 6. Sagittal view. Posterior transsphincteric fistula tract (arrows) enhanced by injection of H_20_2 through the external opening. Internal opening is located mid-posteriorly, 3 cm from the anal margin.

3D EAUS findings are heavily dependent on examiner expertise. Nevertheless, literature has supported enhanced 3D EAUS with high frequency probes, as an indisputable tool in evaluating pre-operatively patients with perianal fistulas when compared to pelvic MRI. Recent meta-analysis has shown that 3D EAUS with H_2O_2 enhancement is comparable to pelvic MRI in accuracy for both simple and complex fistulas, mostly for transsphincteric tracts, IO location and accessories tracts [11].

When reporting a typical exam for perianal fistula it is necessary to identify at least three landmarks: location of internal openings that might be located in the rectal wall, the position of main tract and relation to sphincter complex measuring how much sphincter is involved by the main tract and when present, accessory tracts. The main tract identified on ultrasound is classified by using the same types as described by Parks et al. [12].

Lastly, it is worth noting that 3D EAUS has as well a significant role in diagnosing perianal fistula recurrences. Previous surgery, scars and inflammatory process may hinder an adequate exam, influencing ultrasound results. Nonetheless, 3D EAUS is capable of diagnosing accessory tracts or IO not identified intraoperatively or even undrained abscesses as depicted in **Figure 7**.

2.2. Hemorrhoidectomy, sphincterotomy and sphincteroplasty

Many anorectal surgical procedures like hemorrhoidectomy, transanal rectal endoscopic operations or sphincterotomy hold potential in disrupting the integrity of sphincter muscles [13, 14]. 3D EAUS has been used as an adjunctive tool in evaluating such cases pre- and post-operatively.

Hemorrhoidopexy, by using transanal staplers, involves stapling mucosa and submucosa layers in anorectal junction, where lies the hemorrhoidal complex. In this technique, internal anal sphincter and more rarely external anal sphincter are prone to injury during the stapler firing—what may cause long-term rectal pain or fecal incontinence [15].

In this regard, 3D EAUS is suitable to disclosing sphincter defects pre-operatively and, more importantly, identifies some muscle involvement after hemorrhoidopexy.

Likewise, transanal rectal endoscopic operations require introducing a large proctoscope for better assessment and visualization of rectal lumen in order to properly resect rectal tumors, what may stretch or even disrupt the circular sphincter integrity. Therefore, 3D EAUS as indicated for evaluating the rectal tumors in itself should pay close attention to sphincter integrity as well.

Lateral sphincterotomy was devised to intentionally divide the distal part of IAS in patients with chronic anal fissure not responsive to clinical treatment. In this situation, 3D EAUS coupled to anorectal manometry are obligatory pre-operative exams in order to assure surgeons about muscle integrity and even post-operatively to check the extension of the sphincter section (**Figure 8**).

Once all the situations above cited carry just a theoretical risk in sphincter damage, it is arguable whether every patient in a pre-operative setting should have a complete anorectal evaluation related to function or anatomy.

Nonetheless, we would like to stress that some patients are prone to develop symptoms of anal or fecal incontinence after anorectal operations, mainly older women with asymptomatic sphincter defects [14].

After vaginal delivery it is believed that over one-third of women may have unsuspected clinical obstetric anal sphincter injuries (OASIS), only detected by endoanal ultrasound. The impact on anorectal function and fecal continence in the long term is long term [16].

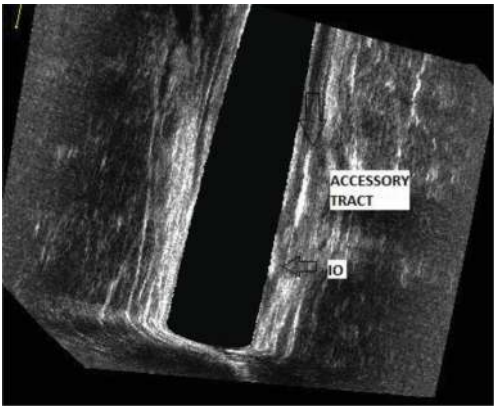

Figure 7. Recurrent fistula, 3 months after fistulotomy. Note the ascending accessory tract (upper arrow) in the intersphincteric plane. Internal orifice (IO) patent in middle anal canal.

Nonetheless, a superimposed surgical procedure could, in theory, initiate or even worsen incontinence in asymptomatic or mildly symptomatic cases, respectively.

In this context, we believe it is recommended that surgeons are beforehand aware about this potential risk and make sure that anal sphincters' morphology and function are intact or even not severely damaged, by a comprehensive history, physical examination and image techniques, even though no clear-cut association between sphincter lesions and incontinence has been proven so far.

Therefore, patients who had had previous perianal operations or present abnormal anorectal manometry findings, women >60 years old specially with a history of vaginal delivery, those elected for sphincterotomy or fistulotomy and those with incontinence symptoms should have their anal sphincter and pelvic floor muscles anatomy evaluated in the pre-operative period.

Conversely, 3D EAUS should be an integral part of a routine work-up in incontinence cases, as it could add valuable information to anorectal manometry findings. For instance, patients with an identifiable defect on 3D EAUS are possible candidates to sphincteroplasty procedures depending on how severe the sphincter defect is, while cases with intact sphincters are definitely not candidates to surgical treatment [3].

Moreover, in cases where sphincteroplasty is indicated, 3D EAUS is the golden standard in identifying anal sphincter defects. It allows measuring the angle between health muscle bundles and the longitudinal extension of the defect. These findings help surgeons in better planning of the surgical procedure, taking into consideration muscles bundles quality, angle of separation and tension of overlapping. In the post-operative setting, 3D EAUS may confirm the adequacy of a surgical procedure by showing the final aspect of EAS overlapping (**Figure 9**).

