ENDOLUMINAL MAGNETIC RESONANCE IMAGING IN FECAL INCONTINENCE

Elena Rociu

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BIJ FECALE INCONTINENTIE

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Aan Ewout
en mijn ouders

Contents

CHAPTER 1

INTRODUCTION

Fecal incontinence is a chronic disability, has serious emotional impact and increased risk for social isolation. Imaging has become important in the diagnostic work-up of fecal incontinence. The research described in this thesis continues the line of efforts to improve the quality and the amount of information provided by imaging to the clinicians, aiming better diagnosis and consequently more accurate treatment of incontinent patients. The purpose of this thesis was to evaluate the role of endoanal MR imaging in the assessment of patients with fecal incontinence.

Fecal incontinence is defined as the involuntary loss of gas, liquid, or solid stool. Data from Great Britain suggest a community prevalence of 10.9 men and 13.3 women per 1000 people who are 65 and older (1). The prevalence of fecal incontinence ranges from 10 to 17 percent in nursing home residents and from 13 to 47 percent in hospitalized elderly patients (2). It has been estimated that as many as 3% of women who give birth by vaginal delivery will develop fecal incontinence (3). Fecal incontinence ranks as the second leading cause for nursing home placement in the United States, being more common then dementia (4). Despite these impressive statistics, the epidemiology of fecal incontinence remains largely unknown because individuals may be embarrassed to admit being incontinent (5). The stigma associated with the complaint leads to its underreporting by patients to physicians and often results in self-imposed social isolation, especially in elderly patients, some of whom regard it as an inevitable part of the aging process (6). Patients generally present with either passive incontinence (anal leakage without awareness) or urge incontinence, which describes an inability to defer defecation. According to the Parks classification, the degrees are I-continent, II-incontinence for flatus, III-incontinence for liquid stool and flatus, IV incontinence for solid stool (7).

Physiology

Fecal continence means the ability to perceive and retain rectal contents as well as to evacuate the rectum when at the appropriate place and time. It is based on the reservoir capacity of the rectum, the presence of the sphincter barrier and on the pelvic sensations and reflexes. The internal sphincter, the thickened circular smooth-muscle layer of the distal rectal wall, is under autonomic control and accounts for 80% of resting sphincter pressure (8,9). The voluntary sphincter is made up of the external sphincter and puborectalis muscles. These skeletal muscles behave as a functional unit, in spite of independent innervation (the external sphincter by the pudendal nerves and the puborectalis by pelvic branches of S-3 and S-4) (10). A spinal reflex causes the striated sphincter to contract during sudden increases of intra abdominal pressure, such as coughing. Voluntary sphincter contraction normally doubles the pressure in the anal canal, though this cannot be sustained for more than a few minutes (11). The anorectal angle, produced by the anterior pull of the puborectalis muscle, was thought to be important in maintaining continence. Parks proposed a flap valve mechanism, in which increased intraabdominal pressure compressed the anterior rectal wall against the pelvic floor. However, physiologic and radiological studies have failed to demonstrate such a mechanism, and successful repair of the pelvic floor does not appear to depend on restoring the anorectal angle, therefore its importance is still questionable (2).

The sequence of events leading to defecation is initiated when material from the sigmoid colon enters the rectum. Rectal distension causes reflex relaxation of the internal anal sphincter, exposing the rectal contents to the anal mucosa so that sampling may occur. The sensation of a full rectum, and the ability to discriminate gaseous, liquid and solid content, are important components of continence. After feces fills the rectum to a sufficient degree, the urge to defecate is experienced and voluntary contraction of the external sphincter and puborectalis occur until circumstances for defecation are appropriate. When a conscious decision to initiate defecation is made, relaxing voluntary control allows defecation to proceed. A Valsalva maneuver is performed to increase intraabdominal pressure and push the feces toward the anal canal. The pelvic floor descends, the rectum contracts, external sphincter activity is inhibited, and the fecal bolus is expelled out of the rectum (11).

Etiology and pathology

Normal continence depends on a number of factors: stool volume and consistency, colonic transit, rectal distensibility, anal sphincter function, anorectal reflexes, anorectal sensation and mental function. Abnormalities of any of these factors, alone or in combination can lead to incontinence (2).

A. The main cause of fecal incontinence in women is childbirth, which can lead to mechanical or neurological injury to the anal sphincter (12). After vaginal delivery only 0.7% of women have clinically overt sphincter damage (13). Sultan revealed that 35% of the primiparous have occult sphincter damage after vaginal delivery and one third of them directly have disturbances of anal continence (14). Occult sphincter defects may precipitate overt symptoms later in life as menopause (15), neuropathy and muscle loss cumulate their effects (16).

B. Idiopathic fecal incontinence is caused by denervation of the pelvic floor (17). Denervation is caused by traction injury to the pelvic nerves, such as that sustained during childbirth (3) or from prolonged straining at stool (18) and can be detected on pudendal nerve terminal motor latency studies. Risk factors for postpartum pelvic neuropathy include a prolonged second stage of labor, use of obstetrical forceps, and delivery of a high-birth-weight infant (3).

C. Anorectal surgical procedures carry the risk of subsequent fecal incontinence. Iatrogenic sphincter trauma may occur during anal dilatation (19), fistulotomy (20) and hemorrhoidectomy (21). Often, the patients being considered for anal procedures already have some preoperative impairment of anal function and a new sphincter trauma may precipitate fecal incontinence.

D. Accidental perineal injury and unwanted anal penetration are other traumatic causes of sphincter damage (22,23).

E. Many incontinent patients will have intact sphincters. Their symptoms will be due to causes located higher in the digestive tract, like chronic diarrhea and rectal prolapse (24). For example, the high volume of liquid stool and enhanced colonic transit of diarrhea can lead to incontinence, even if the anal sphincter is normal (25). Similarly, the poorly distensible rectum characteristic of inflammatory bowel disease and radiation proctitis (26) precludes adequate reservoir function. Abnormal function at any level of the nervous system can lead to fecal incontinence. Incontinent patients with high spinal lesions have better function than patients with low lesions (27). Rarer causes of incontinence with intact sphincters include fibrosis, as occurs in scleroderma (28).

F. Adequate anorectal sensation is necessary for normal continence. Patients with fecal impaction and overflow incontinence have diminished rectal sensation, as do patients with incontinence due to diabetes mellitus or spinal disease (2). Incontinent elderly patients have abnormal rectal sensation and decreased resting sphincter pressure, as compared with continent elderly patients (29).

G. Congenital anorectal anomalies, an uncommon cause of fecal incontinence, occur in 1 in 5000 live-born infants (30).

Diagnostic modalities

A. Medical history

Medical history should be assessed for the following factors: associated medical diseases like diabetes mellitus, medication use, and previous gastrointestinal or anorectal surgery. Obstetrical history should include information of the number of vaginal deliveries, the occurrence of prolonged labor, the use of forceps, and the occurrence of substantial perineal lacerations. True incontinence should be differentiated from perianal leakage of material other than stool that can occur because of fistulas, anorectal neoplasms, and sexually transmitted diseases. Once incontinence is diagnosed its severity must be assessed by evaluating the frequency of incontinent episodes and the need of perineal pads.

B. Functional diagnostic tests

There are a variety of techniques available that test anorectal nerve integrity, conduction, and muscular performance. They provide objective data that confirm the clinical impression and occasionally alter treatment.

A. *Digital examination* can reveal perianal hypoesthesia, decreased sphincteric resting or squeezing tone and sometimes sphincter defects (31).

B. *Anorectal manometry* is important for measuring the resting pressure (mainly due to the internal sphincter) and the squeezing pressure (mainly due to the external sphincter). Dual sphincter pathology is implicated when both resting and squeezing pressures are reduced (32). Manometry is also important for establishing the presence of the rectoanal inhibitory reflex, which is often reduced or absent in fecal incontinence (33).

C. *Pudendal nerve terminal motor latencies (PNTML).* The pudendal nerve terminal motor latency was defined as the time between stimulation of the pudendal nerve from the anal canal near the ischial spine and contraction of external sphincter muscles (34). The nerve has both sensory and motor components and slow conduction reflects pathology, thought to be predominantly due to stretch induced injury (17). Snooks at al. (3) estimate that as many as 80% of women with idiopathic fecal incontinence have evidence of nerve injury to the pelvic floor musculature. Patients undergoing sphincter repair do less well if they also have neuropathy (34).

D. *Electromyography* is useful in mapping external sphincter defects and in studying the fiber density of muscular fibers, which is increased in neurogenic fecal incontinence (32). Electromyography will frequently reveal mild neuropathy that is clinically unsuspected and confirm marked neuropathy that is clinically evident. This blind, painful and invasive method is now replaced by endoluminal imaging (35).

C. Imaging techniques

The selection of patients likely to benefit from surgery as well as the type of surgical procedure relies on accurate visualization of the anal complex. Physical examination can characterize impaired anal function but gives limited information on the existence and location of sphincter lesions that can be corrected surgically. Therefore imaging techniques became mandatory in the preoperative diagnose of fecal incontinence. The advantage of endoluminal techniques is the high local resolution and a 360° image perfectly suiting the cylindrical shape of anal structures.

