Imaging Atlas of the Pelvic Floor and Anorectal Diseases

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Forewords by
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To our parents for their permanent dedication and love during our entire lives, and to our children, for the patience during the times we have been out of their convivial company

F.S.P. Regadas and S.M. Murad Regadas

To my parents who instilled in me the desire for knowledge through its articulation, dedication to its pursuit and in its recapitulation

A.P. Zbar

To my daughter Camilla and my son Lorenzo Carlo

M. Pescatori

Foreword

Imaging is now central to the investigation and management of anorectal and pelvic floor disorders. This has been brought about by technical developments in imaging, notably, three-dimensional ultrasound and magnetic resonance imaging (MRI), which allow high anatomical resolution and tissue differentiation to be presented in a most usable fashion. Three-dimensional endosonography in anorectal conditions and MRI in anal fistula are two obvious developments, but there are others, with dynamic studies of the pelvic floor using both ultrasound and MRI coming to the fore.

This atlas provides an easy way to gain a detailed understanding of imaging in this field. The atlas is divided into four sections covering the basic anatomy, anal/perianal disease, rectal/perirectal disease and functional assessment.

One of the difficulties with developing an atlas is to strike the right balance between text and images. Too much text and it is not an atlas; too little text and the images may not be understood. The editors of this atlas are to be congratulated on achieving an appropriate balance. The images are all that one expects from an atlas, and the diagrams are excellent. The commentaries at the end of invited chapters are a valuable addition, placing what are relatively short, focussed chapters into context. They add balance and depth to the work and are well worth reading.

The range covered in this atlas is extensive and includes all the coloproctologist would expect to encounter. Anorectal cancer is included, as are other primary pelvic tumours and metastatic diseases. Again, this increases the breadth of the work, as when working in this field it is important to know about tumours in other related systems. I am pleased that colonic transit time is included, as this is such an integral part of the investigation of constipation and pelvic floor disorders. The chapters on ultrasound, which more directly address clinicians, are detailed, practical and well illustrated.

This is a well-laid-out atlas, with several imaginative innovations. It is readily accessible and will be most helpful to all health care providers in this field of expertise.

London, June 2008

Professor Clive I. Bartram, FRCS, FRCP, FRCR
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Foreword

The field of coloproctology is an increasingly complex one. Knowledge of both benign and malignant anorectal diseases has expanded dramatically, and with this growth, a new array of available treatment options has emerged. In addition, continued steady progress in the study of pelvic floor disorders has led to an ever-broadening range of available therapies. Moreover, treatment of anorectal and pelvic floor disorders, be they organic or functional, is increasingly informed by the anticipated functional consequences of the proposed therapy. Gone are the days when every fissure was treated by sphincterotomy, fistula by fistulotomy, or cancer by radical surgery (or radical surgery alone).

In order to optimally treat these difficult problems, the surgeon must have the most accurate possible preoperative information, including – especially – imaging. Fortunately, the increasing availability of new imaging techniques, coupled with a dramatic improvement in image quality, is now positioned to provide exactly this information. However, as with many opportunities, this one comes with a challenge. Colorectal surgeons need to know which test to perform when, and how to interpret the results. Radiologists need to understand the fine points of functional anatomy and the clinical relevance of specific findings. Much is written advocating a "team approach" to complex clinical problems, and the concept applies particularly well to disorders of the anorectum and pelvic floor. *Imaging Atlas of the Pelvic Floor and Anorectal Diseases* fills an important void at the interdisciplinary juncture.

There is much to recommend this book. The authors are internationally recognized authorities, many of them pioneers in their specific subspecialty fields. The book is practical, logically organized, and clearly written. The illustrations and diagrams are sharp, well labeled, and easy to understand. At the end of several chapters, the editors provide helpful commentaries that emphasize key issues and provide the appropriate clinical context.

I congratulate Drs. Pescatori, Regadas, Murad Regadas, and Zbar on this outstanding work, which can only serve to advance the dialog between specialties and care of affected patients.

Minneapolis, June 2008

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SECTION I

Normal Anal Canal and Rectum Anatomy

Chapter 1

Two-dimensional Ultrasonography of Pelvic Floor and Anorectal Anatomy

Felix Aigner, Hannes Gruber

Abstract

This chapter should help to clarify the anatomical relationships and complex anorectal topography that can be clearly visualized by modern ultrasound techniques and should be recognized by the pelvic surgeon. The pelvic floor forms the supportive and caudal border of the abdominal cavity. Previous anatomical studies have demonstrated that the pelvic connective tissue can be divided into three compartments: anterior, middle, and posterior. This chapter is dedicated to the posterior compartment and reflects the supportive function of the pelvic floor muscle systems as well as its impact on continence function and defecation.

Introduction

Diagnosis of pelvic-floor and complex anorectal disorders has been revolutionized by the introduction of endosonography over the last 20 years. Additional applications of ultrasound to the perineum, such as noninvasive transperineal ultrasound (NITUS) or three-dimensional (3-D) endoanal ultrasound extend the spectrum of imaging this complex anatomical region with regard to the longitudinal extent of normal anal structures and of perianal pathologies. Techniques such as endorectal (ERUS) or endoanal (EAUS) ultrasound gained popularity among physicians mainly because of their minimally invasive, painless, and inexpensive modality compared with other imaging techniques such as computed tomography (CT) scan or magnetic resonance imaging (MRI). Moreover, improvements in the technology of ultrasound transducers, such as high-resolution 3-D machines, also increased the accuracy of ERUS and EAUS for local staging of malignant lesions in the anorectal region. However, history and physical examination remain essential cornerstones of diagnosis, especially concerning the pelvic floor, and should inevitably precede any imaging technique in proctological practice.

Main indications for ERUS and EAUS are local staging of rectal and anal carcinomas, on the one hand, and evaluation of fecal incontinence, on the other hand. The accuracy of endosonography in staging primary rectal cancer varies from 69% to 93% [1], which is stage dependent and thus high in T1 and T2 tumors and low in locally advanced rectal cancer (T3 and T4) with regard to tumor depth and perirectal lymph node involvement. Several other conditions can be evaluated by endosonography or transperineal ultrasound, such as inflammatory disorders and fistulas in ano. This is especially so in areas marginally accessible for MRI or CT scan, such the intersphincteric or rectogenital compartments. By consequence, NITUS techniques – using “conventional” curved array ultrasound probes – improved over recent years as first-line ultrasound modalities for assessing the perirectal and perianal soft tissues – even with the possibility of including color-Doppler ultrasound (CDUS) techniques.

To summarize, high-resolution endosonography represents a useful tool for evaluating anorectal anatomy and its topographical relationships. The information they provide is indispensable for clinical routine to improve and optimize surgical treatment for both benign and malignant conditions.

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Techniques

We recommend cleaning the rectum from feces for both ERUS and EAUS, even though the anal canal is usually devoid of stool. This is attained by using a cleansing enema of sodium phosphate 1 h prior to the examination. Patients are then positioned in the left lateral position with their knees and hips flexed. Digital examination should precede the endosonography procedure. This allows the examiner to assess the anal canal width as well as the anal sphincter apparatus for morphological disorders and for functional analysis (i.e., anal resting tone and squeeze pressure). Proctoscopy/anoscopy should be performed prior to ERUS to exclude any obstruction of the distal rectum, which cannot be reached by digital examination. The ultrasound probe is then inserted through the proctoscope, which is pulled back as far as possible to obtain reliable ultrasound imaging. For EAUS the proctoscope is not necessary, as the probe is inserted into the anal canal blindly after thorough digital examination.