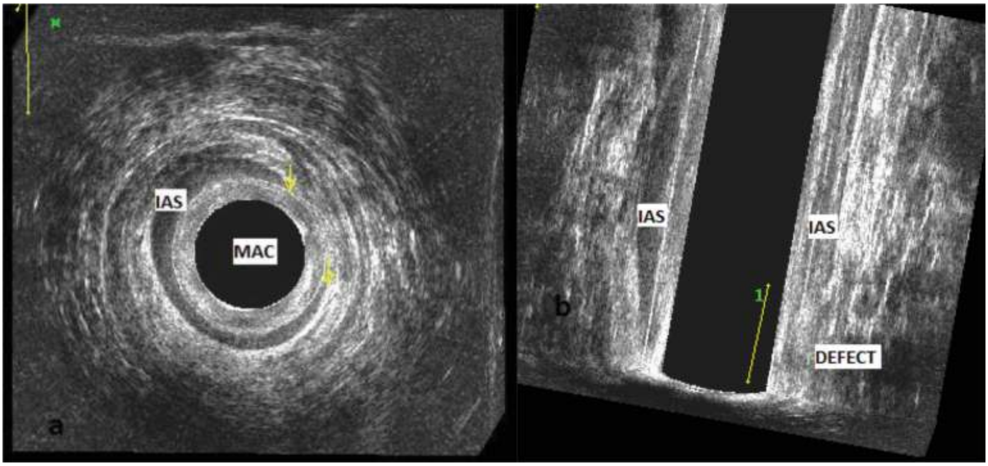

Figure 8. (a) Axial view. Lower defect of internal anal sphincter (IAS) after left lateral sphincterotomy (arrows). (b) Coronal view. Longitudinal extension of the defect.

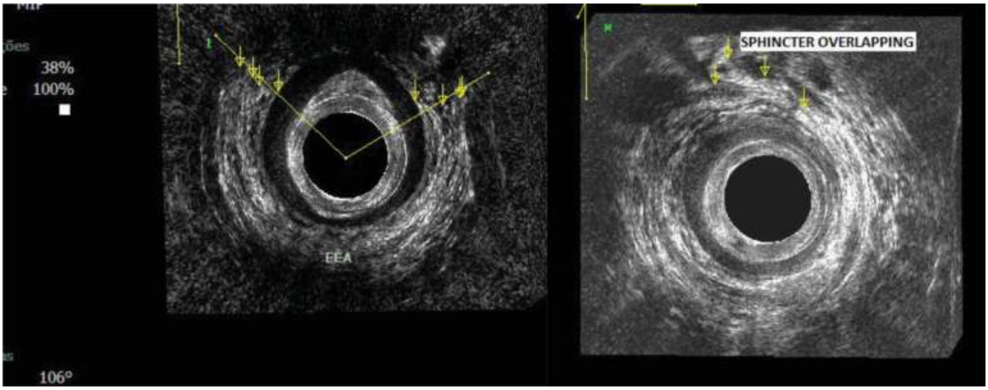

Figure 9. Complete anterior defect of external anal sphincter (EAS) after childbirth. Left: angle of muscle disruption measured by the confluence of two lines drawn from the irregular borders of EAS (arrows) to the center of the anal canal. Right: aspect 1 month after sphincteroplasty.

3. 3D EAUS in malignant anorectal diseases

3.1. Rectal cancer

Colorectal cancer is the third most common tumor in mortality worldwide and rectal cancer is responsible for over one-third of all colorectal cancer cases [17]. Recently, the widespread use of colonoscopy in campaigns for colorectal cancer screening has increased the number of cases diagnosed as early rectal lesions, hence, amenable to local excision.

On the other hand, patients with more advanced lesions frequently present symptoms as anal bleeding associated with tenesmus, rectal pain or change in bowel habits. Digital rectal examination, colonoscopy and imaging exams are necessary to accurately assess the disease and define proper treatment strategy.

Regarding local extension, both early and advanced lesions are better evaluated by 3D EAUS, MRI or a combination of both [18–20].

The aim of locoregional staging is to sort out cases to upfront surgical treatment from cases selected for neoadjuvant radio and chemotherapy, followed by re-staging and posterior definitive rectal excision [21]. In more favorable cases, rectal tumors may show a complete clinical response after neoadjuvant step. Such cases must be followed closely with serial digital rectal examination, proctoscopy and endoanal ultrasound or MRI in order to identify endoluminal, parietal or mesorectal nodal recurrence [22].

In all these situations, 3D EAUS is an important tool in rectal tumor management with accuracy comparable to MRI [5, 18, 20, 23].

Hildebrandt and Feifel have proposed a step-wise form to stage loco-regional rectal cancer based on endoanal ultrasound findings, by dividing rectal walls into five layers. These five layers show different echogenic properties, which enable accurate T evaluation, notably for early lesions T1-2 [24]. According to this classification, lesions that present thickening of muscularis mucosa with no breach in submucosa are classified as Tis tumors. In its turn, lesions with the disruption of the submucosal layer with no thickening of muscular propria are classified as T1 tumors, as seen in **Figure 10**.

Lymph nodes present in perirectal fat are easily observed on 3D EAUS. They must be evaluated up to the retrosigmoid transition, regardless of tumor location in the rectum, in order to not miss any suspect node. Lymph nodes are likely to be metastatic when they are hypoechoic, are >10 mm and show a round form and irregular borders, suggesting lymph node tissue substitution for tumor tissues [5, 26].

3D EAUS allows node differentiation from blood vessels, once blood vessels have a branch-like configuration in sagittal planes while lymph nodes are round or oval in shape, both in axial and in sagittal planes (**Figure 11**).