Endosonography

Anal endosonography made sphincter imaging for the first time possible. A cylindrical transducer (7.5-10 MHz) is inserted in the rectum with the patient in left lateral position and then withdrawn until the high reflectivity puborectalis sling is seen and used as main landmark. Hard copies of axial images of the puborectalis muscle, internal and external anal sphincter are made at four levels in the anal canal (31,36). External sphincter presents on endosonography with heterogeneous borders that sometimes make it difficult to evaluate for lesions. The internal sphincter appears sharply delineated allowing fine examination by this technique (31). Endosonography is fast, inexpensive and painless and has a higher accuracy than electromyography (35).

Endoluminal MR imaging techniques

Endoanal MRI has multiplanar capabilities and high inherent contrast resolution. Earlier studies demonstrated that sonography or body coil MRI without endoluminal device do not result in adequate contrast and spatial resolution (37). The role of phased array coil MRI has not yet been evaluated, but the local spatial resolution of this technique is inferior to endoluminal techniques. Endoanal MRI provides excellent demonstration of all sphincter muscles (39,40). The endoanal coil is inserted in the anal canal. Axial sequences are perpendicular to the long axis of the endoanal coil while sagittal and coronal images are parallel to it (38). The axial plane is the most relevant surgically, longitudinal scans provide additional information on disease extent.

Evacuation proctography

Evacuation proctography (defecography) radiographically evaluates defecation during evacuation of a simulated barium stool. Static and dynamic measurements of the anorectal angle, pelvic floor, and puborectal function are made during rest, squeeze, and attempted defecation (41). Pathology best recognized during defecation, such as perineal descent, rectal prolapse, enterocele, and rectocele, can be diagnosed, although symptoms may not correlate well with these defects (42). Repair of those gastrointestinal conditions should be combined with anal repair if sphincter lesions are detected on endosonography or endoanal MRI. Recent studies presented MR defecography as a promising method in the dynamic evaluation of the pelvic floor (43).

Management and treatment of fecal incontinence

Careful medical history and physical examination will orient the physician about the etiology of fecal incontinence. Fecal incontinence caused by dynamic conditions as: prolapse, enterocele, cystocele and intussusception, can be assessed with defecography.

In the diagnose of fecal incontinence due to anal sphincter pathology after assessing the sphincter function by digital examination, PNTML and manometry, visualization of the sphincter and detection of sphincter lesions will play an important role. Where available, endoanal imaging is the most valuable tool in the evaluation of anal incontinence, and manometric studies are determining the functional contribution of any sphincter defects found.

Minor degrees of fecal incontinence can often be satisfactorily managed in a conservative way. If present, diarrheal stools must be treated. If possible, the underlying cause of diarrhea should be corrected, if not, anti-diarrheals agents can be used (44). High-fiber diet, bulking agents will produce formed stool that is easier to control than liquid stool. Another way of controlling incontinence is to make sure the rectum contains no fecal material. Some patients therefore use suppositories or disposable enemas to achieve this (45). Practice of sphincter exercises several times daily to improve both the tone and the awareness of the pelvic diaphragm is a useful adjunct to the treatment. Biofeedback training was reported to initially have 54% rate of success, however, results deteriorate over longer follow-up time (46).

For those patients with a sphincter tear and persistent incontinence after conservative treatment, operations such as anal sphincter repair or sphincter reconstruction may achieve complete restoration of continence (47). New techniques include muscle transplantation, with or without electrical stimulation, sacral nerve stimulation, or surgical implantation of an artificial sphincter (48, 49). Finally, as a last resort, placement of a colostomy should be considered and may significantly improve the quality of life for selected patients.

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CHAPTER 2

ENDOLUMINAL MR IMAGING OF THE RECTUM AND ANUS: TECHNIQUE, APPLICATIONS AND PITFALLS

Introduction

Anorectal diseases require imaging for proper management. Initially barium studies and fistulographies were used. The subsequent introduction during the last two decades of computer tomography (CT), defecography, endoluminal ultrasound, magnetic resonance imaging (MRI) and endoluminal MRI has broadened the armamentarium significantly. These modalities had profound impact on the diagnostic work up of patients with anorectal diseases. The widespread use of MRI and to a lesser extent endoluminal sonography has diminished the role of CT to relatively sparse indications. However, both techniques have drawbacks. The spatial resolution of body coil MRI is too limited, while endoluminal sonography has a limited contrast resolution (1,2). During the first half of this decade endoluminal MRI of the rectum and anus was introduced (1,2,3). This technique combines the strength of the two previous techniques: the high spatial resolution of an endoluminal technique and the high intrinsic contrast resolution of MR imaging. For an optimal endoluminal MRI attention should be paid to adequate patient preparation, imaging protocols and potential pitfalls in interpretation. Important issues in patient preparation are a patient position as comfortable as possible and the use of an antiperistaltic drug. Imaging sequences and imaging planes are used in tailored protocols for specific diseases. Adequate patient preparation combined with adequate technique and the knowledge of potential pitfalls will result in an optimal endoluminal MRI of rectum and anus. The methods to perform endoluminal MR imaging as well as the role of endoluminal MR imaging in patients with anorectal diseases will be discussed.

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Technique

Endoluminal coil

The type of coil used for endoluminal MRI depends on the vendor of the MR machine. For endoluminal MRI of the rectum commonly a coil with a balloon is used (Fig. 1). These coils give satisfactory results for imaging rectal diseases. An important disadvantage of these coils is that they are developed for endorectal imaging and not for endoanal imaging. Dedicated endoluminal coils for rectum and anus have been developed to overcome these problems (1,2,4-6).

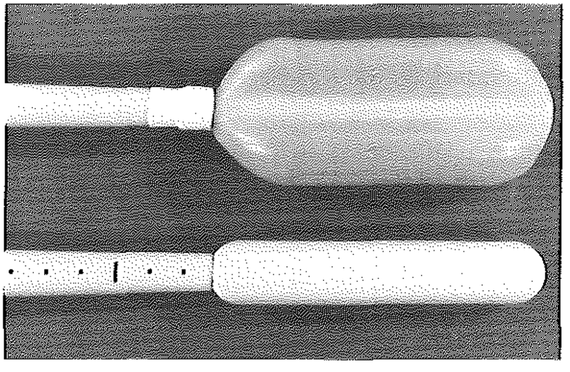


Figure 1. Endoluminal coil for (upper) endorectal and (lower) endoanal MRI.

Two types are presently used. One type is a cylindrical saddle-geometry receiver coil. This coil is used in varying diameters and lengths: 7-12 mm diameter and 6-10 cm length (5-8). The coil is placed in a rigid thin protective cover and immobilized by an external clamp. The coil we use is a rectangular, receive-only coil with a length of 8 cm and a diameter of 17mm (1,2,4,9-11). The coil is surrounded by a rigid cylindrical coil holder with a length of 10 cm and a diameter of 19 mm (Fig. 1). The coil holder is 2 cm longer at the handgrip side of the coil to prevent expulsion by anal squeezing. As the coil has no balloon and no external fixation, the angulation of the coil can be easily adjusted to the most comfortable position. The position of the coil has to be secured by placing small sand bags on the part of the coil outside the patient.

Endoluminal MR-procedure

Patient preparation is part of every MR-procedure. The aim of patient preparation is to familiarize the patient with the procedure, to make the procedure as comfortable as possible, and to stress the importance of preventing motion. The presence of an endoluminal coil may induce motion by anal squeezing or pelvic floor contraction. Minimizing motion during acquisition is even more important with endoluminal MRI where small voxels are used and which is therefore more susceptible to image degradation by motion.

In patients with an anorectal tumor the examination is preceded by an enema to clean the rectum. All patients are asked to void prior to the examination to prevent motion artifacts caused by discomfort of a distended bladder. A rectal digital examination is only performed in patients with rectal tumors to determine the tumor location for optimal coil positioning. The endoluminal coil is covered by a condom and a very limited amount of lubricant is applied on the top of the coil. Superfluous lubricant should be prevented as it may give rise to very high signal intensity next to the coil, the so called near field effect. This is a well known phenomenon with the use of surface coils and can therefore also occur with an endoluminal surface coil. Near field effect is caused by the high sensitivity close to the coil and the steep drop-off. This results in large differences in signal depending on the distance to the coil.

The endoanal coil is introduced in left decubitus position. The patient turns to the supine position and the coil position is checked. The coil position is secured by sand bags. A small pillow positioned over the coil and sand bags, and a fixation band around the legs will contribute to a comfortable position. The patient is instructed not to squeeze during the sequences, and to relax the pelvic floor and related muscles as much as possible.

A sagittal survey is performed, followed by an off-axis coronal and axial survey angulated respectively, parallel and orthogonal to the coil. The coil position is evaluated and when necessary the coil is repositioned. After confirming the optimal coil position 20 mg butylscopalaminebromide (buscopan) or 1 mg glucagon is injected intramuscularly. This is important for both rectal and anal imaging as it will reduce motion artifacts by rectal contractions.