For ERUS a 5-10 MHz transducer is used with a balloon filled with degassed water placed over the transducer. Air bubbles should be completely removed from the balloon to produce high-quality images. After insertion into the rectum, the balloon is further filled with 40-60 ml of water, which should be adjusted according to the rectal diameter. For EAUS a hard plastic cone is used to cover the 5-10 MHz transducer, which is rotated mechanically so that the beam is emitted at right angles for a 360° radial-swept image [2]. A condom containing ultrasonic gel is placed over the transducer and lubricated on its exterior. Recently, a 3-D ultrasound system using computerized software with data interpolation to create 3-D images of the anal canal (Pro Focus 2202, B-K Medical, Herlev, Denmark) with a 6-16 MHz 360° rotating endoprobe was introduced into proctological practice. Thus, it seems a promising strategy to define constitutive gender and age differences in the normal anal canal [3]. For NITUS we use a normal curved-array ultrasound probe. In this context, our standard iU22 ultrasound device (ATL Philips, Washington, DC, USA) with use of a 9-4 MHz broadband curved-array transducer shows sufficient resolution power versus penetration combined with the depiction of all necessary topographic landmarks [4]. For transperineal ultrasound, the probe must be covered by a lubricant-filled plastic sac. Thereby, the handling of the probe is not hampered. Patients are positioned in the left lateral position with their knees and hips flexed. The probe is attached to the perineum sagittally (Fig. 1). Thus, all perineal structures can be assessed to an acceptable extent in real time, and CDUS assessments can be easily performed. This procedure is performed very quickly without patient preparation in a relatively convenient manner.

Fig. 1. Noninvasive transperineal ultrasound with use of a 9-4 MHz broadband curved-array transducer. The patient is positioned in the left lateral position with the knees and hips flexed. The probe is attached to the perineum sagittally

Normal Anatomy

Pelvic floor connective tissue is divided into three compartments: anterior, middle, and posterior. Each one contains the respective pelvic organs as well as different kinds of connective tissue. The posterior compartment can be subdivided into the presacral subcompartment with the presacral vessels and the perirectal subcompartment or mesorectum, which develops along the rectal vessels, nerves, and lymphatics and is enveloped by the mesorectal or rectal fascia. The latter is crucial for rectal resection techniques and a powerful predictor for oncological outcome and local recurrence rate following treatment of rectal cancer. The anterior and middle compartments contain the urogenital organs, with the middle compartment existing only in the female individual.

The Rectum

In ERUS the rectal wall can be divided into concentric rings of hypo- and hyperechoic regions (Fig. 2). According to Beynon et al. [5], the series of rings starts with an inner hyperechoic ring representing the interface of the balloon with the rectal mucosa. The inner hypoechoic ring indicates the muscularis mu-

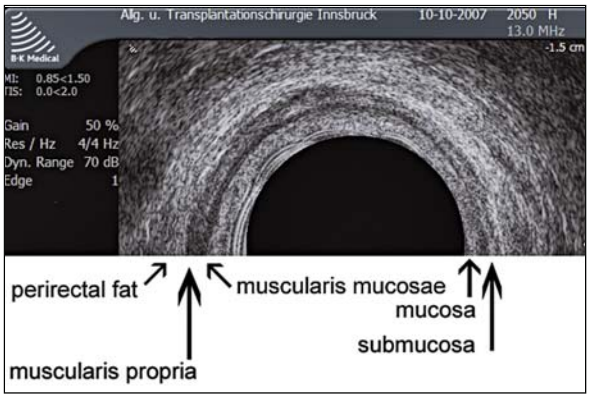

Fig. 2. Endorectal ultrasound using a 5-10 MHz transducer with demonstration of the typical concentric rings of hypo- and hyperechoic regions [5]. *Mucosa inner hyperechoic ring, muscularis mucosae* inner hypoechoic ring, *submucosa* middle hyperechoic ring, *muscularis propria* outer hypoechoic ring, *perirectal tissue* outer hyperechoic ring

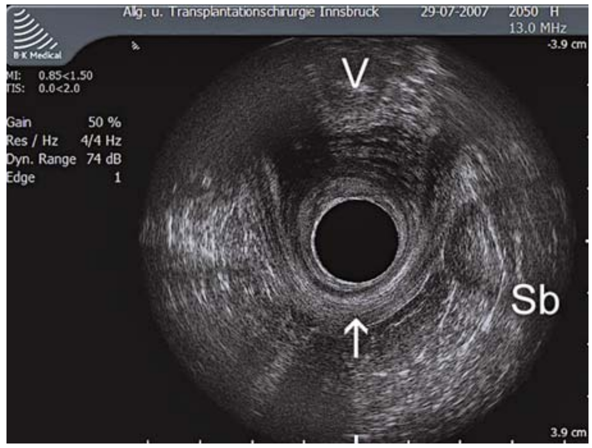

Fig. 3. Endorectal ultrasound of the anorectal junction demonstrating the puborectalis muscle sling (*arrow*) and adjacent structures to the rectal wall, such as the vagina (*V*) and small bowel (*Sb*) in a female individual

cosae and is surrounded by the next hyperechoic layer, which represents the submucosa. The outermost hypoechoic ring corresponds to the muscularis propria and is bordered by the outer hyperechoic ring, which represents the interface between the muscular coat of the rectum and the perirectal fat. Adjacent structures or organs to the rectal wall, such as the prostate and the seminal vesicles in the male and the vagina and uterus in the female individual are detected even with lower resolution (Fig. 3). Blood vessels and lymph nodes are visualized as hypoechoic structures. The rectum is surrounded by the perirectal subcompartment or mesorectum, which develops along the superior rectal vessels and therefore is broad in dorsolateral position and thin in ventral position. The rectal fascia constitutes the external border of the mesorectum, which is directly attached to the inferior hypogastric plexus at the lateral pelvic wall in the male and the uterosacral ligament, which lies between the rectal fascia and the autonomic nerve plexus, in the female individual.

The Anal Canal

The anal canal length can be defined either from a functional or an anatomical point of view. The functional anal canal extends from the intersphincteric groove at the anal verge to the anorectal junction (approximately 4 cm). The latter corresponds with the level of the striated puborectalis muscle sling, which is part of the pelvic diaphragm (levator ani muscle). The anatomical anal canal extends between the anal verge and the dentate line and therefore is roughly half the distance of the functional anal canal. In EAUS the anal canal can be divided into three levels: the *upper anal canal* is the level midway between the inferior margin of the puborectalis muscle sling and the complete formation of the deep portion of the external anal sphincter (EAS) muscle anteriorly (Fig. 4a). At this level, the inner hypoechoic ring corresponds with the circular layer of the muscular coat of the rectum. Three-dimensional reconstructions of histological sections of the pelvis demonstrated that the deep portion of the EAS is not a completely circular muscle in ventral position at the anorectal level (Fig. 4b) [6]. However, the muscular components of the pelvic diaphragm (puborectalis, pubococcygeus, and iliococcygeus) are usually depicted as hypoechoic linear structures. They are separated by their respective fascias, which are depicted as shiny hyperechoic linear bands orientated to the course of the respective muscle.

The *middle anal canal* is defined by the completion of the EAS anteriorly in combination with the maximum thickness of the internal anal sphincter (IAS) muscle [7] (Fig. 5), which forms a direct continuation of the circular layer of the muscular coat of the rectum and is uniformly hypoechoic. This area also corresponds with the high-pressure zone of the anal canal, which can be assessed by anal manometry. The IAS is sharply demarcated from the anal subepithelial tissue medially (inner hyperechoic ring) and the intersphincteric longitudinal anal muscle laterally, which forms a direct continuation of the longitudinal layer of the muscular coat of the rectum and is of heterogeneously hyperechoic appearance (Fig. 5). The IAS thickness positively correlates with age and body mass index [7], in contrast to EAS width, which decreases with age.