Acquisition in rectal scanning mode is more challenging than in anal mode, and it requires from the examiner more experience in performing the captures [5]. Typically, it demands multiple insertions in order to clean up rectal lumen to minimize artifact interference. Likewise,

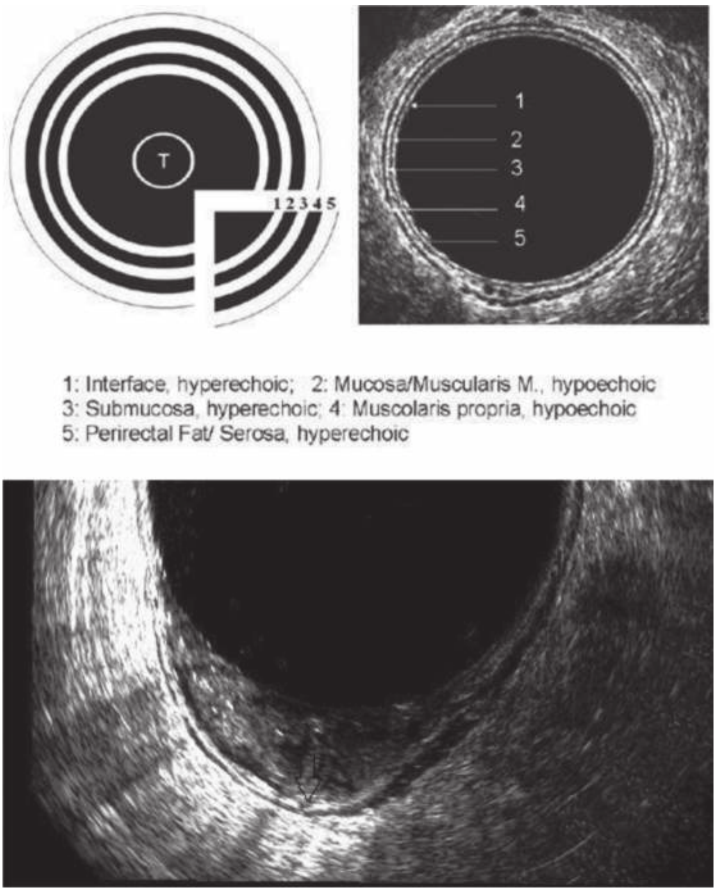

Figure 10. uT1 early polypoid tumor in lower rectum. Note the small breach in the submucosa (arrow) indicating tumor infiltration.

rectal walls must be fully distended to prevent wall folding and all captures must be done with a properly centralized probe in the perpendicular position, related to longitudinal rectal axis.

By using this technique, it is possible to address almost every rectal tumor at any height in a reliable and reproducible fashion (**Figures 12** and **13**).

However, it must be recognized that 3D EAUS has some limitations that may hinder adequate image capture or even prevent the exam completion.

First, when analyzing very small lesions one must be careful during rectal balloon distention. Whether excessive, such lesions could be compressed leading to tumor overstaging. Second, ulcerated lesions may create a gas-filled gap between lesion surface and the balloon, what is responsible for producing posterior acoustic shadows, impeding adequate perirectal fat evaluation or making the evaluation impossible in some situations. Third, stenosing tumors may prevent the exam simply by not allowing the probe to pass through the lesion up to proximal rectum [18].

Moreover, the examiner must be aware of two or more special situations that are worth mentioning: first, the inflammatory process shortly after the rectal cancer biopsy, could lead to T overstage and second, after neoadjuvant treatment, the inflammatory process caused by radiation only subsides in 55/60 days. An exam taken during this period is likely to be inaccurate in differentiating rectal layers and to overstage T or N status. In such cases, performing 3D EAUS at least 2 weeks after the endoscopic biopsy and roughly over 2 months after radio and chemotherapy completion is recommended [5].

Many studies have shown that 3D EAUS is comparable to MRI for T staging and in early rectal lesions, namely Tis-2 lesions; 3D EAUS is more accurate than MRI in identifying very small differences of compromised rectal walls layers. Albeit suboptimal, both methods are seemingly equivalent in accuracy regarding node status, although some authors have favored MRI [25–29].

When reporting pre-operative rectal cancer staging, the examiner must obligatorily fulfill some steps that encompass all information needed for proper stage lesions as well as for enabling comparison after neoadjuvant treatment [5, 26]. These steps are outlined below:

1. T staging
2. Percentage of rectal circumference involved by tumor
3. Axial, longitudinal measurements of the lesion
4. Mesorectal infiltrating extension
5. Distance from the most distal part of the lesion to the puborectal muscles
6. N stage (number and size)
7. Circumferential radial margin related to prostate or posterior vaginal wall
8. The prefix “u” must be added to the final report, ex.: final staging uT3 N0

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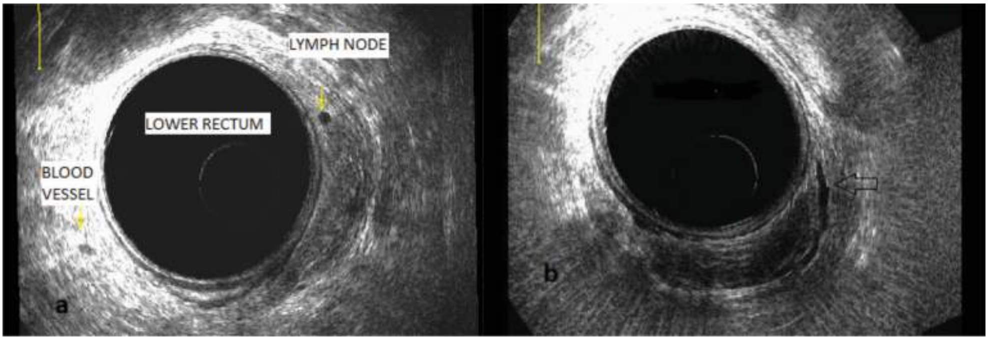

Figure 11. (a) Aspect of a lymph node in perirectal fat: hypoechoic, round-shape with regular borders (arrow). (b) In contrast, blood vessels appear as branch-like shape (arrows), in axial or sagittal views.