Sequences

Until now, the optimal imaging sequences for endoluminal MRI of rectum and anus have not been definitely established. The use of T1w imaging with intravenous contrast medium, short-tau-inversion recovery (STIR) and T2w spin-echo has been advocated (5,6,8). In our experience proton density (PD) weighted gradient echo (GRE) and T2w turbo spin-echo (TSE) give very good results without the need of intravenous contrast medium. The anal anatomy as well as pathology are excellently demonstrated using 3D PDw or T2w sequences (1,2,4,9). These sequences are therefore the mainstay of our imaging protocols for endoluminal MRI of rectum and anus. For patients with fecal incontinence a detailed demonstration of the anal sphincter anatomy is a prerequisite. 3D PDw GRE will give this high spatial resolution. For anovaginal and especially perianal fistulas the higher contrast resolution of T2w TSE is of more importance. In patients with perianal fistulas T2w TSE facilitates the identification of even small amounts of fluid or thin inflamed walls. In subtle cases fat suppression (fat saturation, spectral inversion recovery [SPIR] or STIR) might be valuable for increasing the level of confidence and is therefore included in our imaging protocol for perianal fistulas. Intravenous contrast medium might be used in the detection of perianal fistulas, but to our knowledge no study has demonstrated the superiority of this technique over other imaging sequences. Anovaginal fistulas are most easily identified against the background of hyperintense veins in the anovaginal septum. Imaging sequences resulting in hyperintense veins, such as T2w sequences, GRE sequences or T1w sequences after intravenous contrastmedium, should be used. In patients with anorectal tumors the contrast between tumor and wall is most optimal using T2w TSE. PDw GRE is too susceptible to motion artifacts by rectal contractions. Tumor extension through the wall into the perirectal fat or anal sphincter and the identification of enlarged lymph nodes is most optimal with T1w images. Intravenous contrast medium can be of help in determining tumor extent. The use of dynamic turbo-FLASH has been advocated to improve the differentiation between T2 and T3 tumor. Despite buscopan or glucagon often some motion artifacts in the phase encoding direction occur due to rectal contractions. The phase encoding direction in patients with fecal incontinence and anovaginal fistulas is left-right as pathology is expected anteriorly.

For perianal fistulas there is no clear preference for the phase encoding direction. The external opening might be an indicator but often the track has no simple superior-inferior extent. For anorectal tumors the findings at rectal digital examination can indicate the preferred phase encoding direction. However, in most cases, part of the tumor will be in the phase encoding direction.

Scan planes

All scan planes used for endoluminal MRI are off-axis orthogonal or parallel to the coil and anorectum. This facilitates the identification of normal anatomy and diseases and reduces partial volume effects. The axial plane is the most informative plane for evaluating anorectal pathology. One or more longitudinal sequences will give a better appreciation of the superior-inferior extent of disease (12). Coronal and sagittal sequences or a radial sequence can be used. The slices of a radial sequence are not parallel to each other but have a spoke wheel like orientation. The signal void at the center of the sequence is in the signal void of the center of the coil and will therefore not interfere with imaging. The sequence has the theoretical advantage that all slices are perpendicular to the coil and anorectum with therefore less partial volume effects. A major reason to use this sequence is that it is more time efficient than performing a coronal and sagittal sequence (12). The interpretation of the anal anatomy is somewhat more difficult with a radial sequence. The coronal and sagittal sequences are therefore the preferred longitudinal sequences in patients with fecal incontinence. Perianal fistulas and anorectal tumors can be evaluated using axial and radial T2w TSE. This is especially of importance in anorectal tumors as it will give less partial volume effects. For anovaginal fistulas the axial plane and the sagittal plane are most informative as the track will have an anterior-posterior orientation.

Table 1. Imaging sequences and scan planes*

Sequence	TR (ms)	TE (ms)	FA	Slice (mm) /gap	FOV	Matrix	TF (ETL)	NEX
PDw GRE**	23.7	13.8	60°	2 / 0	112 x 140	256 x 256	-	2
T2w TSE***	2500	100	90°	3 / 0.3	90 x 160	253 x 512	10	3
T1w TSE	500	17	90°	4 / 0.3	135 x 180	255 x 512	5	4

*Note: Imaging sequences for endoluminal MRI of rectum and anus used at our institution at 1.5T (Philips Gyroscan ACS-NT, Philips Medical Systems, Best, The Netherlands).
**Note: PDw GRE should be performed first because of susceptibility to motion artefacts.
***Note: T2w TSE can be combined with fat suppression (SPIR, fat sat) for perianal fistulas, or STIR-TSE can be used.

Table 2. Imaging protocols for endoluminal MRI#

Disease	Scan plane	Sequence	Scantime (min)	Roomtime (mm)
Fecal incontinence	axial	PDw GRE		
	coronal	T2w TSE	16	40
	sagittal	T2w TSE		
Perianal fistula	axial	T2w TSE		
	axial SPIR	T2w TSE	17	45
	radial	T2w TSE		
Anovaginal fistulas	axial	T2w TSE	10	30
	sagittal	T2w TSE		
Anorectal	axial	T2w TSE		
tumors##	axial	T1w TSE	21	50
	radial	T2w TSE		
	radial	T1w TSE (iv contrast)		

#Note: Imaging protocols for endoluminal MRI of rectum and anus used at our institution at 1.5T (Philips Gyroscan ACS-NT, Philips Medical Systems, Best, The Netherlands).

Note: additional sequence for the detection of liver metastases and iliacal lymphnodes should be performed with body coil or phased array coil.

Imaging protocols

Imaging sequences and protocols for endoluminal MRI of rectum and anus used at our institution at 1.5T (Philips Gyroscan ACS-NT, Philips Medical Systems, Best, The Netherlands) (Table 1 and 2).

As dedicated endoanal coils can also be used for endorectal imaging, this type of coil is preferred at our institutions for both anal and rectal imaging .

Anatomy

The anal sphincter comprises several muscular structures (4). With endoluminal MRI using T2 weighted images these layers can be identified as distinct structures (Fig. 2) and are more accurately demonstrated than with phased array coil MRI (2,13,14). The innermost muscle is the internal sphincter, which is the continuation of the circular muscle of the rectum.

Outside the internal sphincter is the fat containing intersphincteric space. In this space is the longitudinal muscle, which is the continuation of the longitudinal muscle of the rectum. The intersphincteric space is bordered by the external sphincter and the puborectalis muscle. The external sphincter surrounds the lower half of the intersphincteric space, and the puborectalis muscle the upper half of the intersphincteric space. This concept of the anal anatomy, based on endoluminal MRI, is different to previous concepts with regard to the external sphincter (4,15). In the previous concepts, based on surgery or dissection, the external sphincter was thought to comprise almost the complete outer part of the sphincter. The current concept results from the detailed demonstration of the anal anatomy and the multiplanar capabilities of endoanal MRI, which facilitates the identification of the external sphincter and puborectalis muscle more accurately. Although the presence of a coil will compress the sphincter components, it will not significantly alter the relationship between the sphincter structures. Therefore the different concept is not caused by the presence of the coil but by the detailed multiplanar demonstration of the anal anatomy. The upper part of the anal sphincter is continuous with the rectum. The rectal wall comprises the mucosa, submucosa and the circular and longitudinal muscular layer.