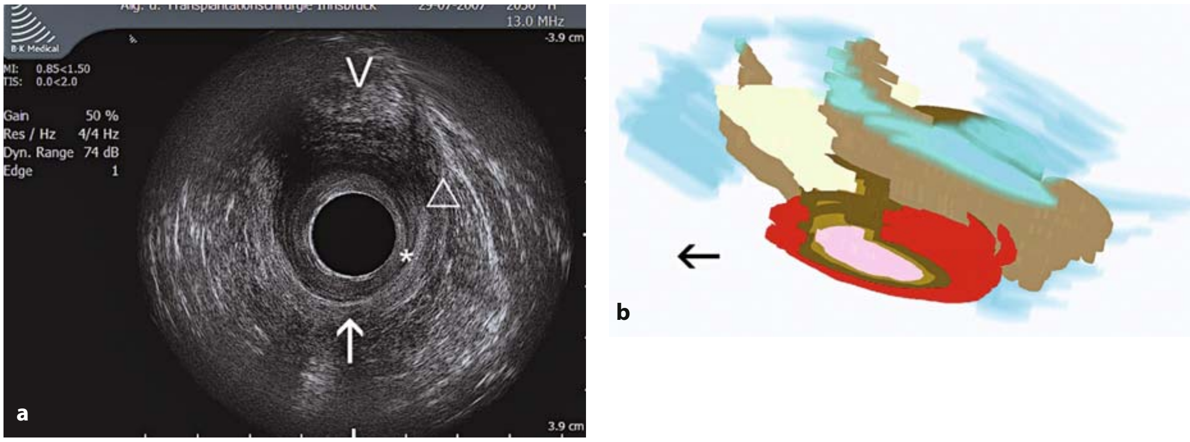

Fig. 4 a, b. Endoanal ultrasound using a 5-10 MHz transducer. **a** Upper anal canal with the puborectalis muscle sling (*arrow*) and the muscular coat of the distal rectum (*asterisk*). At this level, the deep portion of the external anal sphincter muscle (*arrowhead*) is attached to the puborectalis and is not completely circular in ventral position. *V* vagina. **b** Three-dimensional reconstruction of histological sections of the pelvis demonstrating that the deep portion of the external anal sphincter muscle (*red*) is not a completely circular muscle in ventral position (*arrow*) at the anorectal level. Puborectalis (*light brown*), muscular coat of the distal rectum (*dark brown*). Reprinted from [6]

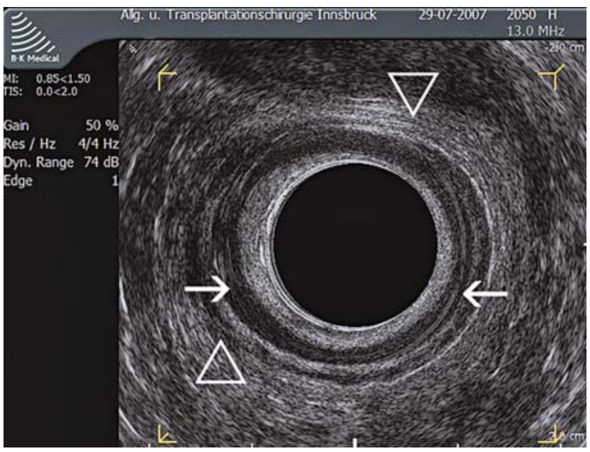

Fig. 5. Endoanal ultrasound of the middle anal canal showing the external (*arrowheads*) and internal (*arrows*) anal sphincter muscles in the high-pressure zone

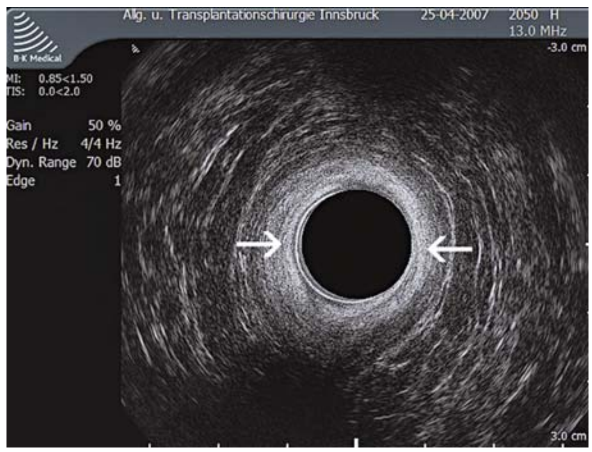

Fig. 6. Endoanal ultrasound of the lower anal canal showing the subcutaneous portion of the external anal sphincter muscle (*arrows*)

The *low anal canal* is defined as the level below the inferior margin of the IAS and comprises the subcutaneous portion of the EAS, which is complete ventrally (Fig. 6). In dorsal position, the EAS turns inward and forms a muscular continuum with the smooth IAS and the longitudinal muscles. According to Gold et al. [8], the EAS is generally longer in the male than in the female individual (32.6 ± 5.3 mm vs. 15.3 ± 2.8 mm; $p < 0.001$) and thinner anteriorly in the female than in the male individual.

The EAS remains an anatomical structure difficult to visualize at its outermost layers and to discriminate them from surrounding structures, such as the perianal and/or ischioanal adipose tissue. For better visualization of the perianal and perirectal region, NITUS is a promising strategy for detection of perianal abscesses, fistula tracks, or simply variations in the anorectal vascularization status.

The Perineal Body

The perineal body can be visualized by EAUS and its thickness measured by inserting a finger, held gently against the posterior vaginal wall, into the vagina and measuring the distance between the inner surface of the IAS and the ultrasonographic reflection of the finger (Fig. 7) [9]. Studies confirmed that perineal body thickness < 10 mm was more commonly associated with fecal incontinence [10]. The perineal body consists of dense connective tissue and separates the urogenital hiatus from the anal hiatus.

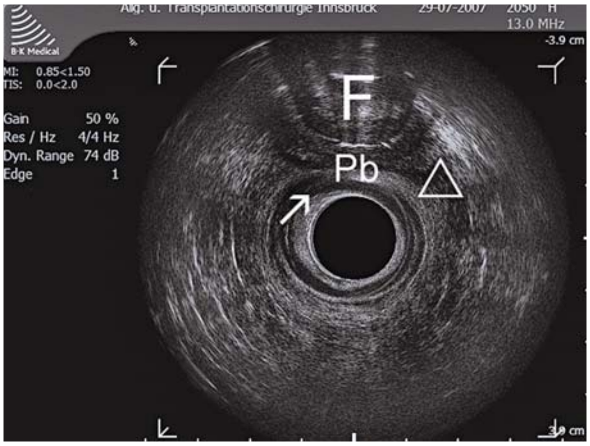

Fig. 7. Perineal body measurement using a finger (*F*), held gently against the posterior vaginal wall, into the vagina and measuring the distance between the inner surface of the internal sphincter (*arrow*) and the ultrasonographic reflection of the finger. Fibers of the subcutaneous portion of the external anal sphincter muscle (*arrowhead*) intermingle with the perineal body (*Pb*)

