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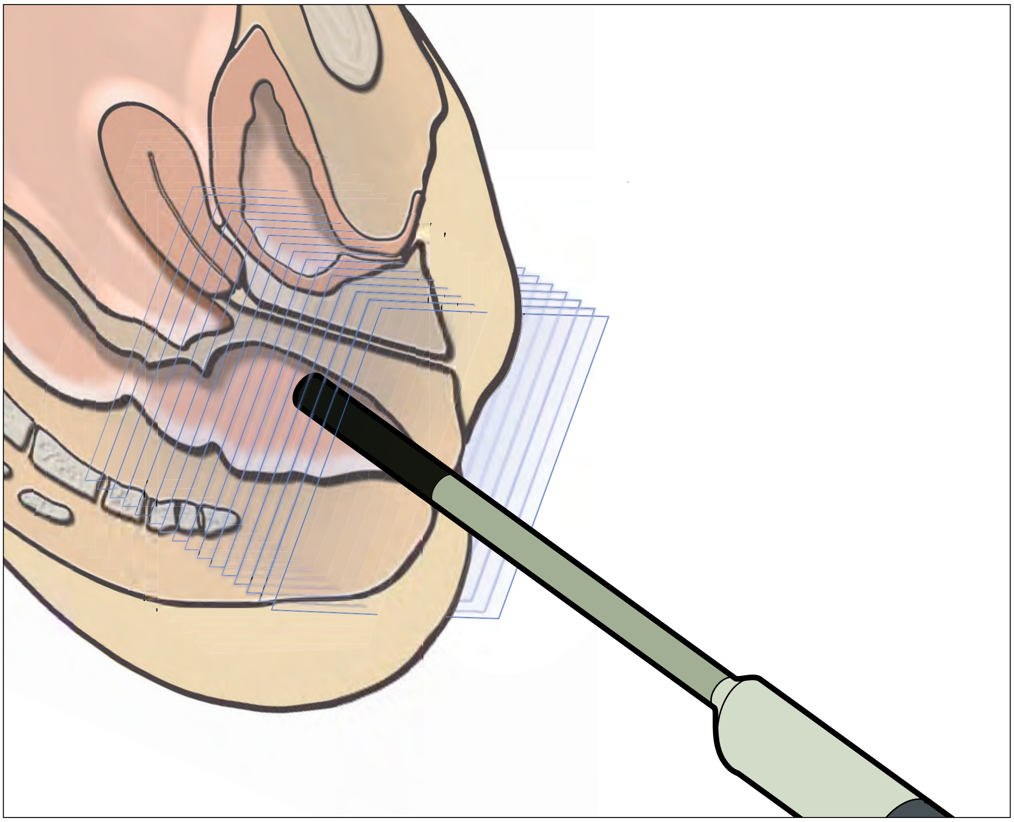
3D Anorectal Ultrasound



Ultrasound Image Credits

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2D and 3D anorectal endosonography has proved its usefulness, and today medical specialists within such areas as pelvic floor imaging, coloproctology, colorectal surgery, incontinence, and urogynecology are well aware of its value.

Introduction

Although two-dimensional endosonography is very valuable, it has some shortcomings[1]. Images are normally produced only in the transaxial scanning plane with the anterior of the patient at the 12 o'clock position. The only way to extend a scanning in the proximal-distal direction is to move the transducer farther in or out of the anal canal or rectum. Precise positioning of the transducer is crucial to the examination.

3D anorectal endosonography extends the usefulness of anal endosonography[2,3,4,5,6]. The data from a series of closely-spaced two-dimensional images are combined to create a 3D image that can be freely rotated and sliced to allow the operator to get the most information out of the data – while not under the time pressure of the examination itself. In some situations, if it is difficult to pass the area occupied by a rectal tumor, only one acquisition of images may be possible. The data stored in a file originating from an acquisition can then be reviewed at any time.

After a data set is acquired, it is immediately possible to select coronal anterior-posterior (A-P) or posterior-anterior (P-A) as well as sagittal right-left (R-L) views (Figs. 1-2). Coronal and oblique views are also available to the examiner.

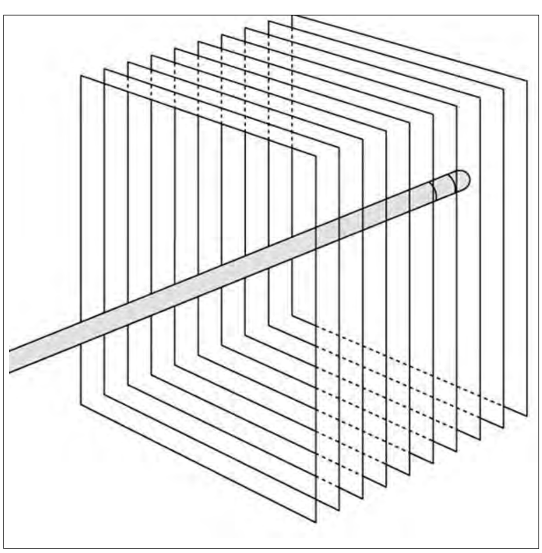


Fig. 1. Closely spaced 2D images are combined to create a 3D image. The 3D image can be rotated and sliced for further inspection.