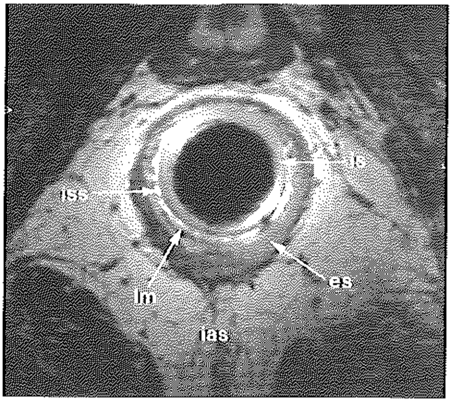


Figure 2a

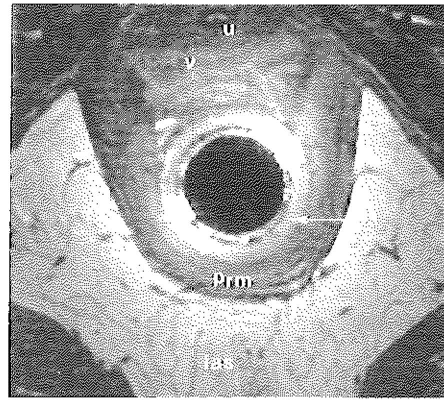


Figure 2b

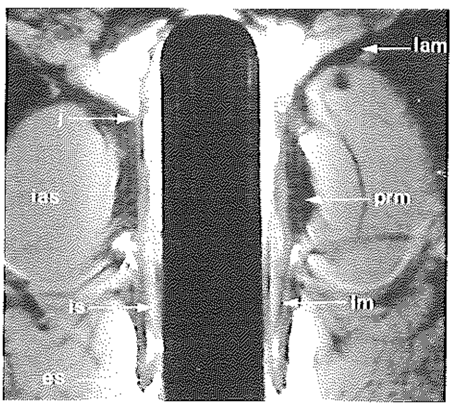


Figure 2c

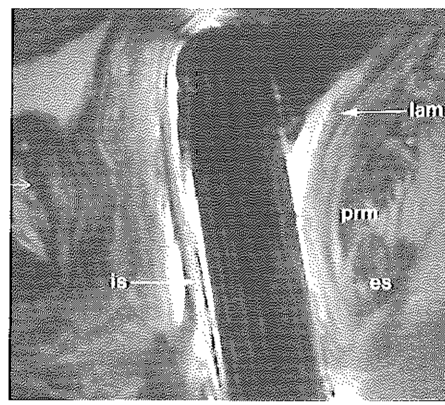


Figure 2d

Normal anatomy of the anal sphincter in the axial, coronal and sagittal planes.
2a. Axial proton-density weighted GRE [TR 23.7ms, TE 13.8ms] through the lower part of the anal sphincter. The external sphincter (ES) is the outer part of the sphincter complex and is relatively hypointense. The internal sphincter (IS) is the inner muscular part of the sphincter complex and is relatively hyperintense. The longitudinal muscle (LM) is within the intersphincteric space (ISS) between the internal and external sphincter. The sphincter complex is surrounded by the ischioanal space (IAS).
2b. Axial proton density weighted GRE [TR 23.7ms, TE 13.8ms] through the upper part of the sphincter complex. The sling-like puborectalis muscle (PRM) is at this level the outer part of the sphincter complex. The puborectalis muscle is relatively hypointense. Internal sphincter (IS), vagina (V), urethra (U), ischioanal space (IAS).
2c. Mid coronal T2w TSE [TR 2500 ms, TE 100 ms] through the anal sphincter. All muscular parts of the anal sphincter and their relationship are clearly demonstrated: external sphincter (ES), internal sphincter (IS), puborectalis muscle (PRM) and longitudinal muscle (LM). Also the levator ani muscle (LAM) and the anorectal junction (J) are visualized. Ischioanal space (IAS).
2d. Mid sagittal T2w TSE [TR 2500 ms, TE 100 ms] through the anal sphincter. The relation between the external sphincter (ES) and puborectalis muscle (PRM) can be appreciated, especially posteriorly. Internal sphincter (IS), levator ani muscle (LAM).

The levator ani is connected to the anal sphincter complex at the level of the anorectal junction. Controversy exists concerning the anal sphincter anatomy. The present anatomical concept is based on the results of anatomical dissection and surgery. The discussion is focused on whether the external sphincter comprises several parts and whether the puborectalis muscle is an important component of the sphincter complex. The advantage of endoluminal MRI over anatomical dissection and surgery is the multiplanar capability which is of paramount importance for understanding the anatomy of the anal sphincter and related structures.

Fecal incontinence

Fecal incontinence is an important medical and social problem. Approximately 2% of the population older than 45 years suffer from this disease (16). Sphincter defects and pudendal neuropathy are major causes of incontinence. Treatment can be conservative (e.g. rectal cleaning by enema, drugs, biofeedback) or surgical. The surgical treatment will in the majority of patients be directed towards repair of defects of the external sphincter. Pudendal neuropathy can thereby negatively influence the outcome of treatment. The role for imaging is in identifying anal sphincter defects, which may be treated by surgery. Sphincter defects are often caused during vaginal delivery or anal surgery. A less common cause is a deficient sphincter after surgery for anal atresia or trauma. The role for imaging in patients with fecal incontinence is in the identification and characterization of sphincter defects. Most anal sphincter defects are in the anterior part of the external and internal sphincter as vaginal delivery is the major cause of fecal incontinence. Until this decade, digital examination, anal manometry and electromyography were used in the detection of anal sphincter defects. Digital examination and anal manometry proved to be too insensitive for the detection of sphincter defects. Electromyography has the advantage that it gives direct functional information, but major drawbacks are that the method is blind and invasive. Electrodes will commonly be placed at four standard positions and therefore defects between these points will be missed. Endoanal sonography was the first imaging technique to visualize the anal sphincter muscles and had significant impact on patient management.

The technique is now part of the routine diagnostic work up of patients with fecal incontinence. However, it has a limited contrast resolution. The differentiation between the external sphincter and the surrounding fat is often cumbersome, resulting in a hyperechoic region outside the internal sphincter. This region includes the intersphincteric space, the longitudinal muscle, the external sphincter and the ischioanal space. Lesions of the external sphincter are defined as disturbance of this hyperechoic region but the external sphincter itself is often not directly visualized. For an optimal treatment an accurate visualization of the external sphincter is mandatory.

MRI has an inherent contrast resolution superior to sonography. The spatial resolution of body coil MRI is too limited for an adequate visualization of the sphincter complex (17). With the introduction of endoanal MRI an accurate demonstration of the anal anatomy, including the external sphincter, has become possible. Recent studies using endoanal MRI have led to a new insight in the anal anatomy (see anatomy section)(4,15). This better visualization of the anal anatomy results in an improved detection of external sphincter lesions (Fig. 3,4).

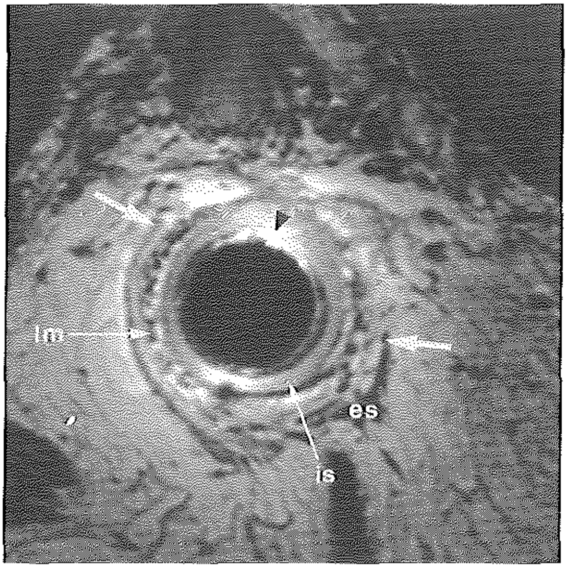


Figure 3. Axial proton density weighted GRE [TR 23.7ms, TE 13.8 ms]. Large anterior defect (arrows) of the external sphincter (ES). The external sphincter is somewhat atrophic. Relatively small left anterior internal sphincter (IS) lesion (arrowhead). Longitudinal muscle (LM).

In a study of 22 patients, comparing imaging results to surgical findings, endoanal MRI was more accurate than endoanal sonography in detecting sphincter lesions (11). MRI detected 20 of the 22 external sphincter lesions, while sonography detected 16 of the 22 external sphincter lesions.

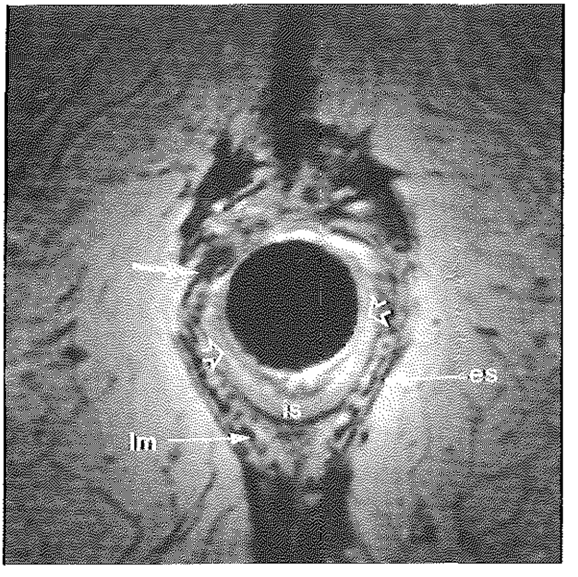


Figure 4. Axial proton density weighted GRE [TR 23.7 ms, TE 13.8 ms]. Anterior defect (open arrows) of the internal sphincter (IS). Anterior defect and scar tissue (arrow) of the longitudinal muscle (LM) and external sphincter (ES).

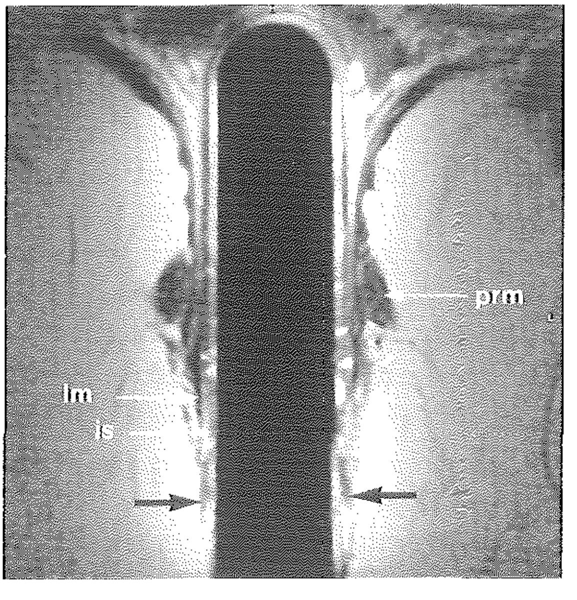


Figure 5. Coronal T2w TSE. Atrophic external sphincter (ES) (compare Fig. 2c). Only some thin parts of the external sphincter have remained (arrows). The internal sphincter (IS), longitudinal muscle (LM) and puborectalis muscle (PRM) are normal.