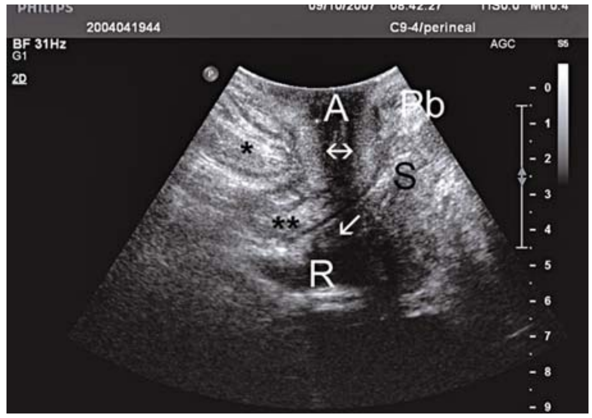

Fig. 8. Noninvasive transperineal ultrasound showing the rectogenital septum (*S*) cephalad to the perineal body (*Pb*), which constitutes an incomplete partition ventrocranial between the rectum (*R*) and the urogenital organs. Anal canal (*A*), internal anal sphincter (*double arrow*), subcutaneous portion of the external anal sphincter muscle (*), puborectalis muscle sling (**), anorectal flexure of the rectum (*arrow*); male individual

It is intermingled with numerous originating and inserting muscles (subcutaneous portion of the EAS, longitudinal anal muscle, bulbospongiosus and superficial transverse perineal muscle), along with the longitudinal smooth muscle fibers of the rectogenital septum. It must be considered a tendinous center for muscles without bony origin or attachment.

Cephalad to the perineal body, the rectogenital septum (Denonvilliers fascia) constitutes an incomplete partition to the ventrocranial segment between the rectum and the urogenital organs (Fig. 8). It is formed by local condensation of mesenchymal connective tissue during the early fetal period and intermingled by longitudinal smooth muscle fibers, which can be traced back to the longitudinal layer of the rectal wall. The rectogenital septum serves as a guiding structure for the cavernous nerves arising from the autonomic inferior hypogastric plexus at the lateral pelvic wall. It forms a borderline for limiting the spread of malignancy and inflammation and a functional gliding sheath between urogenital organs and rectum, enabling shortening and opening of the anal canal during defecation. It is crucial for stabilizing the ventral rectal wall as well as in rectal filling and asymmetric rectal distension [11], which is also visualized in dynamic transperineal ultrasound.

Anorectal Blood Supply

Blood supply to the rectum and the transitional zone comprising the corpus cavernosum recti (CCR), an arteriovenous cavernous network without interposition of a capillary system, is provided by the superior rectal artery. The anal canal and the anal sphincter muscles receive branches from the variable middle and the inferior rectal arteries. The CCR is located within the rectal submucosa above the dentate line at about 3–5 cm from the anal verge. Its filling and drainage partly depends on the contraction status of the IAS and forms a gas-tight seal of the anal canal at anal resting tone, thus sustaining fecal continence. The CCR is drained through transsphincteric veins during IAS relaxation at defecation. The CCR supplying arterial vessels courses downward in the rectal submucosa, on the one hand, and continues the course of extramural terminal branches by perforating the rectal wall in an axial plane close to the levator ani muscle, on the other hand. These afferent vessels as well as CCR drainage can be detected and even assessed by NITUS, especially for assessing the vascularization status in hemorrhoidal disease (Fig. 9). Arterial and venous drainage signals can be clearly analyzed at this depth by performing spectral wave analyses, which could be groundbreaking concerning the differentiation of several different functional forms of hemorrhoidal disease presently under definition [12]. Changes of arterial and venous spectra – all found in extensive grades of hemorrhoidal disease – may resemble shunt-flow patterns detected usually also in, e.g., arteriovenous fistulas (e.g., intrahepatic vascular malformations).

It was demonstrated that NITUS is a relatively sensitive procedure for assessing perianal inflammatory conditions [13]. Resembling the previous descriptions, the rectal and anal walls are layered hyper- and hypoechoically but are depicted linearly. The entire extent of the anorectum is usually shown in its course distally from the distal sacral flexure. When

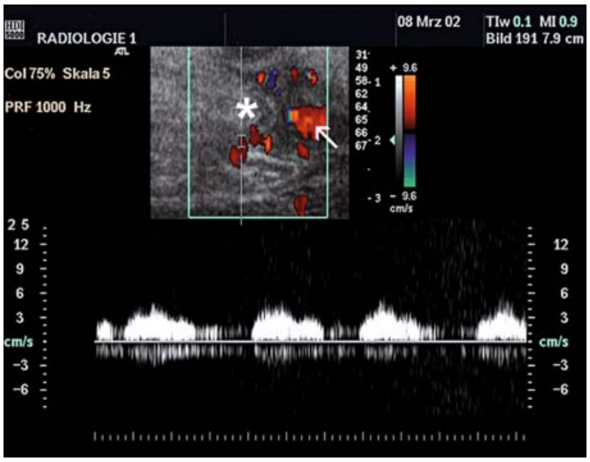

Fig. 9. Detection of anorectal vascularization in a healthy male individual by noninvasive transperineal ultrasound. The corpus cavernosum recti is shown (*arrow*) with the supplying arterial vessels and the respective flow spectrum. Some vessels perforate the rectal wall close to the anal sphincter complex (*asterisk*)

tilting the probe, the levator ani is shown encompassing the anorectal junction. Combined gray-scale and CD ultrasonography have a high detectability rate and comprehensive characterization of perianal abscesses and fistulas. Compared with the walls of the anal canal or rectum, respectively, they usually present hypoechoic nodular to globular structures, where pus can often be detected by compression and decompression of the probe.

Conclusion

In conclusion, 2-D and 3-D endosonography and NITUS represent innovative tools for diagnosing complex anorectal disorders. Knowledge of the normal anorectal anatomy and its topographical relationships is necessary for deciding upon the appropriate treatment of anorectal diseases.

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CHAPTER 2

Three-Dimensional Ultrasonography of Pelvic Floor and Anorectal Anatomy

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Abstract

Here we discuss precisely the anatomic configuration of the anal canal and the length and thickness of the anal sphincters using 3D anorectal ultrasonography in both genders, demonstrating the anal canal's asymmetrical configuration. The rectum and all adjacent pelvic organs are shown in multiple anatomic planes.

Anatomic Planes: Ultrasound View

Advances in ultrasound scanning technology over the past few years includes the development of the 360° rotating anorectal transducers featuring high frequency and between 6-16 MHz, focal distance between 2.8 and 6.2-cm, and automatic image acquisition without manual movement of the transducer. Images up to 6.0-cm long are captured along the proximal-distal axis during up to 55 s by moving two crystals on the extremity of the transducer. The examination involves a series of transaxial microsections up to 0.20-mm thick producing a high-resolution digitalized volumetric image (cube) (Fig. 1). This image is highly mobile and allows for real-time evaluation in all planes, multiview (4–6 simultaneous images) (Fig. 2), and volume-rendered (VR) 3D imaging with low-brightness and high-contrast adjustment for semitransparent dark cavities (Fig. 3). The several anatomic planes are in accord with the planimetric display suggested by Santoro and Fortling [1] (Figs. 4–8).