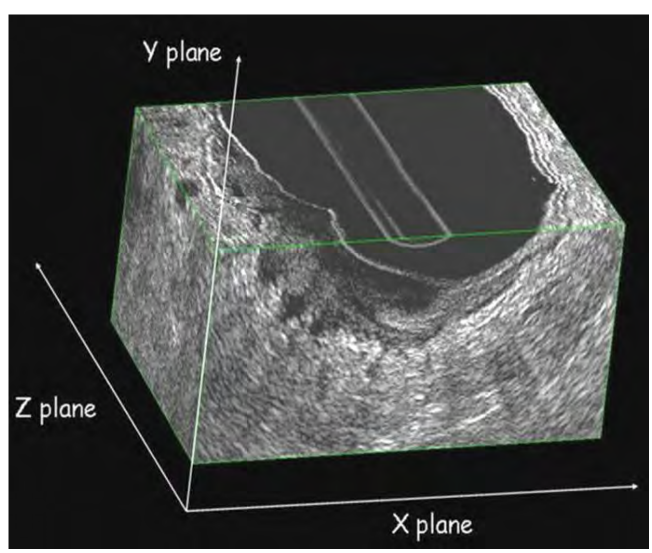


Fig. 2. High resolution 3D ultrasound image.

Anal Endosonography

In contrast to a conventional 2D image or indeed a 3D image, new techniques such as Volume Render mode contain features for modifying the opacity of a 3D data set[7]. This can be combined with filter and thickness features for truly new presentations of sphincter tears and for following fistulas-in-ano in all anatomical planes. These views offer an unsurpassed source of information to use in evaluating the patient. The results of the 3D anorectal scan can change the treatment of the patient. It is possible to see the invasion of a rectal tumor, the type of a fistula, and the extent of anal sphincter damage. This knowledge can be used to change the surgical management of the patient. The diagnosis is less dependent on one examiner, because the data can be reviewed by several specialists.

A 3D image can be freely rotated and sliced, allowing the operator to get the most information out of the data.

Previously the gold standard for imaging anal fistula cases was magnetic resonance (MR) using an endoanal coil. Using an MR machine for this application, however, is delicate and time-consuming. The introduction of very high frequency ultrasound transducers and 3D anorectal ultrasound, with the improved imaging possibilities that result, may change the standard to using ultrasound for imaging anal fistulas[3,6,7,8,9,10].

Several studies have been done on morphology of the anal canal seen on 2D and 3D endoanal ultrasound[5,11,12] and correlation between endosonographic sphincter defects and anal incontinence[13,14,15,16,17,18]. Today ultrasound is the gold standard when investigating fecal incontinence[19].

The value of endoanal ultrasound in anal cancer is more controversial[20,21,22]. Some find it very useful for preoperative staging as well as for follow-up after radiation treatment[20,21].

MR, using an endocoil in staging of rectal tumors, has not shown higher accuracy in early rectal cancer than 2D rectal ultrasound[3,23,24,25]. To date, no comparative studies have been done on 3D endorectal ultrasound and MR in benign tumors or early rectal cancer.

Using 2D and 3D endorectal ultrasound, it is possible to see the invasion of a rectal tumor[23,26], to distinguish between benign lesions and early rectal cancer[27,28], and it has shown to be useful in follow up of rectal cancer[29]. When compared to 2D, 3D endorectal ultrasound is advantageous because the image can be saved and studied in different planes after the examination (Fig. 3).

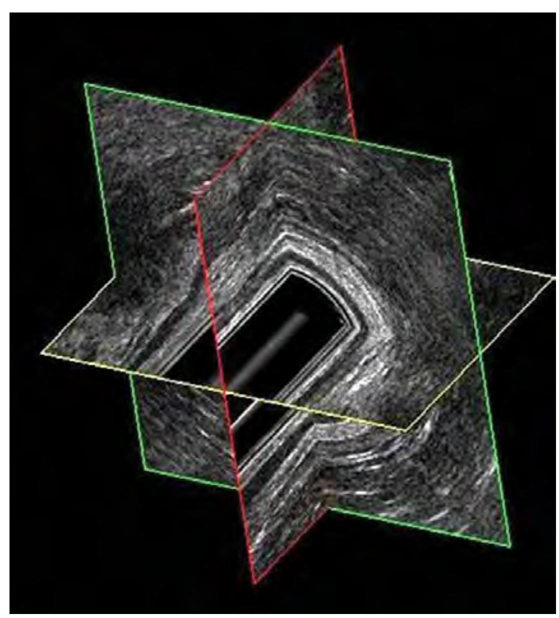


Fig. 3. Multiplanar reconstruction of 3D ultrasound image.