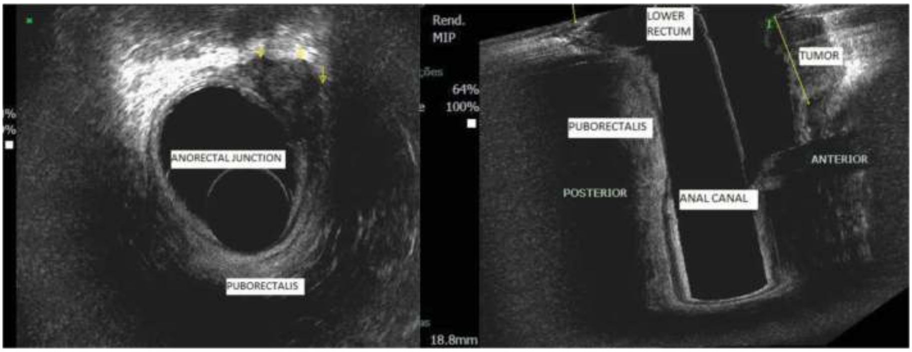

Figure 12. T3N0 tumor in lower rectum invading left puborectalis muscle. Axial view. Note the outer limits of the tumor infiltrating the perirectal fat (arrows). Sagittal/coronal view showing left anterolateral tumor locate at puborectalis level without invading intersphincteric plane.

3.2. Anal cancer

Anal cancers are rare lesions that correspond to less than 1% of all colorectal tumors. Anal canal tumors are more prevalent in women in their 5th–6th decades [30]. Despite radio/chemotherapy being the mainstay treatment of anal canal neoplasms, three-dimensional EAUS helps the surgeon in identifying sphincter or rectal involvement before treatment. Moreover, three-dimensional EAUS is capable of determining precise lesion measurement, identifying compromised perirectal or pelvic nodes or prostate/posterior vaginal wall invasion.

More importantly, three-dimensional EAUS is used to measure treatment response after radio/chemotherapy in order to discriminate cases for local excision, abdominoperineal resection or just follow-up with no organ resection instead. Furthermore, the presence of a well-delimited hypoechoic lesion identified 4–5 months after radio/chemo completion is very likely a tumor recurrence, needing excisional biopsy for confirmation [5, 31, 32].

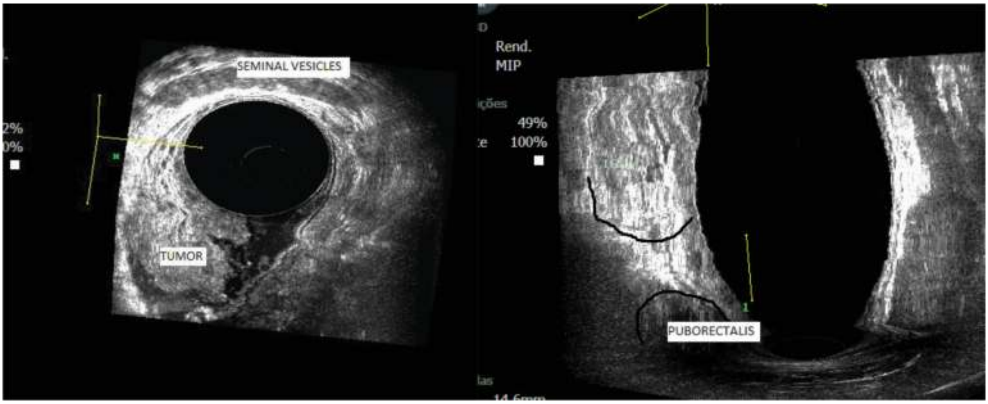

Figure 13. uT1N0 right lateral and posterior voluminous lateral spreading tumor (LST) in middle rectum. Left. Axial/coronal view: tumor spreads from seminal vesicles to the lower rectum. Right. Coronal view: lowest border located 1.5 cm proximal to the puborectalis muscle.

4. 3D EAUS dynamic scan ecodefecography

Constipation is a very common symptom with over 10% of patients reporting weekly episodes of difficult or obstructed evacuation in specialized centers. Despite considerable controversy on precise definition of constipation, recently published ROME IV criteria have separated constipation into two distinct types: inadequate defecatory propulsion and dyssynergic defecation [33]. Not rarely, some patients will present one or both types requiring more in-depth investigation.

Excluding extremely rare cases of colonic inertia, where a subtotal colectomy is required, surgical treatment of constipation will be reserved to patients with obstructed defecation which anatomical defects originate from dyssynergic pelvic floor symptomatic enough to justify surgical repair, mostly represented by anorectocele, internal intussusception or mucous and rectal prolapse or when associated with pelvic organ prolapse (POP).

Anorectal manometry, rectal balloon expulsion test, pudendal nerve latency test and defecography are complimentary techniques devised to assess the evacuation physiology and pathophysiology with arguable accuracy on reproducing such a dynamic and variable process [34].

Currently, 3D EAUS is a new adjunct technique that addresses dynamic pelvic floor motion during evacuation, in an ordered and reproductive fashion, comparable with defecography and better tolerated than MR defecography, without using radiation and taking no longer than 15 min [35, 36].

This novel modality known as echodefecography was devised by Murad-Regadas et al. in order to assess the middle/posterior pelvic compartment. It is capable of diagnosing occult sphincter defects, pelvic floor abnormal motion during straining, anismus, anorectocele, enterocele and anal/rectal prolapse. More recently, transvaginal scan was added to evaluate pubovisceral muscle injuries and urogenital hiatus measurement, as described below [37].

The exam comprises four sequential scans:

Scan 1: Image acquisition is undertaken at rest to serve as reference for the normal position and measurement of pelvic muscles and organs.