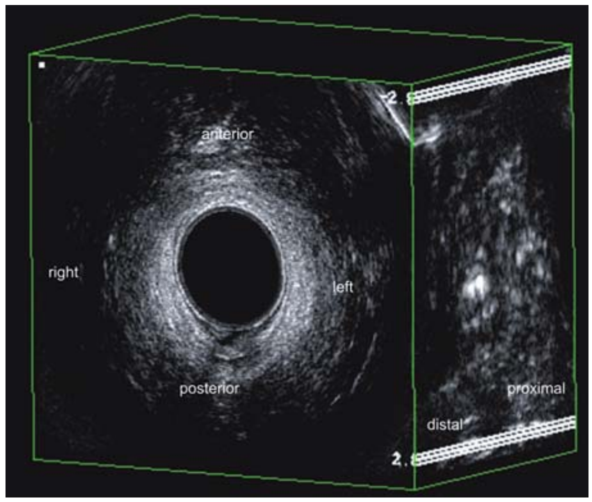

Fig. 1. Digital volume image

Anal Canal Configuration

In a recent study using 3D anorectal ultrasonography, Regadas et al. [2] demonstrated the asymmetrical shape of the anal canal and compared positions and sizes of anal sphincters between genders (Fig. 9). The anterior anal canal starts and ends more distally and it is formed by the external anal sphincter (EAS) and the internal anal sphincter (IAS). The distance between the anterior anorectal junction and the EAS is called the gap. It corresponds to the upper anal canal and is formed by normal rectal wall proximally and by the IAS distally (Fig. 10). The lateral EAS and puborectalis (PR) muscle were significantly longer than

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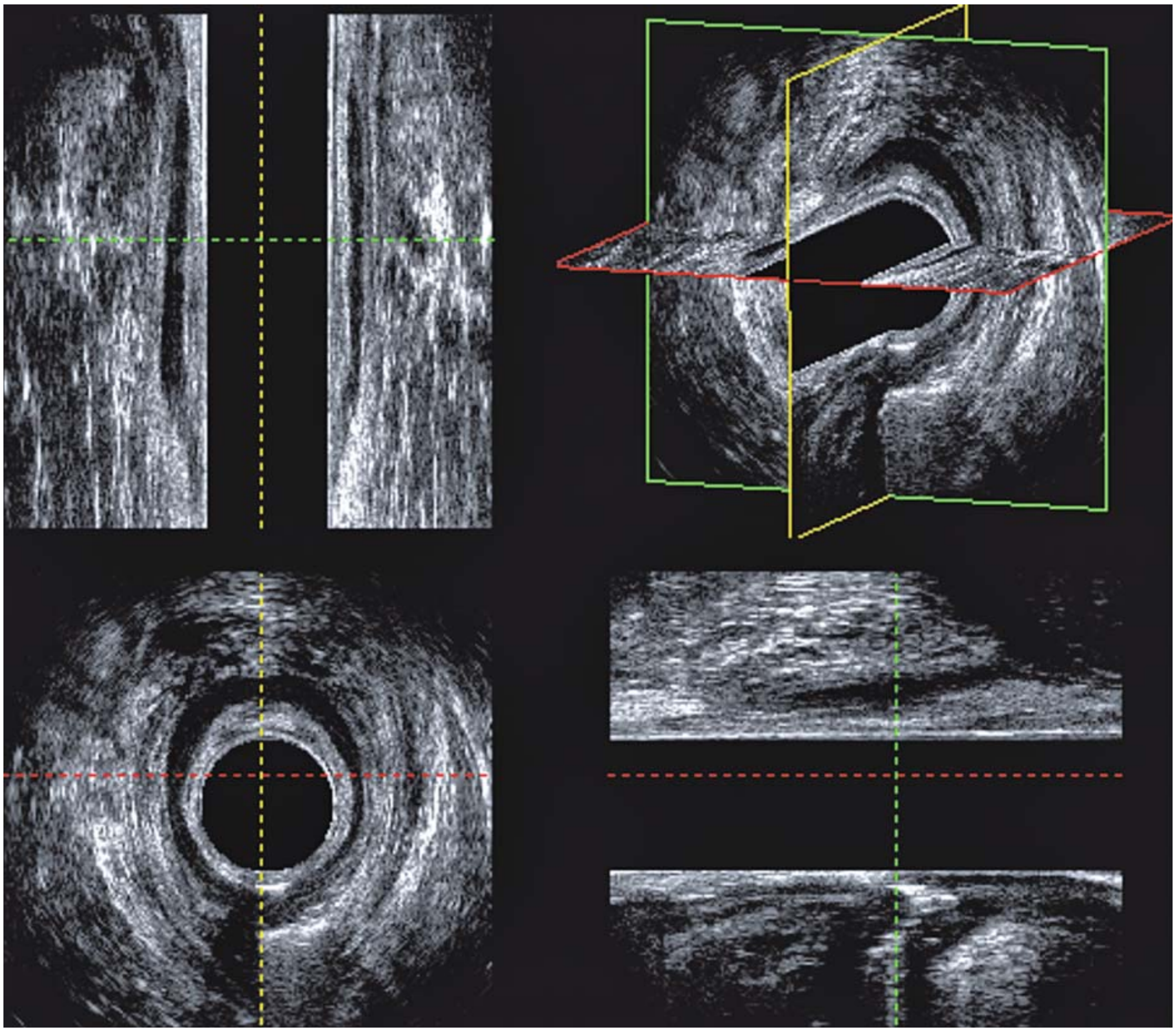


Fig. 2. Multiview: four simultaneous images

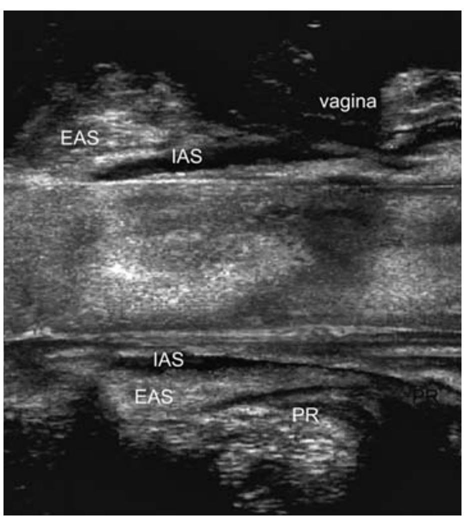


Fig. 3. Female anal canal: midsagittal plane, render mode, enhanced image. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PR* puborectalis muscle

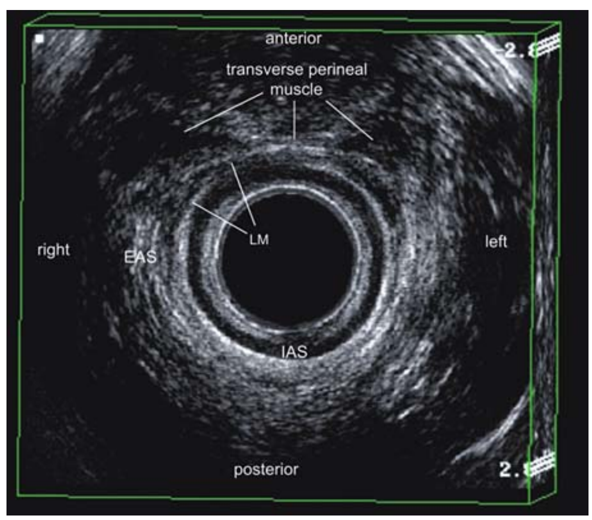


Fig. 4. Normal female anal canal; longitudinal muscle: axial plane (transverse). *EAS* external anal sphincter, *LM* longitudinal muscle, *IAS* internal anal sphincter