Equipment

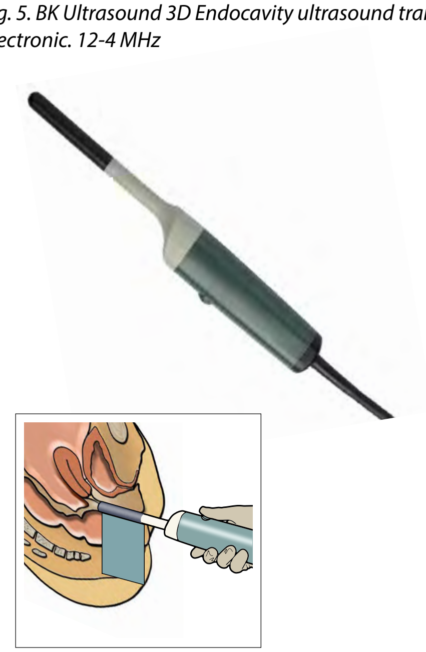
Obtaining high-quality images of the anal canal and the rectal wall makes specific demands on the equipment used. The transducer technology required for recording high quality images of the anal canal and the rectal wall is unique when compared to transducers used for other endosonographic applications. An endoanal transducer must permit a 360° image mode, and it must facilitate a high center frequency. The transducer head diameter should be relatively small and cylindrical for maneuvering the transducer in the anal canal. The walls must be parallel over the length of the scanning.

In endorectal ultrasound, a water standoff system is applied to ensure acoustic contact between the sound-emitting crystal and the rectal wall.

A multifrequency transducer is an advantage for imaging a process deep in the tissue. The 3D Anorectal transducer (Fig. 4) offers a wide frequency range — from 16–6 MHz.
The 3D Endocavity transducer (Fig. 5) uses a rotating sagittal array to create very high 3D image resolution. With both transducers, 3D image aquisition is automatic, and no moving parts touch the patient.

Fig. 4. BK Ultrasound 3D Anorectal ultrasound transducer. Mechanical, rotating crystals. 16–6 MHz

Fig. 5. BK Ultrasound 3D Endocavity ultrasound transducer. Electronic. 12-4 MHz



Acquisition of 3D Anorectal Images

The same type of transducer facilitates both 2D and 3D imaging techniques.

A 3D reconstruction is based on a high number of parallel transaxial images acquired by means of a precision movement of the crystal assembly inside the Anorectal 3D transducer.
The built-in high-resolution 3D acquisition system can be operated at different levels of definition. For the anorectal application, the usual setting is 0.25 mm between adjacent transaxial images. Scanning the anal canal or the rectum wall with these settings over an acquisition distance between 30 and 60 mm will typically yield from 120 to 240 parallel image slices (Fig.1).

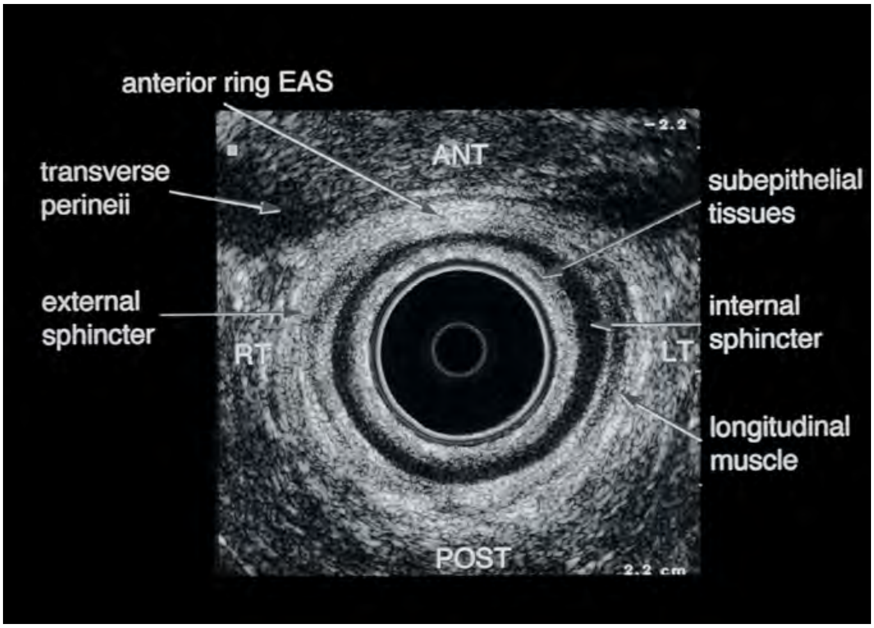


Fig. 7. The normal 2D anal sphincter complex.

Fig. 8. Female; high canal. Puborectalis seen.

Fig. 9. Female; mid canal. Approximately at the level of the dentate line.

Fig. 10. Female; low canal. Only the subcutaneous EAS is seen.