Scan 2: The probe is inserted up to 6 cm. After 15 s at rest, the patient is asked to simulate an effort as during evacuation, sustained for 20 s.

Scan 3: The probe is inserted up to 7 cm until the anorectal junction is clearly viewed. After 15 s at rest, the patient is asked to simulate an effort as during evacuation, sustained for 20 s.

Scan 4: After rectal injection of 120 ml of US gel, image acquisition is set to the rectal scan mode. The probe is inserted up to 6 cm. After 15 s at rest the patient is asked to simulate an effort as during evacuation, sustained for 20 s [4].

In women with a history of vaginal delivery the measurement of the perineal body is routinely made in order to reveal occult sphincter injuries as well as guide surgeons in cases amenable to surgical repair of anterior/middle pelvic compartment prolapse. It is obtained by measuring the distance between the examiner's index finger held against posterior vaginal wall and the internal border of IAS in the middle anal canal (**Figure 14**).

4.1. Anismus

Anismus is diagnosed by gathering information from scans 1 and 3 as follows. At rest (scan 1) the angle formed between the line drawn parallel to the internal border of puborectalis muscle and the plane perpendicular to longitudinal axis of canal anal is measured.

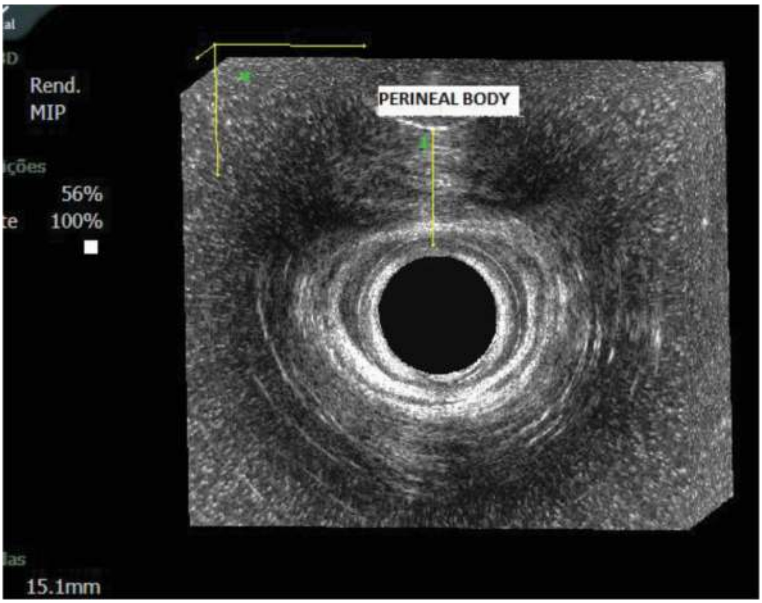

Figure 14. Normal perineal body thickness. Note the examiner index finger held against posterior vaginal all as reference. In women with no previous perineoplasty operation, measurement >10 mm is considered normal.

In scan 3, the angle is measured in the same way during straining. Normal puborectalis motion during straining occurs when the angle increases, suggesting that the muscle has moved away from the probe. In contrast, whether the angle narrows, indicating that the puborectalis muscle moves toward the probe, a diagnosis of animus can be made (**Figure 15**).

Albeit anismus is not amenable to surgical repair, we believe it should be addressed in symptomatic cases before surgical repair of initial pelvic organ prolapse or anorectocele; otherwise, surgical results can be compromised due to sustained strain during evacuation caused by a non-relaxing puborectalis muscle. Results of biofeedback training have shown improvement in over 60% of patients [38].

4.2. Anorectocele

The term anorectocele refers to the prolapse not from the rectal wall but rather from the anterior wall on the anorectal junction where the largest area of herniation lies. It can be identified and graded in scan 4 by measuring the distance between the posterior vaginal wall position at rest and the maximum distension observed during straining.

In normal conditions, the vaginal wall moves posteriorly compressing the anterior rectal wall and anal canal, during straining. When there is a defect in superior anal canal, the evacuation effort increases the rectal intra-luminal pressure forcing the vaginal wall forward, which creates herniation.

Likewise, the patient with the rectum filled with gel strains in order to expel the rectal content, simulating an evacuation effort. Whether an anterior defect in anorectal junction wall is present, one can easily identify the anorectocele herniation.

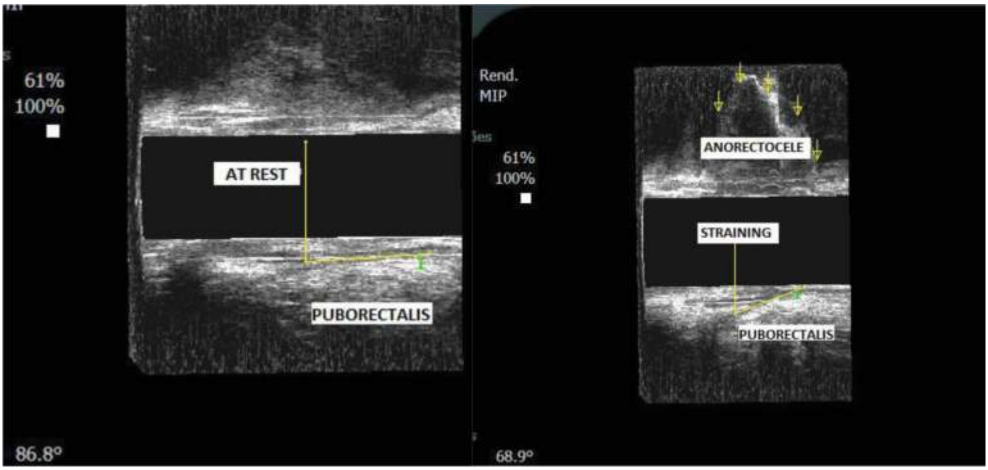

Figure 15. Left. Normal position of puborectalis muscle related to main anal canal axis, at rest. Right. Anismus and anorectocele. Decreased angle formed by the confluence of two lines drawn parallel to the internal border of puborectalis muscle and perpendicular to the anal canal axis, during straining. In anorectal junction (arrows), one can also note a grade III anorectocele.