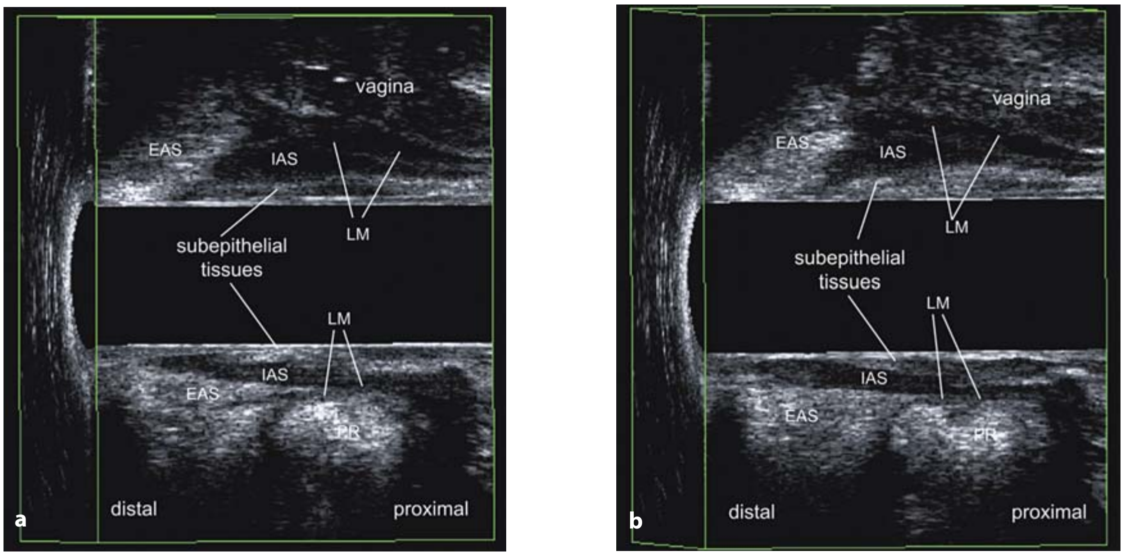


Fig. 5 a, b. Normal female anal canal: **a** sagittal plane; **b** midsagittal plane. *EAS* external anal sphincter, *IAS* internal anal sphincter, *LM* longitudinal muscle, *PR* puborectalis muscle

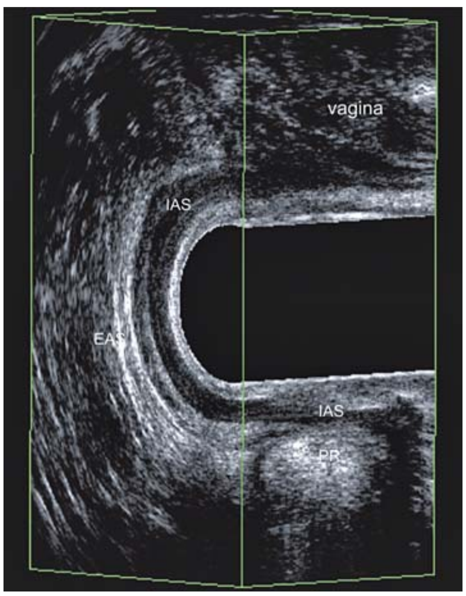


Fig. 6. Normal female anal canal: sagittal with axial transverse planes. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PR* puborectalis muscle

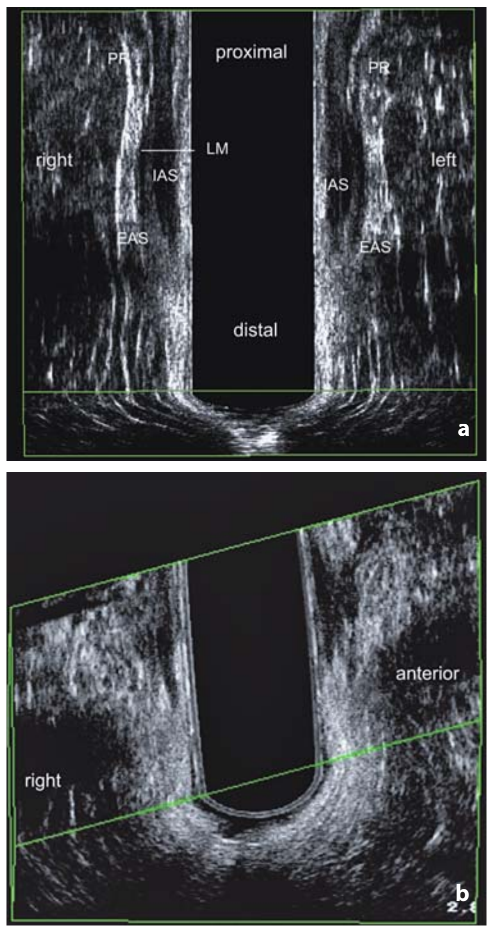


Fig. 7 a, b. Normal female anal canal: **a** coronal plane; **b** coronal with diagonal planes. *EAS* external anal sphincter, *IAS* internal anal sphincter, *LM* longitudinal muscle, *PR* puborectalis muscle

the posterior part of the muscles in men (3.9 cm vs. 3.6 cm, respectively) than in women (3.6 cm vs. 3.2 cm, respectively). They form at the same level but the lateral part of the EAS-PR ends more distally (Fig. 10). The anterior IAS was significantly shorter than the posterior and lateral parts of the muscle in men (2.7 cm vs. 3.5 cm vs. 3.5 cm, respectively) than in women (2.0 cm vs. 3.0 cm vs. 3.3 cm, respectively)

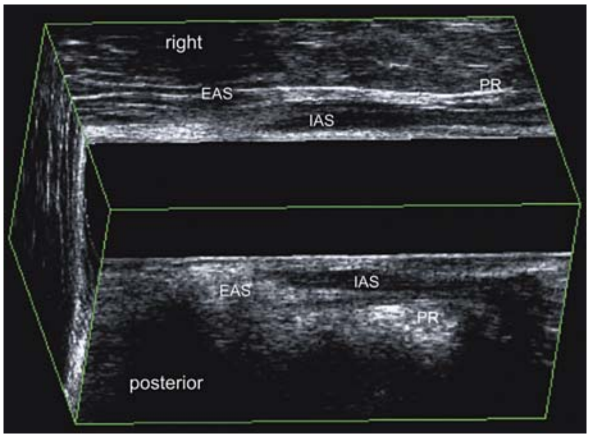


Fig. 8. Normal female anal canal: midsagittal with coronal planes. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PR* puborectalis muscle

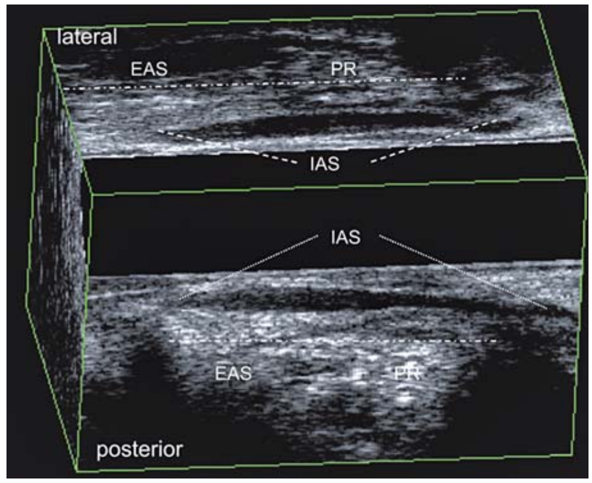


Fig. 10. Female anal canal: transverse and midsagittal planes. Lateral anal canal is longer than the posterior anal canal. Internal anal sphincter (*IAS*) is formed before the puborectalis (*PR*) muscles in both quadrants. *EAS* external anal sphincter