Anal Endosonography

Fig. 7 shows a 2D image of the anal canal. The external sphincter is seen forming a 360° intact circle. The image is recorded as a mid-canal image (slightly higher than the level of the dentate line). The perineal body is partially visible ventral to the anterior external anal sphincter (EAS), and the transverse perineii are imaged at 11 and 1 o'clock. Note the conjoining longitudinal muscle and the complete internal anal sphincter (IAS).

The first ultrasound image recorded is normally at puborectalis level (high), where the perineal body is also seen in females. This image is normally documented and labeled HIGH (Fig. 8).

In a normal patient, moving the transducer a few mm in the distal direction will show an intact anterior EAS forming just below the superficial transverse perineal muscles. This image is a mid-canal projection where the IAS conjoining the longitudinal muscle (LM) and the superficial EAS all are identified. This image will be labeled MID (Fig. 9).

When the transducer is pulled farther out, the image of the IAS will disappear, and only the subepithelium and the subcutaneous segment of the LM+EAS will be seen. This last image will be labeled LOW (Fig. 10). The labels in Fig. 11 indicate Level I, II and III positions on a 3D coronal A-P image.

In Fig. 12, note the perfect circular EAS anteriorly and left-lateral in this nulliparous female.

Anal Sphincter Tears

Anal sphincter tears can either be isolated to a defect in the EAS or the IAS alone or be a combination of an internal and an external sphincter defect. Scars can be either hypo- or hyperechoic.

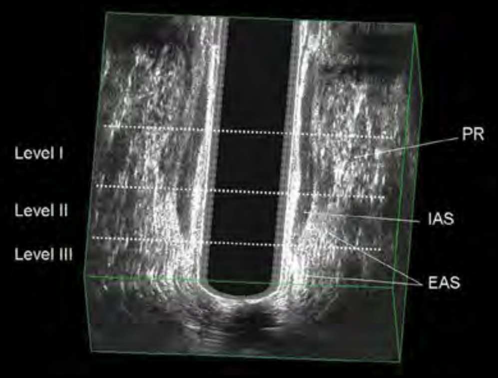


Fig. 11. The three levels of the anal canal visualized in the coronal plane.

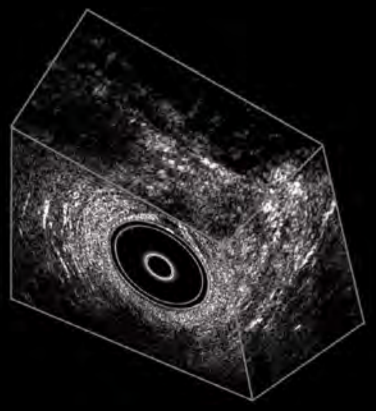


Fig. 12. Female; 3D image of normal EAS complex.

Fig. 13 shows a transaxial image of an EAS tear, while Fig. 14 shows a 3D image of an anterior EAS tear using volume rendering techniques. A combined internal and external sphincter defect is seen in Fig. 15. 3D image of the same female illustrates the missing anterior part of both sphincters in the longitudinal plane (Fig. 16).

Ultrasound is very useful to assess the results after an anterior sphincter repair (Fig. 17) or after injection of bulking agents (Fig. 18)[14,30,31,32].

Anal Fistulas and Abscesses

It is considered a delicate and problematic task to image anal fistula cases using only 2D transaxial ultrasound. The fistula tracts are almost impossible to follow, and it is even harder to identify any internal opening.

In these cases, 3D endoanal ultrasound offers a significant advantage over conventional 2D ultrasound. If an external opening can be identified, some doctors will introduce hydrogen peroxide H_2O_2 (3–5%) into the opening immediately before acquiring a 3D data set. Data acquisition will take approximately 60 sec for a high-resolution scan. For this short period, the H_2O_2 enhances the fistula tracts

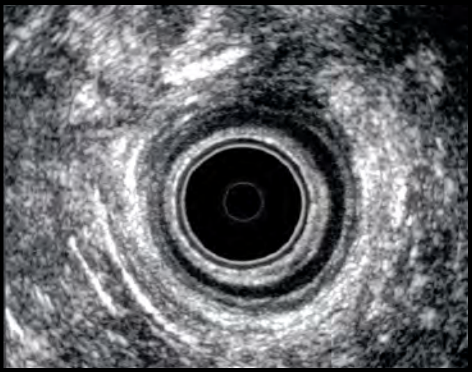


Fig. 13. A large anterior EAS tear is seen at 12-1 o'clock in this female (postpartum).

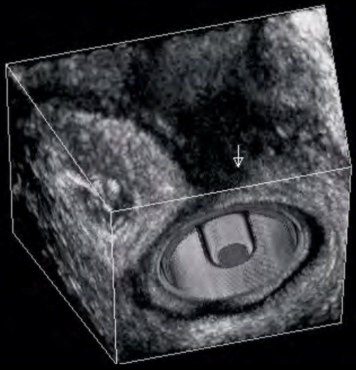


Fig. 14. Anterior EAS tear.