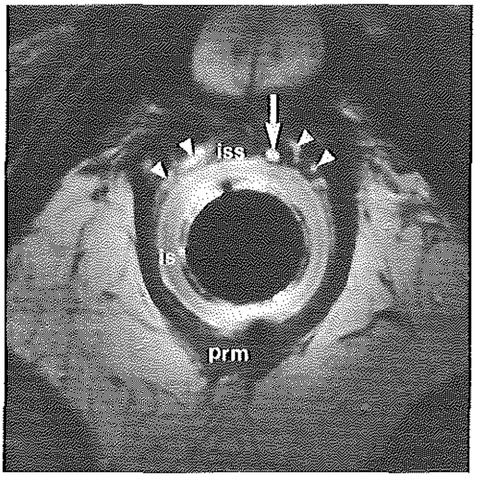
Endoanal MRI was also more accurate in detecting the type of sphincter lesion (e.g. defect, scar). Another advantage of endoanal MRI is the detection of external sphincter atrophy that is not possible with endoanal sonography (Fig. 5). External sphincter atrophy is a diffuse thinning of the external sphincter muscle or replacement of muscle by fat. In a study of 15 patients endoanal MRI proved to be accurate in the detection of external sphincter atrophy as compared to histopathology (18). In a retrospective study the presence of external atrophy proved to be an important predictor for the negative outcome of anal repair (10). The anal anatomy is accurately demonstrated with PDw or T2w sequences or T1w sequences after intravenous contrast medium. We prefer a 3D PDw gradient-echo for an optimal contrast resolution and spatial resolution. The axial plane is the most informative plane and one or more additional longitudinal planes should be used to fully evaluate the anal anatomy and anal sphincter pathology. To our knowledge, no studies on the value of phased array coil MRI in fecal incontinence have been performed. In our opinion the spatial resolution of phased array coil MRI is too limited for an adequate demonstration of the subtle abnormalities in sphincter lesions.

Perianal fistulas

Perianal fistulas can occur without predisposing disease or in patients with Crohn's disease. Inflammation of the cryptal glands in the anal submucosa result in the development of a track. In general, one track will develop but especially in patients with Crohn's disease multiple tracks may occur. Commonly the track will only extend downward, towards an external opening at the skin, but upward extension to or above the levator ani muscle may occur. The presence of an active perianal fistula is often obvious on clinical grounds. The major role for imaging in patients with perianal fistulas is in classification of the track. Classification is important as it will determine the type of surgery and thereby the risk of post-surgical fecal incontinence. Commonly, the classification according to Parks is used (19).

In this classification a track confined to the internal sphincter and intersphincteric space is an intersphincteric fistula. Extension of a track through the external sphincter is classified as a transsphincteric fistula.

A suprasphincteric track has extension above the levator ani muscle and an extrasphincteric fistula has a course outside the anal sphincter to the rectum. A track can be simple, complex or may have a horse-shoe shape. Initially fistulography was used for classification. However this is often a cumbersome procedure with only limited results (20). The major drawback of this technique is that the classification is indirect as the anal sphincter is not visualized. In the eighties, endoluminal sonography was introduced and resulted in improved classification (21).



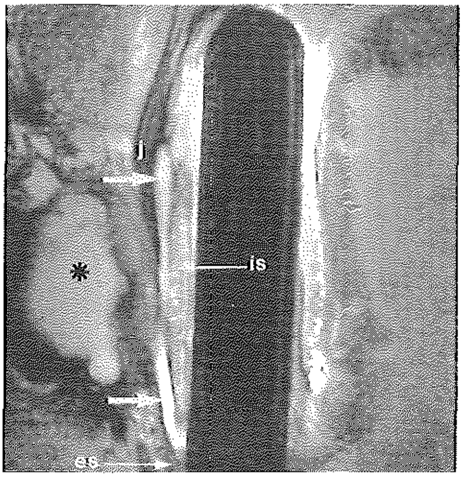


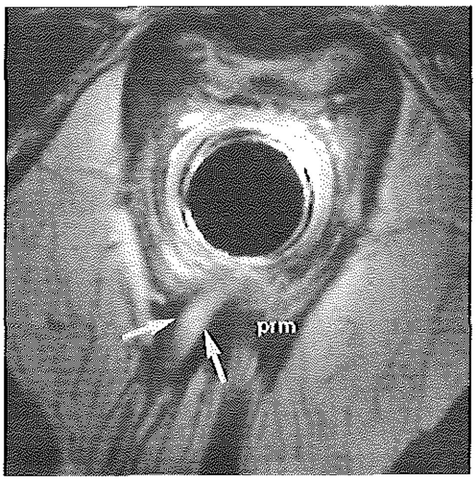
Figure 6a **Figure 6b**

6a. Axial T2w TSE [TR 2500 ms, TE 100 ms] at the upper part of the anal sphincter demonstrates a fistula (arrow) anteriorly in the intersphincteric space (ISS). Some veins anteriorly (arrowheads). Internal sphincter (IS), puborectalis muscle (PRM).

6b. Slightly oblique sagittal T2w TSE [TR 2500 ms, TE 100 ms]. The track (arrows) is limited to the intersphincteric space between internal sphincter (IS) and external sphincter (ES) and therefore classified as an intersphincteric fistula. It reaches close to the anorectal junction (J), but does not extend into the supralevator space. Cavernous body anteriorly (asteriks).

Major drawbacks of endoluminal sonography were the inaccurate identification of the external sphincter and the difficult differentiation between scar tissue and a track. Several years ago the value of body coil MRI in the identification and classification of perianal fistulas was demonstrated (22). However, the limited spatial resolution of body coil MRI often prevents the identification of tracks and their relation to the sphincter (1).

Endoluminal MRI proved to be superior to body coil MRI and endoluminal sonography (1,2). A comparative study of endoluminal sonography and endoluminal MRI in 28 patients revealed a better classification with endoluminal MRI (2).



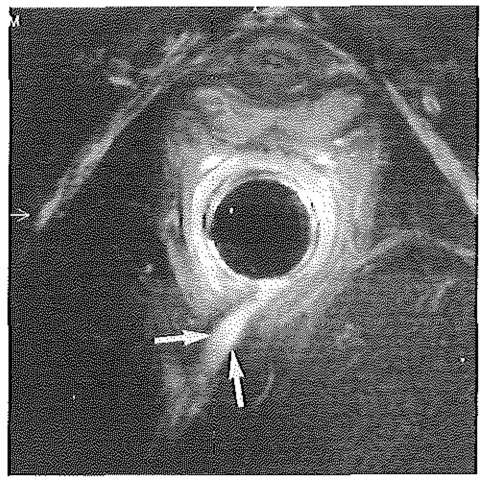
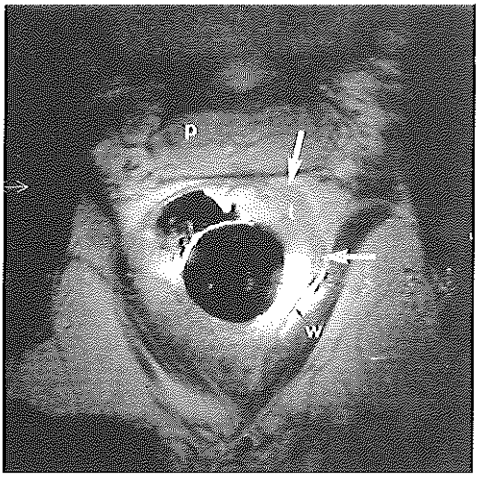


Figure 7a **Figure 7b**

7a. Axial T2w TSE [TR 2500 ms, TE 100 ms] of the upper part of the anal sphincter demonstrates a fistula (arrows) transversing the puborectalis muscle (PRM) right posteriorly. The track is classified as a transsphincteric fistula. This fistula has the typical morphology of an active perianal fistula, as the track is fluid filled.
7b. Axial T2w TSE [TR 2500 ms, TE 100 ms] with SPIR (fat sat). The track (arrows) is more conspicuous than without SPIR.