Depending on the distance measured between the vaginal position at rest and the maximum herniation at straining, anorectocele can be graded as follows: grade I—up to 7 mm, grade II—7–13 mm and grade III—more than 13 mm or whether it exceeds the focal distance of the transducer. It is possible as well to visualize the herniation in axial planes (**Figure 16**).

Anorectocele could be present in 80% of adult population; most of them are asymptomatic, not requiring treatment. However, patients with external vaginal prolapse or with symptoms of rectal obstruction should be offered surgical repair, mostly cases with large anorectoceles (grades II and III). Recurrence, fecal urgency or incontinence and risk of dyspareunia must be thoroughly discussed with patients prior to surgery.

Colorectal surgeons usually prefer a transanal approach to treat anorectocele by using procedures such as stapled transanal rectal resection (STARR) specially devised to repair anorectocele plus internal rectal prolapse [39].

Even though STARR addresses these conditions simultaneously, anorectocele is frequently associated with other conditions as pelvic organ prolapse (POP), especially in older women; see Section 4.5. Peters et al. estimated that in women with rectal prolapse and obstructed defecation, over 60% had rectocele or occult rectal prolapse associated [40].

By using ecodefecography, we have observed that the majority of women with obstructed defecation have at least one anatomical pelvic floor abnormality. More importantly, occult rectal prolapse can mimic an anorectocele during a physical exam, therefore, misleading surgeons to unnecessary repair. 3D EAUS can easily depict anatomical and dynamic disturbances in posterior pelvic compartment, separating these two entities reliably. Besides, ecodefecography has very good correlation with defecography, is better tolerated by patients than MRI defecography and a total scan acquisition is no longer than 15 min, without using radiation (**Figure 17**).

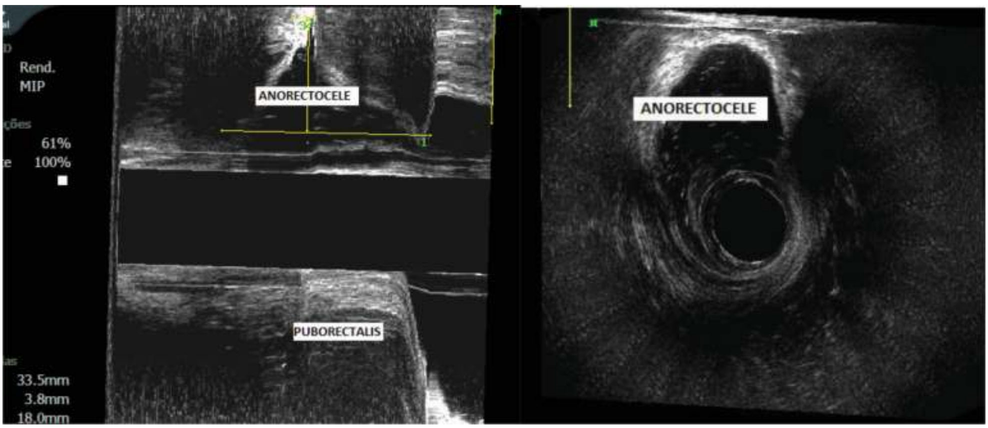

Figure 16. Patient with grade III (18.0 mm) anorectocele. Sagittal and axial views, image with gel.

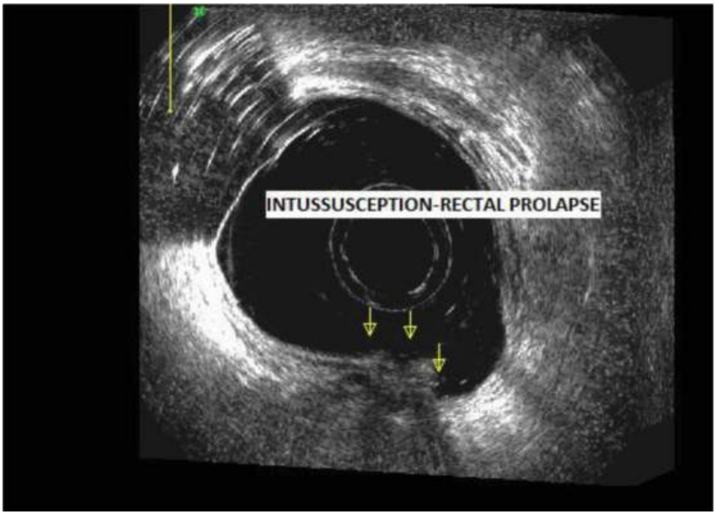

Figure 17. Posterior rectal prolapse. Rectal wall movement toward the lumen during straining (arrows).

4.3. Perineal descent

In all four scans previously described, probe position must follow the pelvic floor movement during straining, and the displacement of pelvic muscles is not taken into account. However, when measuring pelvic floor downward motion, we should add another scanning, this time keeping the probe static. By doing that, the probe will serve as a neutral reference allowing a reliable measurement of pelvic motion.

The transducer is introduced up to 5–6 cm until the puborectalis muscle is clearly visualized. Keeping the probe static, the capture is initiated and the patient is asked for continuously straining until the puborectalis muscle is visible again, when straining is stopped. Hence, this technique allows to quantify perineal descent movement by measuring the distance between the cranial border of puborectalis muscle at rest and at its final position, after completing an evacuation effort (**Figure 18**).

Perineal descent is not a surgically correctable disease. When associated with other correctable anatomical posterior compartment defects, we believe it must be treated prior to operation in order to not compromise surgical results, as in anismus [38].