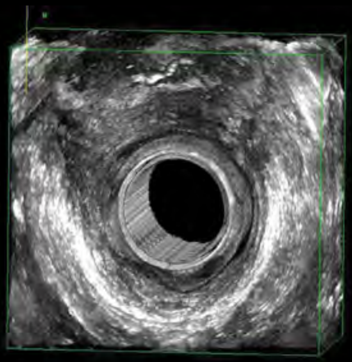


Fig. 15. Combined defects of IAS from 9 to 3 o'clock and EAS from 10 to 2 o' clock.

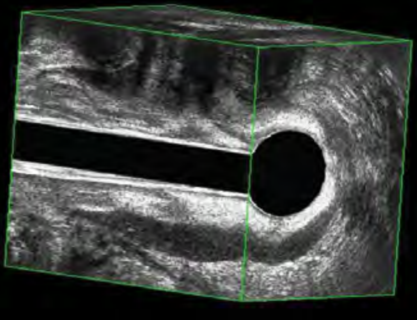


Fig. 16. Combined anterior defects of IAS and EAS visualized in the longitudinal plane.

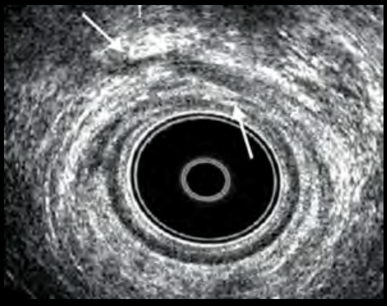


Fig. 17. Ultrasound image after Anterior Sphincter Repair. The arrows show the two arms of the overlapping.

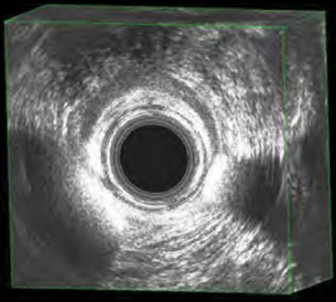


Fig. 18. Bulking Agents implant at 4 and 7 o'clock is visualized as bright echoes at ultrasound.

so that they appear as bright white structures in the ultrasound image. Applying Volume Render Mode to a 3D data set will further enhance the image of the branches of a fistula with or without the presence of any enhancing medium.

A fragment of the fistula in the 2D image and the entire fistula in the 3D image are seen as bright white echoic structures because of the image-enhancing properties of H_2O_2.

Fig. 19 shows a 3D coronal image of a left extrasphincteric fistula. In Fig. 20, the entire fistula is seen as a bright white H_2O_2-enhanced tract. An example of a transphincteric anal fistula is seen in Figs. 21-23.

Abscesses are easily visualized as in this case, where the abscess is seen as an echo-poor cavity (Fig. 24).

Crohn's Fistula

Perianal fistulas constitute one of the most feared manifestations of Crohn's disease. Fistula formation can be the first manifestation of Crohn's disease and precede the onset of the disease in the gastrointestinal tract by several years. Using high-resolution 3D endoanal ultrasound, you can distinguish between typical cryptoglandular fistula and Crohn's fistula.

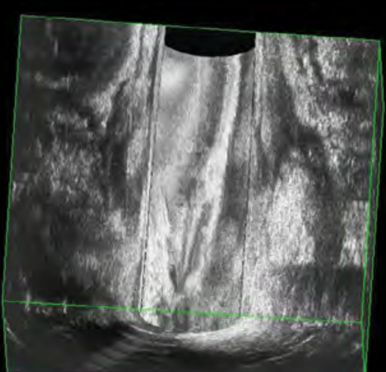


Fig. 19. Extrasphincteric anal fistula.

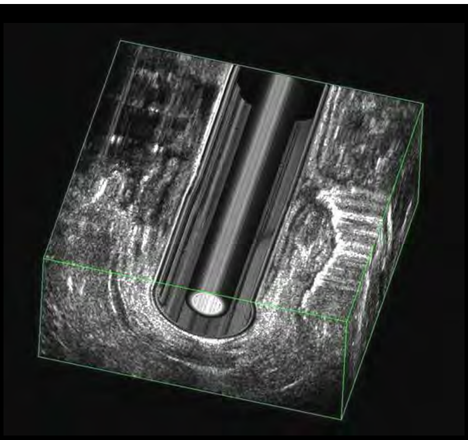


Fig. 20. Same patient as in Fig. 19, with H2O2 enhancement.

Fig. 21. 2D image of internal fistula opening anteriorly.

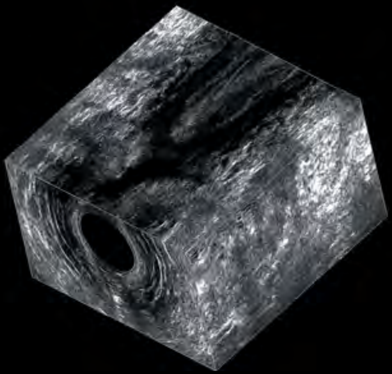


Fig. 22. 3D image reveals the rest of the fistula tract.