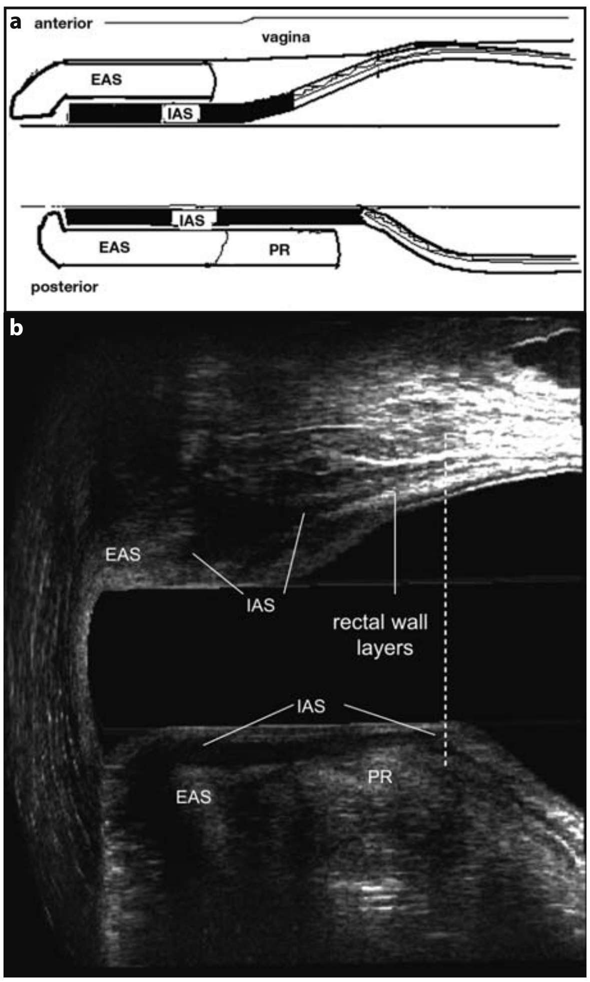


Fig. 9 a, b. Female anal canal and anorectal junction: **a** schematic representation [2]; **b** 3D ultrasound image, midsagittal plane. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PR* puborectalis muscle

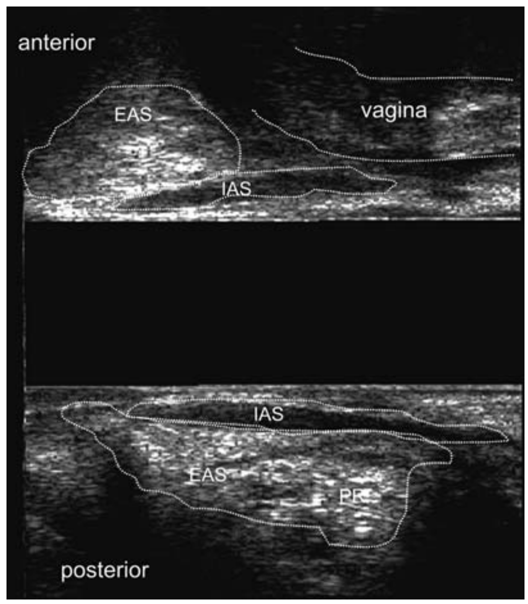


Fig. 11. Female anal canal: midsagittal plane. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PR* puborectalis muscle

(Fig. 11). However, no statistically significant difference was identified in the length of the posterior and lateral quadrants between genders. Comparing the posterior IAS with the EAS-PR, no significant difference in length was determined between men (3.5 cm vs. 3.6 cm) and women (3.0 cm vs. 3.2 cm). However, the posterior IAS is formed proximally but the EAS-PR ends more distally in both genders (Fig. 12). The anterior IAS was significantly thinner than the posterior IAS in women (0.12 cm vs. 0.18 cm).

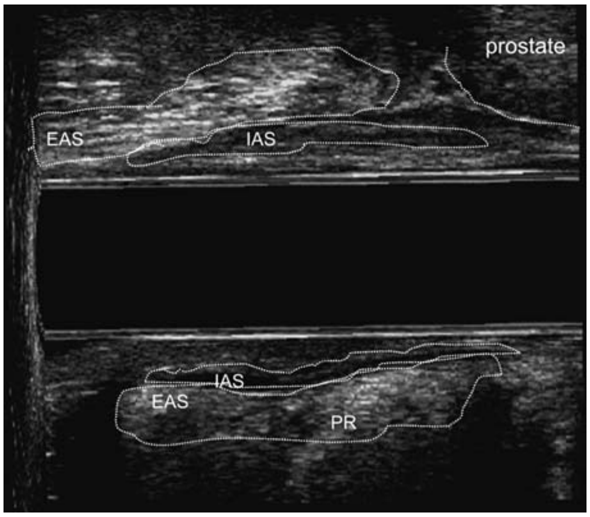
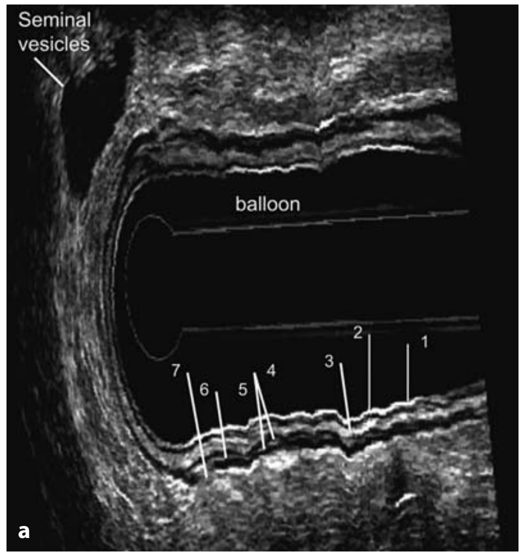
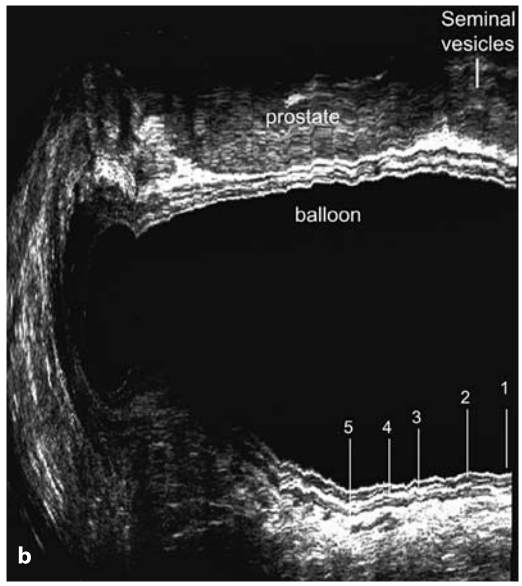


Fig. 12. Male anal canal: midsagittal plane. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PR* puborectalis muscle





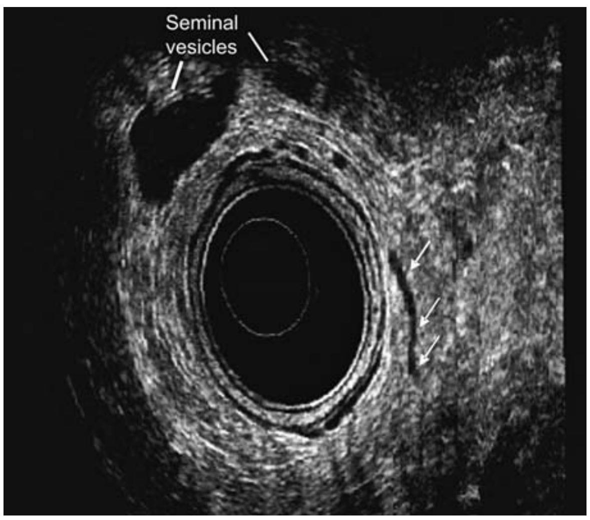


Fig. 14. Normal male rectum: axial (transverse) and sagittal planes. Blood vessel (*arrows*)