The axial plane is the preferred imaging plane while additional longitudinal imaging planes are used to improve classification (Fig. 6a,b) (23). Coronal and sagittal imaging planes or alternatively a radial sequence can be used. With a radial sequence the slices have a spook wheel like orientation (1,23). T2w sequences, fat suppression or T1w sequences after intravenous contrast medium can be used. The advantage of the usage of intravenous contrastmedium is debatable. It increases the cost of the procedure while, to our knowledge, no study has demonstrated the superiority of this technique. We prefer an axial T2w sequence combined with an axial fat suppression sequence (STIR-TSE or fat sat T2w TSE) and an additional T2w sequence in a longitudinal plane. Fat suppression technique may facilitate the identification of tracks, but classification of tracks is not improved as the relation of the track to the sphincter is more difficult to appreciate (Fig. 7a,b). Perianal fistulas present with a thick fibrous wall, are fluid filled, and enhance after intravenous contrast medium. Non-active perianal tracks are fibrous bands without fluid or significant enhancement.

Recently the value of phased array coil MRI for fistula identification and classification was demonstrated. Phased array coil MRI has the advantage that no coil has to be introduced, while the use of a larger field of view can be advantageous in extensive tracks. Phased array coils are more expensive but can be used for numerous indications. In our opinion phased array coil MRI will identify and correctly classify the large majority of tracks. Whether very small tracks or small blind tracks can be as accurately detected as with endoluminal MRI remains to be demonstrated.



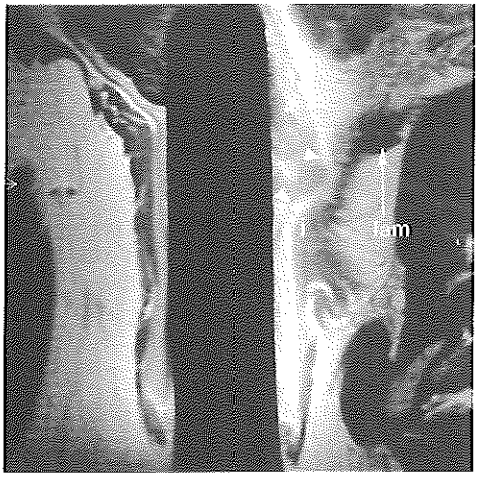


Figure 8a **Figure 8b**

8a. Axial T2w TSE [TR 2500 ms, TE 100 ms] demonstrates invasion of a rectal tumor (T) through the rectal wall (W) into the perirectal fat (arrows). No invasion in the prostate (P).
8b. Coronal oblique radial T1w TSE [TR 500 ms, TE 17 ms] after gadodiamide shows the invasion of the perirectal fat (arrowheads). The tumor displaces the levator ani muscle (LAM) but there is no invasion. A fat plane is visible between tumor and levator ani muscle (LAM). The tumor is very close to the anorectal junction (J).

Anorectal tumors

Tumors of the rectum are relatively common, while anal tumors are relatively rare. The major role for imaging in anorectal tumors is staging. Staging is important as the spread of the disease will influence the prognosis and the type of therapy.

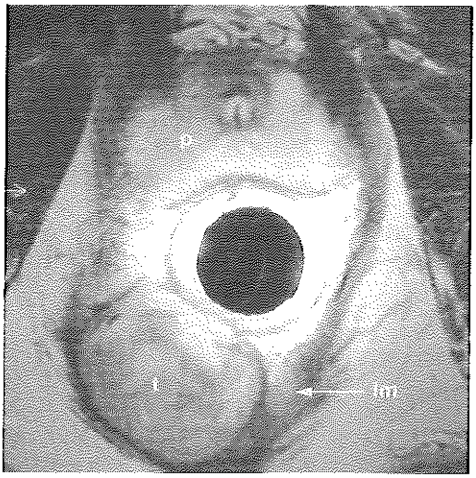


Figure 9a

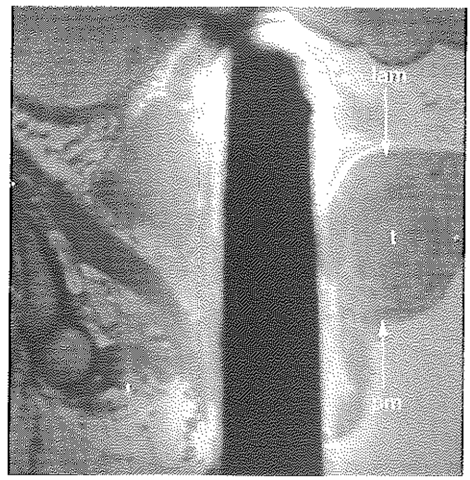


Figure 9b

9a. Axial T2w TSE [TR 2500 ms, TE 100 ms]. Non-Hodgkin lymphoma (T) against the longitudinal muscle (LM). The exact tumor location is difficult to appreciate without a complimentary longitudinal sequence. Prostate (P).
9b. Radial oblique sagittal T1w TSE [TR 500 ms, TE 17 ms] after gadodiamide reveals that the tumor (T) is located between puborectalis muscle (PM) and levator ani muscle (LAM).

Important items to be addressed are the tumor-anus distance, the extension of tumor in or through the wall, the presence of enlarged lymph nodes and distant metastases. Developments in treatment made the tumor – anus distance relevant as anus saving (and thus continence saving) surgery can be performed. The margin of normal rectum between a distal rectum tumor and the anus can be more accurately established by endoluminal MRI than by endoluminal sonography. Endoluminal MRI can visualize the anorectal wall and the tumor in detail (2,13) (Fig. 8,9).

In daily clinical practice the most important issue is the differentiation between tumor limited to the wall (T1 and T2) or tumor extending outside the rectal wall (T3 and T4) (24). The accuracy of T-staging of rectal tumor is approximately 75-85% and is superior to body coil MRI (6,25-27). The results on T-staging are not clearly superior to endoluminal sonography. Limitations are understaging caused by microscopic invasion or overstaging caused by desmoplastic reaction. Overstaging seems to be more frequent. A recent study has reported on the value of dynamic turbo-FLASH for the differentiation between T2 and T3 tumor (27).

Recent developments in coil technology have resulted in phased array coils, which give high resolution possibilities without the use of an endoluminal coil (28). A recent study has demonstrated that the use of an endoluminal coil will result in a more detailed demonstration of the rectal wall than with the use of phased array coils, but this did not result in an improved staging accuracy (13). Significant limitations of endoluminal MRI are the impossibility to perform an adequate study in the presence of a tight stricture or a high stricture and the visualization of spread outside the FOV. These limitations do not apply to phased array coil MRI. Data on the staging of anal tumors are sparse with either technique. Isolated anal tumors are often limited masses at detection. In our limited experience the detailed demonstration of the anal anatomy and pathology with endoanal MRI gives more relevant information on tumor spread than phased array coil MRI.

The data on lymph node staging of rectal tumors are limited. One study has reported an accuracy of 80% (29). The specificity has been reported to be 50-70% (2,25,26). For each imaging technique a major problem is the differentiation between reactive inflammatory lymph nodes and metastatic lymph nodes. With endoluminal techniques small perirectal lymph nodes are more easily detected, but parailiac and paraaortal lymph nodes are missed. In a study comparing phased array coil MRI to phased array coil MRI combined with an endoluminal coil, the accuracy was essentially the same (13). The accuracy of tumor and lymph node staging is not optimal with either technique. Many efforts should be made to establish which technique is preferable. To date phased array coil MRI is the preferred imaging technique for staging rectal tumors, while endoluminal MRI can be used as alternative method.

Miscellaneous

Endoluminal MRI can be also valuable for other indications. For example, anovaginal fistulas or endometriosis of the anovaginal septum may require preoperative localization. Perianal fistulas and anovaginal fistulas have different etiologies (inflammation versus trauma) resulting in a different presentation at MRI.

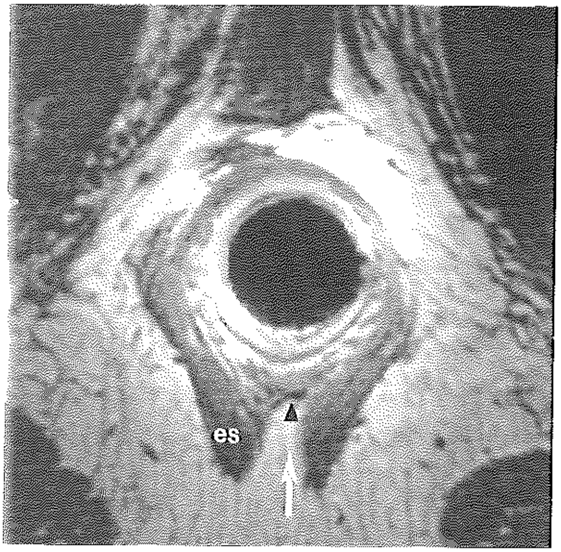


Figure 10. Axial proton density weighted GRE [TR 23.7 ms, TE 13.8 ms] 2.5 cm above the lower edge of the external sphincter in a male. The morphology of the external sphincter (ES) posteriorly (arrow) may suggest a tear, but this is a normal variant of the external sphincter. There is external sphincter tissue present more anteriorly (open arrow).