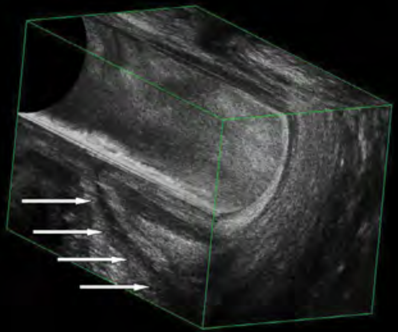


Fig. 23. Posterior transphincteric fistula.

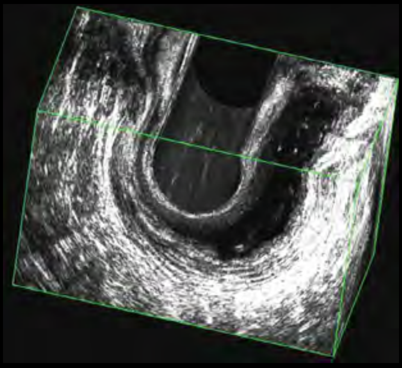


Fig. 24. A left lateral intersphincteric abscess, located between the internal and external sphincter.

A hypoecogenic fistula tract surrounded by a well-defined hyperechogenic area with a thin hypoechogenic edge outside characterized fistulas in patients with Crohn's disease (Fig. 25). We call this unique 3D endoanal feature of perianal Crohn's fistula "Crohn Ultrasound Fistula Sign" (CUFS)[33].

Anal Cancer

Figs. 26 and 27 show an example of anal cancer before and after radiation therapy. The tumor is located from 2 to 8 o'clock and penetrates the external sphincter (T2b). After radiation treatment, the tumor has disappeared.

Rectal Endosonography

The rectal wall consists of 3 layers surrounded by perirectal fat (Fig. 28). Ultrasound studies of the rectum show 5 interfaces represented in the image as 3 hyperechoic and 2 hypoechoic structures (Fig. 29).

The interfaces represent 1) the hyperechoic interface between the water-filled balloon and the mucosa, 2) the hypoechoic deep mucosa (lamina propria and muscularis mucosae), 3) the hyperechoic submucosa, 4) the hypoechoic muscularis propria and 5) the hyperechoic interface between the rectal wall and the perirectal fat tissue.

Before deciding whether management of the patient should include preoperative radiation therapy for rectal cancer, it is important to know whether the tumor is confined to the rectal wall (T1 or T2 tumor) or penetrates into the perirectal fat (T3 tumor).

Studies have shown that endorectal ultrasound is superior to MRI in staging early rectal cancer.
In advanced T3 or T4 tumors, however, MRI should be preferred because of the lower image depth of high frequency endosonography and because it is difficult to insert a transducer past advanced rectal tumors[23,24,25,26,29,34].

Endorectal ultrasound can also distinguish between benign lesions and early rectal cancer when decision for transanal endoscopic microsurgery (TEM) has to be taken[27,28], but staging of malignant rectal polyps in patients with previously excised polyps is difficult[35]. The diagnostic accuracy of the assessment of lymph node involvement is not particularly good using endorectal ultrasound nor MRI[3,36]. Enlarged (>5mm) lymph nodes can be seen on endorectal ultrasound, but it is difficult to assess the etiology of an enlargement with any degree of certainty.

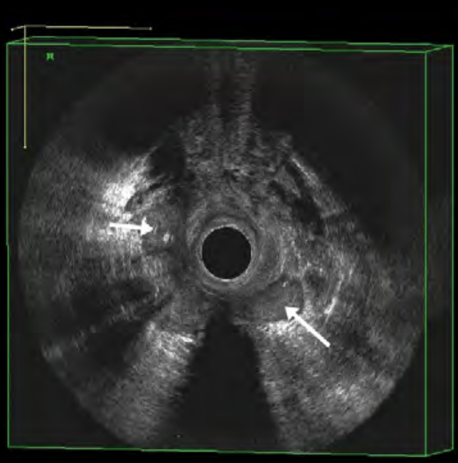


Fig. 25. Crohn's Ultrasound Fistula Sign

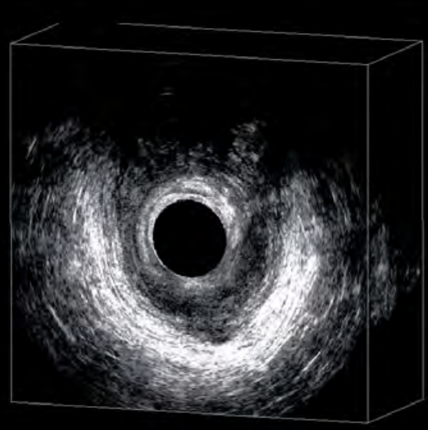


Fig. 26. Anal cancer before treatment.