4.4. Anal/rectal prolapse

Anal prolapse or mucous prolapse is diagnosed by measuring the thickness of the most internal layer that lies between the probe and IAS. Usually, a mucous prolapse can be diagnosed when the thickness measured is over 3 mm.

Rectal prolapse could be divided into overt rectal prolapse (rectal procidentia) and occult rectal prolapse (internal intussusception). Occult rectal prolapse is diagnosed in scan 3 and 4. During straining, one or multiple folds are observed toward rectal lumen. These images are better viewed in sagittal plane as double muscle layers, although it is not uncommon to identify internal intussusception in the axial plane as shown in **Figure 17**.

Internal intussusception can be diagnosed in asymptomatic patients. However, constipated patients with rectal prolapse, partial or circumferential, especially when associated with ano-rectocele, are good candidates to surgical repair, for example, by using a transanal approach to stapler rectopexy as described earlier [39].

Overt rectal prolapse is a self-evident condition, usually without needing any routine imaging exam. However, due to multi-compartment etiology of pelvic organ prolapse it is advisable to assess comprehensively the entire pelvic floor, especially in older women with symptoms of obstructed defecation or fecal incontinence, given in detail in the later section.

4.5. Pelvic organ prolapse

Patients with obstructed defecation, especially whether they have had childbirth trauma in the past, may evolve in the long term with anatomical anterior, middle or posterior compartment disorders on the pelvic floor muscle and endopelvic fascia, sometimes culminating in pelvic organ prolapse (POP) [41].

Frequently, dyssynergic pelvic floor or fecal incontinence is also present in this population so that colorectal surgeons pay close attention to that multi-compartment feature of the syndrome before surgical repair. Rather, the modern assessment of POP is now managed by a multidisciplinary team through female pelvic medicine reconstructive surgery (FPMRS) where the colorectal surgeon is a relevant part.

In some cases, history and physical examination are self-evident but routine a pelvic organ prolapse quantification (POP-Q) is used to measure and report prolapse (**Table 2**).

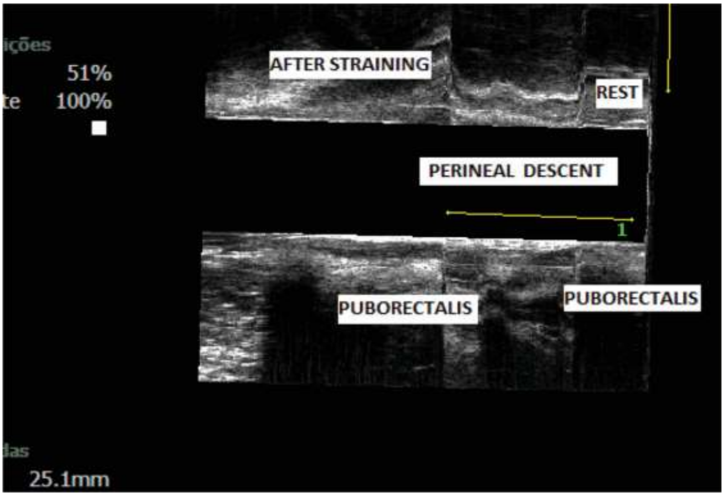

Figure 18. Patient with perineal descent. Puborectalis muscle displacement downward >2.5 cm after straining.

Stage 0	No prolapse; apex descends within 2 cm of the total vaginal length
Stage 1	Most distal portion of the prolapse descends to a point greater than 1 cm above the hymen
Stage 2	Most distal portion of the prolapse descends to a point within 1 cm above the hymen (above and below)
Stage 3	Prolapse extends more than 1 cm beyond the hymen but no more than within 2 cm of total vaginal length
Stage 4	Complete eversion; extension within 2 cm of the total vaginal length

Table 2. Pelvic organ prolapse stages.

Based on symptoms, the POP-Q stage and associated anatomical disorders, some cases may be candidates to surgical treatment [42]. Thus, due to the multi-compartmental nature of the disease, it is imperative before operation to obtain a comprehensive pelvic floor dynamic evaluation to define the best therapeutic planning.

Generally, patients without significant clinical response to conservative treatment and overt pelvic organ prolapse should be submitted to surgical repair. However, some cases are more defying and question the route to surgical approach, whether transvaginal or abdominal, need of colorectal resection or concomitant anti-incontinence procedure; they should all be considered with regard to the patient, in a pre-operative setting.

Pelvic ultrasonography has been used in order to evaluate POP, initially by transperineal bidimensional mode and recently, with modern software, 3D EAUS or even transperineal three-/four-dimensional reconstruction of pelvic images by tomography as pioneered by Dietz et al. [43] .

Recently, a transvaginal scanning has been added to the regular echodefecography exam, in order to address the pelvic floor muscle anatomy alongside the measurement of urogenital hiatus, mainly focusing on middle and posterior compartments [35–37].

The transvaginal scan is acquired in the rectal mode, using the same probe as in rectal capture, needing a rectal balloon attached to it. Usually, the transducer is introduced until the bladder

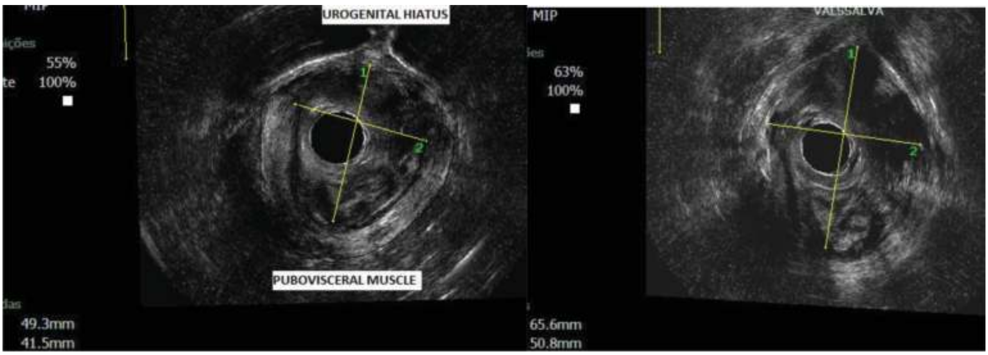

Figure 19. Left. Transvaginal scanning at rest, using the 3D endoanal probe. Detail of pubovisceral muscle. Right. Significant increase of urogenital hiatus during Valsalva maneuver indicating possible room for occult organ prolapse.

neck anteriorly is clearly visualized. A scan at rest and during Valsalva maneuver is sufficient to depict pelvic organs' position and integrity of the pubovisceral muscle bilaterally.