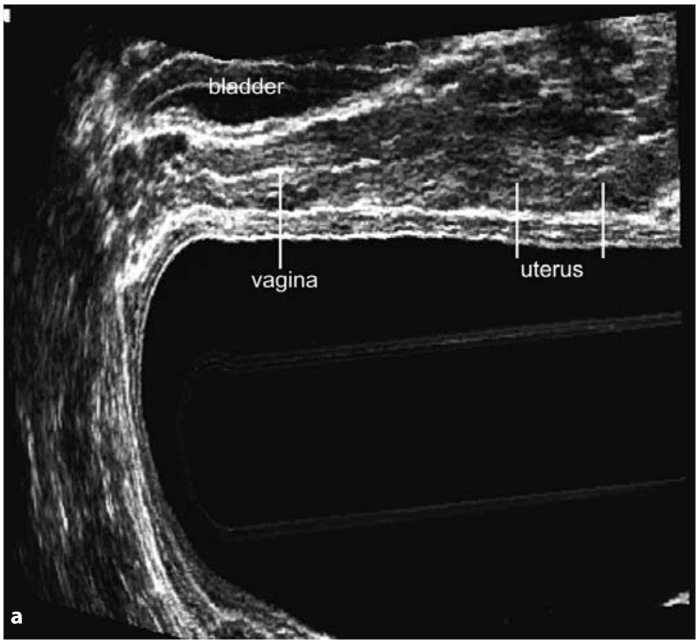
Fig. 13 a, b. Normal male rectum: sagittal plane. **a** Rectal wall is formed by seven layers: *1* mucosa (hyperechoic); *2* muscularis mucosa (hypoechoic); *3* submucosa (hyperechoic); *4* muscularis propria (circular; hypoechoic); *5* muscularis propria (longitudinal; hypoechoic); *6* white line separating both muscular layers; *7* perirectal fat (hyperechoic). **b** Five layers: *1* mucosa; *2* muscularis mucosa; *3* submucosa; *4* muscularis propria; *5* perirectal fat

Comparison between Genders

Comparing muscle distribution between genders, it was identified that the anterior EAS (2.2 cm) was significantly shorter and the gap (1.2 cm) significantly longer in women than in men (3.4 cm and 0.7 cm, respectively) (Fig. 12). The posterior EAS-PR was significantly longer in men (3.6 cm) than in women (3.2 cm) (Fig. 12). The anterior and posterior IAS were significant shorter in women than in men, whereas the anterior IAS was thicker in men (0.19 cm) than in women (0.12 cm) but without significant difference in the posterior muscle.

Rectal Anatomy: Three-dimensional View

All pelvic organs adjacent to the rectum are clearly visualized, identifying its relation with the rectal wall layers (between 5 and 7 layers) in multiple anatomic planes (Figs. 13–16).



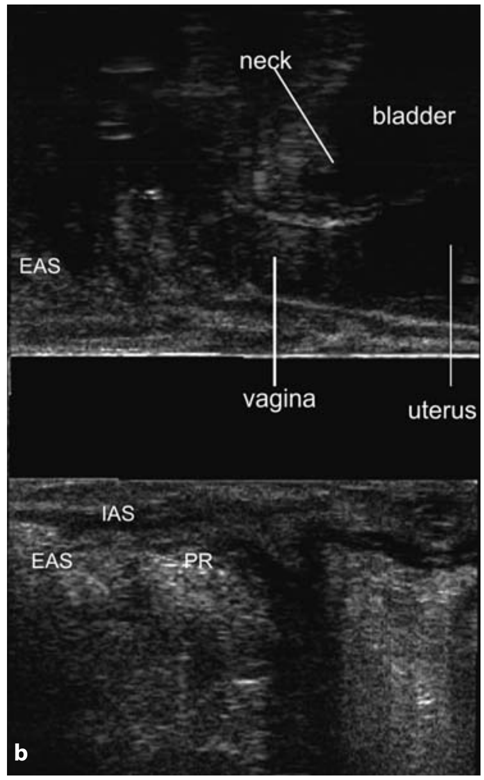
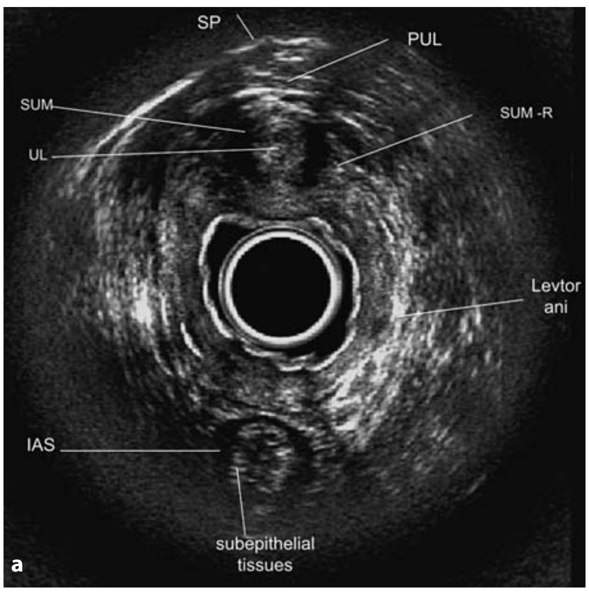


Fig. 15 a, b. Normal female rectum: sagittal plane. **a** With balloon, vagina, uterus, and bladder; **b** without balloon (focal distance 6.0 cm). *EAS* external anal sphincter, *IAS* internal anal sphincter, *PR* puborectalis muscle



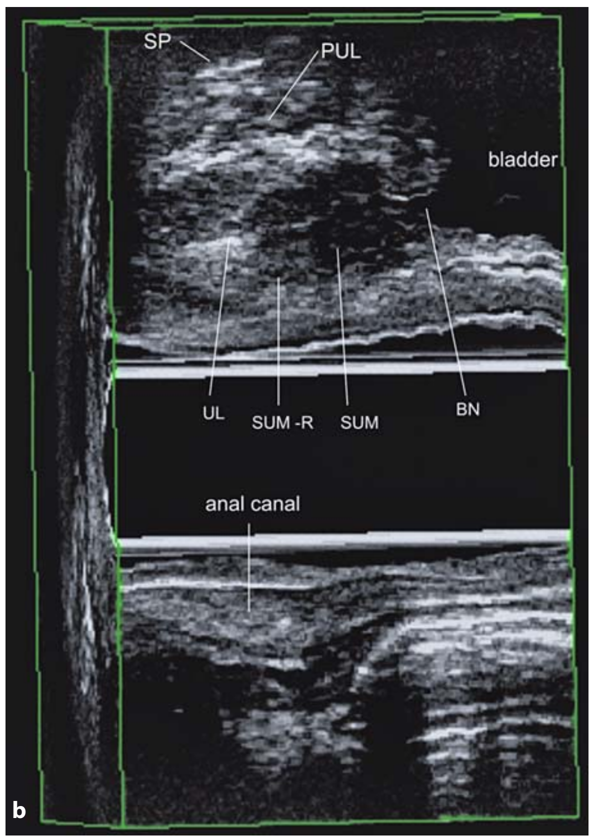


Fig. 16 a, b. Three-dimensional transvaginal ultrasound. All anatomic structures of the pelvic floor are clearly visible. **a** Axial (transverse) plane, **b** sagittal plane. *BN* bladder neck, *IAS* internal anal sphincter, *PUL* puborectal ligament, *SP* symphysis pubis, *SUM* smooth urethral muscle, *SUM-R* striated urethral muscle rhabdosphincter, *UL* urethra lumen