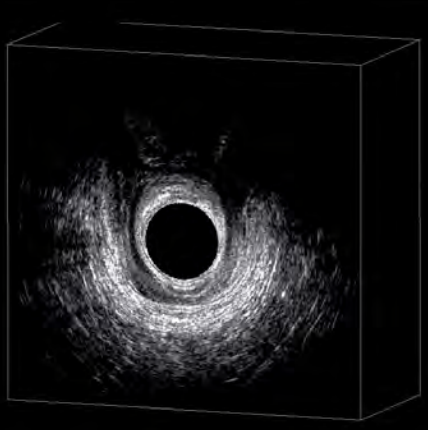


Fig. 27. Anal cancer after treatment.

3D offers a valuable supplement to conventional ultrasound[3]. For example, it makes it possible to project the tumor in the entire proximal-distal anterior-posterior extension.
In Figs. 30 and 31, the images show a normal rectal wall. The 5 layers of the rectal wall are clearly illustrated in the axial plane as well as in the coronal plane.

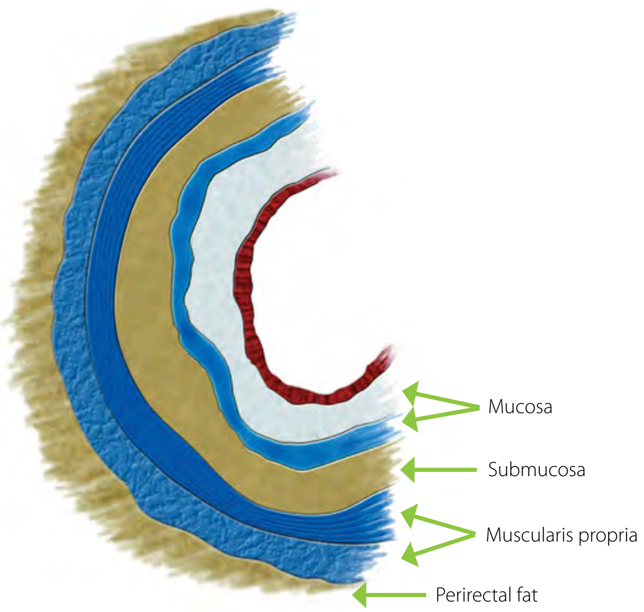


Fig. 28. The anatomy of the rectum.

Fig. 32 is an image of a benign T0 tumor. An enlargement of the mucosa, but no invasion of the hyperchoic submucosal layer, is seen. Fig. 33 shows a T1 tumor with disruption of the submucosa.

A T2 tumor (Fig. 34) is often difficult to distinguish from a T1 tumor. As in a T1 tumor, the submucosa is disrupted, but the muscularis propria is thickened.

Figs. 35 and 36 show a T3 tumor. All the layers are disrupted and the tumor penetrates into the perirectal fat. Observe the typical invasive patterns in the perirectal fat. Fig. 37 shows metastatic lymph nodes.

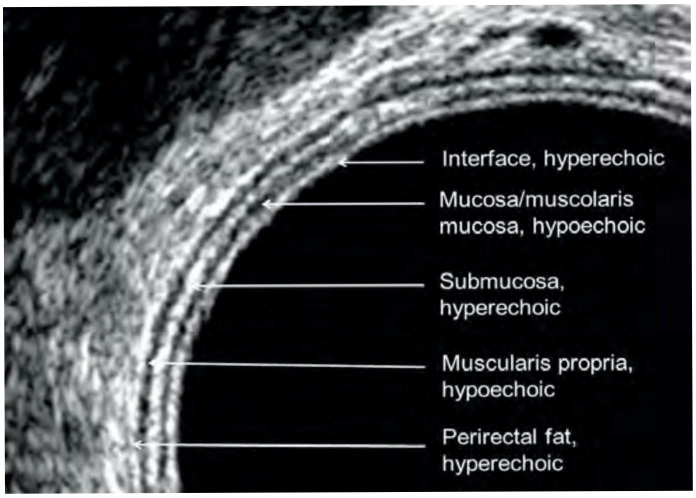


Fig. 29. The 5 layers of the rectal wall as seen on endorectal ultrasound.

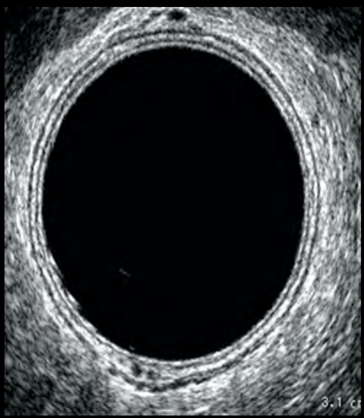


Fig. 30. 2D imaging of five layers structure of the normal rectal wall.