Bilateral pubovisceral muscle integrity is measured at rest paying special attention to its insertion on the pubic rami.

Biometric index of urogenital hiatus is obtained by measuring the anteroposterior diameter (distance between inferior margin of symphysis pubis and the inner margin of pubovisceral muscle) and laterolateral diameter (the distance between the inner margins of the lateral branches of the pubovisceral muscle at the level of their attachments to the pubic bone), at rest and after Valsalva maneuver (**Figure 19**).

Bladder neck position and anorectal junction position, related to the lower margin of symphysis pubis at rest and after Valsalva maneuver, are compared in order to measure pelvic organ motion [37].

Based on these findings, surgeons can define more accurately pelvic floor abnormalities in dubious cases, in those with unsatisfactory response to conservative therapy or after surgical repair of overt pelvic organ prolapse.

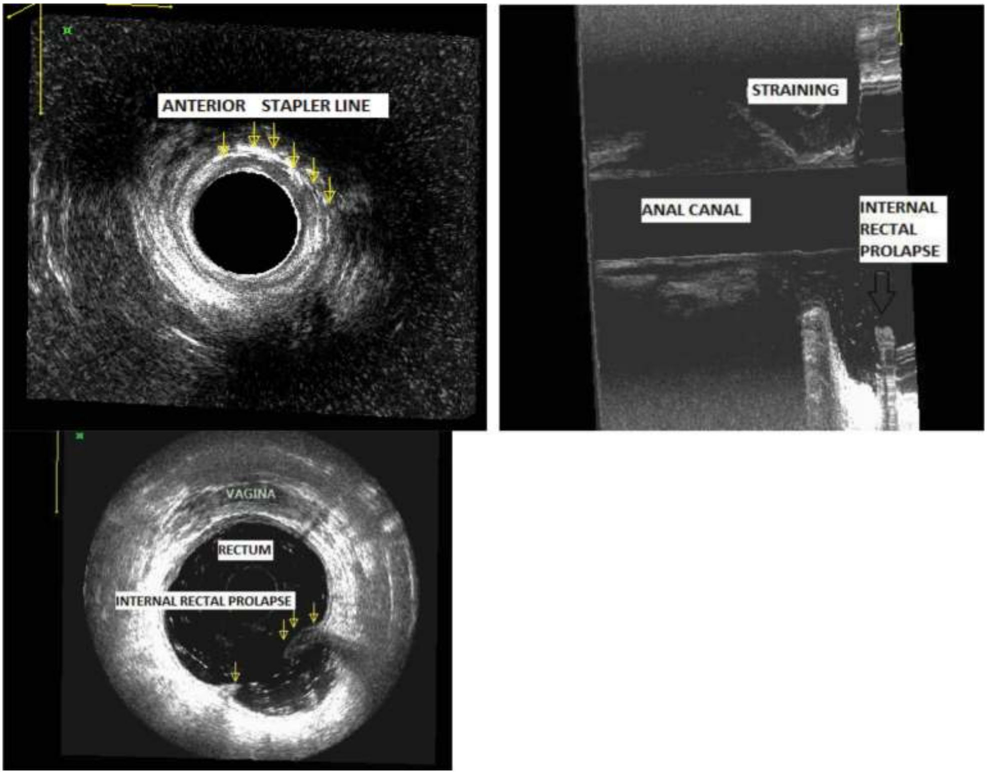

Figure 20. Upper left: axial plane. Anterior suture line after STARR for anorectocele repair. Upper right: Sagittal plane. Normal motion of the repaired posterior vaginal wall during straining. Down: Patient symptomatic for obstructed defecation after surgery due to an unsuspected occult rectal prolapsed not identified during physical examination.

Moreover, before surgical repair of anorectocele or occult rectal prolapse, for instance, echodefecography with transvaginal scanning is able to identify an unsuspected cystocele, an enterocele or sigmoidocele mimicking an anorectocele or even an abnormal anorectal junction motion during evacuation. This comprehensive assessment of the pelvic floor will certainly modify treatment planning.

On the other hand, in post-operative settings, ecodefecography is a suitable tool for evaluation in a reliable and reproducible way; successful surgical repair once is capable of measuring the improvement in pelvic floor abnormal motion, proper mesh position in case of POP surgery and finally the proper stapling line position after anorectocele repair (**Figure 20**).

5. Conclusion

In conclusion, 3D EAUS has now a well-established place in modern colorectal practice providing surgeons with valuable information in pre-operative and post-operative evaluation of patients with benign as well as malignant anorectal diseases and pelvic floor disorders. Conversely, 3D EAUS may benefit not only surgical but non-surgical cases as well, by adding relevant information unsuspected by clinical assessment alone.

We believe that 3D EAUS will keep on gaining ground in colorectal surgery, especially in benign anorectal diseases and pelvic floor evaluation. With the ongoing development of new software as modern transducers, we hope in the near future the exam could be more widespread in the colorectal community, overcoming its examiner-dependent limitation.

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Conflict of interest

I declare no conflict of interest.

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