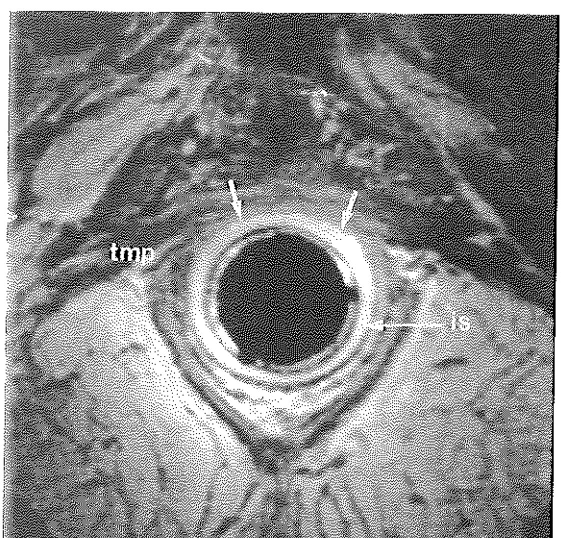


Figure 11. Axial proton density weighted GRE [TR 23.7 ms, TE 13.8 ms] in a female patient at 1.4 cm superior to the caudal edge of the external sphincter. The external sphincter is not visible anterior (arrows). This is not a defect but this is the normal aspect of the anterior sphincter at this level in a female. The external sphincter is approximately 1.4-1.6 cm high in normal females. Internal sphincter (IS), transverse perineal muscle (TPM).

Anovaginal fistulas are thin walled and have no or only a small amount of fluid or air present in the track. Limited data concerning imaging of anovaginal fistulas have been published. To our knowledge, no comparative data on endoluminal sonography, body coil MRI and endoluminal MRI have been performed. In our limited experience endoluminal sonography and endoluminal MRI seem to have comparable results. In patients with scleroderma the fibrosis of the external sphincter can be eva-luated.

Pitfalls

With the use of endoluminal MRI one should be aware of pitfalls specific for this anatomical region as well as pitfalls also encountered at other regions.

A. The wide normal variation of the anal anatomy can lead to misinterpretation. The posterior part of the external sphincter can be partially open in males (Fig. 10). This can be easily recognized as a normal variant as it has a symmetric aspect, the margins are smooth and no scar tissue is present.

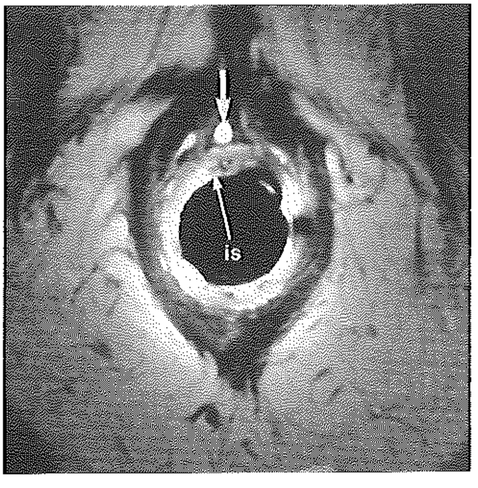


Figure 12a

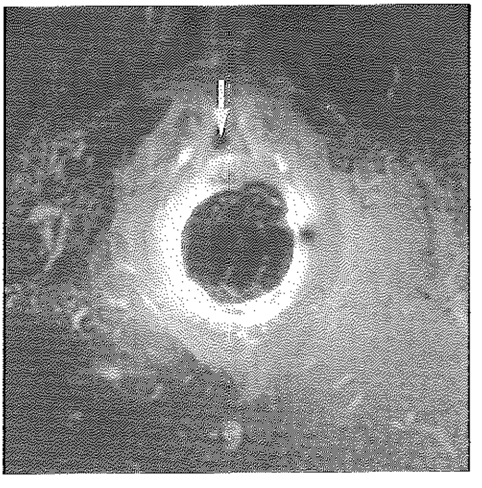


Figure 12b

12a. Axial T2w TSE [TR 2500 ms, TE 100 ms] at the central part of the anal sphincter in a patient with a complex fistula at the lower part of the anal sphincter. The hyperintense oval structure (arrow) anterior to the internal sphincter (IS) might be interpreted as a fistula or small abscess.

12b. With SPIR (fat sat) no high signal intensity is visible (arrow). This high signal intensity is caused by fat in the intersphincteric space which has high signal because of the high sensitivity close to the coil (near field effect).

B. More difficult is the relatively short external sphincter anteriorly in females (Fig. 11). Part of the anterior sphincter complex is supported by the transverse perineal muscle. This normal variant of the anterior anal sphincter might be misinterpreted as an anterior external sphincter defect.

C. With the use of the endoluminal coil the signal intensity close to the coil is relatively high. This may result in fat having a very high signal intensity on T2w TSE what might be interpreted as a fistula or abscess (Fig. 12).This is often easily appreciated as other fat at a comparable distance to the coil also has high signal intensity. Fat suppression can be of use in equivocal cases (Fig. 12b).

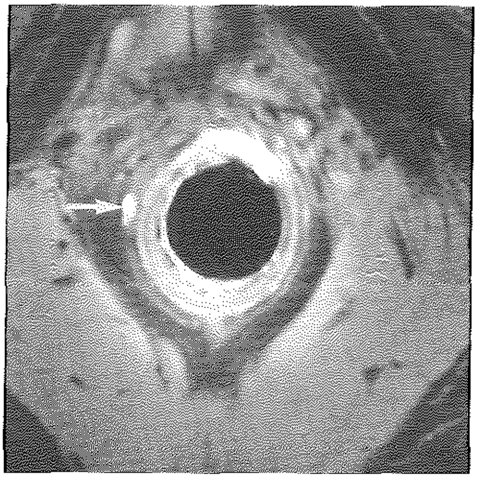


Figure 13a

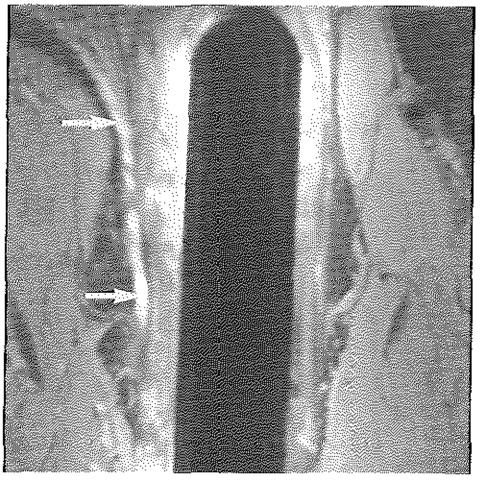
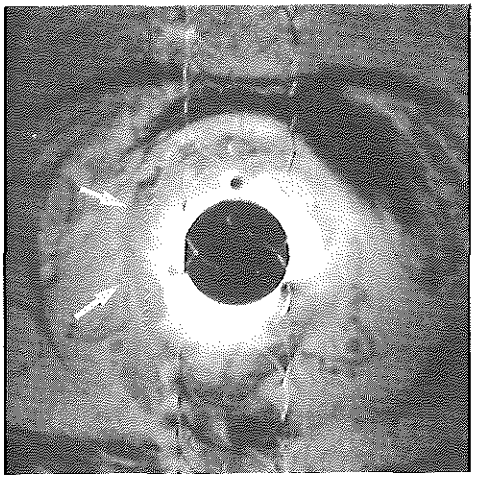


Figure13b

13a. Axial T2w TSE [TR 2500 ms, TE 100 ms] shows a hyperintense structure (arrow) in the intersphincteric space, possibly a fistula.
13b. Slightly oblique coronal T2w TSE [TR 2500 ms, TE 100 ms]. The hyperintense structure right lateral in the intersphincteric space (arrows) has a very thin wall and a lobulated, serpiginuous aspect. This is a vein and not a fistula. The vein is continuous with the periprostatic veins. Compare this case with a perianal fistula as in Fig. 6b. In Fig. 6b the track has a more straight course than in this figure, the wall is thicker and thère is no connection to vascular structures.

D. The venous anatomy of the anal sphincter region is complex and multiple veins are present in the submucosal, intersphincteric and ischioanal space. Although the veins are often identified as such, a vein might be interpreted as a fistulous track (Fig. 13a). Both can be hyperintense on T2w imaging and can enhance after intravenous contrastmedium. Veins can be differentiated from fistulas as veins have a tortuous course, a thin wall and are continuous with other veins (Fig. 13b). Fistulas often have thick fibrous walls, a relatively straight course and have an internal opening.

E. A hemorrhoid can be misinterpreted as an abscess. This pitfall can be identified by recognising that a hemorrhoid has a thin wall and is continuous with other venous structures.