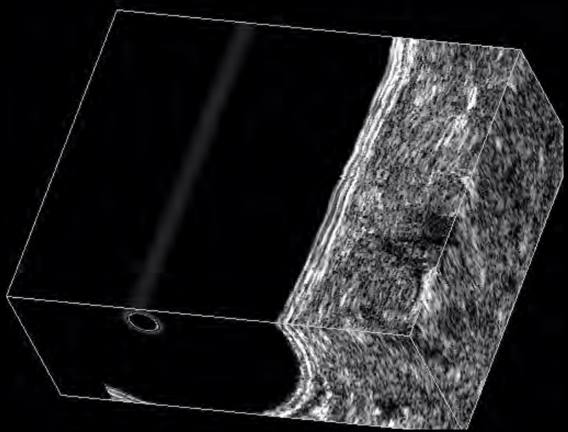


Fig. 31. 3D image of the rectal wall. Same patient as in Fig. 30.

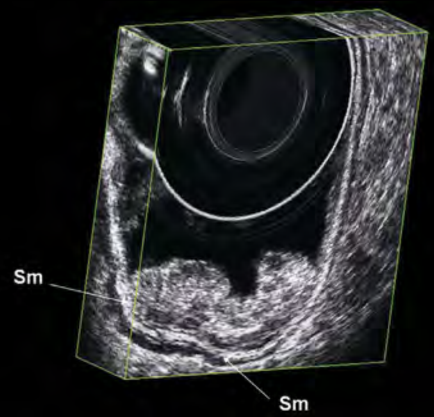


Fig. 32. 3D image of a T0 tumor. The hyperechoic submucosal layer is not invaded.

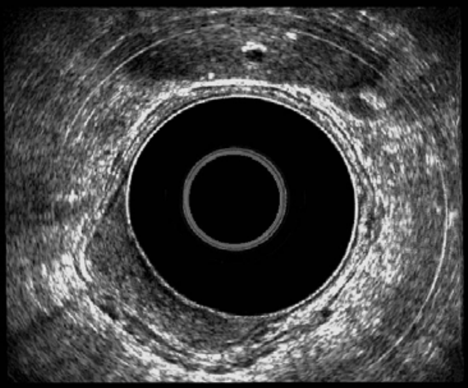


Fig. 33. 2D image of a rectal wall with a T1 tumor.

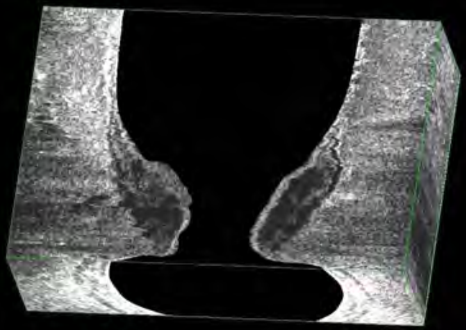


Fig. 34. 3D image of T2 tumor.

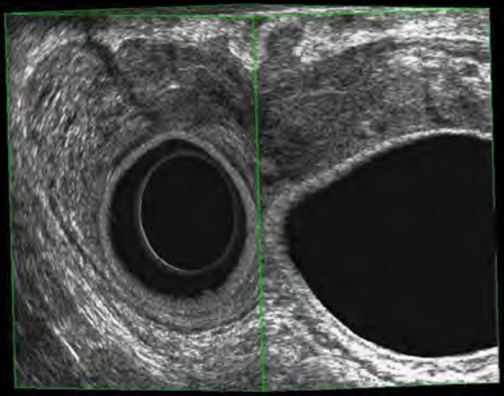


Fig. 35. T3 rectal tumor with invasion of the perirectal fat.

Fig. 36. T3 rectal tumor with massive invasion of the perirectal fat.

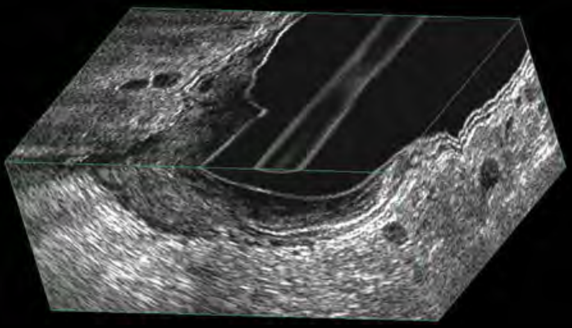


Fig. 37. Metastatic lymph nodes are visualized as round anechoic structures close to the tumor.

BK Ultrasound's 3D imaging possibilities add extra value to anorectal endosonography. Advantages for the patient are that an extensive set of data can be taken at one time. The physician can later study the patient's data in a variety of ways, without the need for an additional ultrasound examination to acquire data from a different position or angle, and a non-examiner can study images recorded by colleagues.

For the physician, the advantages are clear. The 3D ultrasound equipment can be brought to the operating room, and ultrasound scanning can be performed pre- and postoperatively by the surgeon. The diagnosis is less dependent on one examiner, because the data can be reviewed by several specialists. Data acquisition is simple and done without moving the probe inside the patient. Furthermore, there is less need for precise positioning of the transducer to make sure you don't miss something. All the data is captured, ready to be examined later, in as many ways as necessary.

With advantages for both the physician and the patient, 3D imaging extends the usefulness of anorectal endosonography.

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