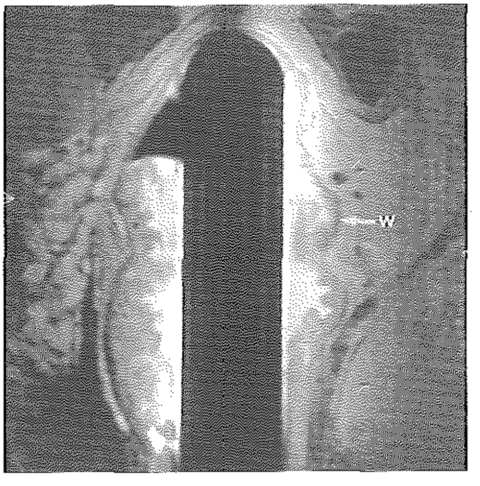


Figure 14a **Figure 14b**

14a. Axial T2w TSE [TR 2500 ms, TE 100 ms] of a patient with a rectal carcinoma. Artefacts in the phase encoding direction are caused by rectal contractions. This study might be read as tumor invasion (arrows) through the rectal wall as there is no normal muscular layer visible. However, the protocol also includes longitudinal sequences.
14b. Sagittal oblique T2w TSE [TR 2500 ms, TE 100 ms] demonstrates that there is no invasion in or through the muscular layer of the rectal wall (W). Partial volume effects were present in the axial plane. This case stresses the importance of longitudinal imaging planes.

F. The use of a single imaging plane can lead to partial volume effects. In tumors this can lead to incorrect staging (Fig. 14). This can be prevented by including an additional plane in the imaging protocol.

G. In distal rectal tumors the distance between tumor and anal sphincter is of importance for the decision for sphincter saving surgery. Cauliflower-like tumors will overhang a part of the normal rectal wall and this can lead to underestimation of the tumor-sphincter distance (Fig. 15). This can be prevented by recognising the cauliflower-like aspect of the tumor at digital rectal examination and by identifying the base of the tumor at endoluminal MRI.

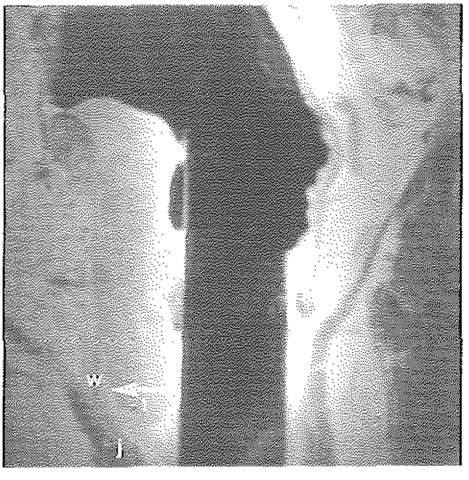


Figure 15. Coronal oblique radial T1w TSE [TR 500 ms, TE 17 ms] after gadodiamide in a patient with a distal rectal tumor. The tumor almost seems to reach to the anorectal junction (J) preventing sphincter saving surgery. However high signal intensity inflammatory tissue between the overhanging lower part of the tumor (T) and the rectal wall (W) is visible (arrow). The tumor base is 2 cm above the anorectal junction. Sphincter saving surgery was performed. At surgery the cauliflower-like tumor was overhanging the distal rectal wall. There was distal enough normal rectum for the anastomosis.

Limitations

Mild discomfort at coil introduction occurs in patients with perianal fistulas (prevalence 10%). Severe discomfort or anal stenosis may prevent endoanal MRI (prevalence 2%). In patients with fecal incontinence, anovaginal fistulas or anorectal tumors no significant discomfort is reported.

The sensitive region of the endoluminal coil is large enough for evaluation of sphincter defects and anovaginal fistulas. Large or high rectal tumors and extensive perianal fistulas may extend outside this region. In these infrequent cases, additional sequences with the body coil or phased array coil can be performed for a complete visualization of the disease. In long, tight strictures the use of body coil or phased array coil is preferable, but even in these patients endoluminal MRI may give the correct staging. Enlarged perirectal lymph nodes will be demonstrated but body coil or phased array coil MRI is necessary for evaluation of parailiacal lymph nodes and liver.

Conclusion

Endoluminal MRI has become an important technique in the diagnostic work up of patients with anorectal diseases. This technique is in several aspects superior to endoluminal sonography and body coil MRI. The advantage of endoluminal MRI over phased array coil MRI is less well substantiated. For perianal fistulas both techniques, endoluminal MRI and phased array coil MRI, are valuable and the results might prove to be comparable. Phased array coil MRI is expected to be superior in extensive disease and endoluminal MRI is expected to be superior in subtle tracks relatively close to the coil. Phased array coil MRI is the imaging technique of choice for rectal tumors. Endoluminal MRI can be used as alternative technique and is the preferred imaging technique in anal tumors. A major field of application of endoluminal MRI is in patients with fecal incontinence. In our opinion, endoluminal MRI is in these patients superior to all other techniques. Current research is directed towards further evaluation of the role of endoluminal MRI in fecal incontinence and in the comparison of phased array coil MRI to endoluminal MRI and the combination of both coils in several applications.

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CHAPTER 3

HIGH RESOLUTION ENDOANAL MRI: AGE AND SEX-RELATED VARIATIONS OF NORMAL ANAL SPHINCTER ANATOMY

Introduction

Knowledge of the normal anatomical features of the anal canal is essential for the diagnosis and treatment of anal diseases. However, unlike the morphology of the rectum, the anatomy of the anal canal was often subject to contradictory views (1,2). Initial descriptions were based on dissection studies and observations during surgery. Introduction of endoanal imaging techniques opened new possibilities of in vivo evaluation of pelvic structures. Endoanal ultrasonography facilitates demonstration of anal structures but is still limited by the often inaccurate delineation of the external sphincter (3). Endoanal MRI provides multiplanar, high-resolution demonstration of anal anatomy and a fine delineation of all sphincter muscles. This led to recent revision of the knowledge of anal sphincter anatomy (4-6). Especially when dealing with sphincter atrophy as a cause of fecal incontinence in elderly, a refined knowledge of anal anatomy and of the impact of aging on sphincter structures is extremely useful.

The purpose of this study was to analyze possible variations of normal sphincter anatomy as seen with high-resolution endoanal MRI. Furthermore, sex- and age-related variations in thickness and length of the anal sphincter were evaluated in order to refine the diagnosis of sphincter atrophy. Additionally, potential pitfalls of endoanal MRI were assessed.

This chapter is adapted from:
Rociu E, Stoker J, Eijkemans MJC, Laméris JS. High resolution endoanal MRI: age and sex-related variations of normal anal sphincter anatomy. Radiology 2000; in press.

Materials and methods

Following approval by the institutional review board and after obtaining written informed consent, 100 healthy subjects carefully selected for no history or symptoms of pelvic floor diseases were included in the protocol. The studied group consisted of 50 females and 50 males evenly distributed between age 20 and 81 (median age 52) as follows: 10 females and 10 males in each of the age categories: 20-35, 36-45, 46-55, 56-65, 66-85.

High-resolution endoanal MR imaging was performed at 1.5 T (Gyroscan ACS-NT, Philips Medical Systems, Best, The Netherlands) without bowel preparation. Before imaging, 1 ml butyl-scopolamine bromide (Buscopan, 20mg/ml; Boehringer Ingelheim KG, Ingelheim, Germany) was injected intramuscularly to reduce bowel motion. The endoanal coil (Philips Medical Systems, Best, The Netherlands) with a diameter of 19 mm was covered with a condom and lubricant was applied to the surface. An axial, proton density weighted (PDw), three-dimensional gradient-echo (3D GRE) sequence (acquisition time 6.5 min., repetition time 30 msec, echo time 13 msec, flip angle 60°, field of view 140 mm x 112 mm, imaging matrix 205x256, section thickness 2 mm, contiguous slices, 2 excitations) was performed perpendicular to the long axis of the endoanal coil. For sagittal and coronal images, T2-weighted turbo spin-echo (T2w TSE) sequences were performed (acquisition time 5.0 min., repetition time 2800 ms, effective echo time 120 ms, echo train length 10, echo spacing 21.8 ms, field of view 120 mm x 90 mm, imaging matrix 186 x 256, section thickness 4.0 mm with an intersection gap of 0.4 mm, 8 excitations). The coronal and sagittal sections were parallel to the long axis of the endoanal coil. Until now, the optimal imaging sequences for endoluminal MRI of rectum and anus have not been definitely established. The use of T1w imaging with intravenous contrast medium, short-time-inversion recovery and T2w turbo spin-echo has been advocated (7,8,9). In our experience PDw GRE and T2w TSE give very good results without the need of intravenous contrast medium. PDw GRE allows thin slices important for the scrupulous examination of the anus and T2w TSE, less susceptible to motion artifacts than GRE, provides fine overviews. These sequences are therefore the mainstay of our imaging protocols for endoluminal MRI of the anus.

Image analysis

The quality of the images (good/moderate/poor) was scored. The essential anatomical structures were evaluated (external and internal sphincter, longitudinal muscle, puborectalis muscle, levator ani muscle, superficial and deep transverse perineal muscle, bulbospongiosus muscle, anococcygeal ligament, central perineal tendon).

Two experienced radiologists evaluated the images separately using an Easy Vision workstation (Philips Medical Systems). The lengths of the anal canal, of the external sphincter and of the puborectalis muscle were measured. The thickness of the anal sphincter muscles (external and internal sphincter, longitudinal, puborectalis muscle) and levator ani muscle were measured as well. All these measurements were performed on mid coronal images, except for the external sphincter anterior part were mid sagittal images were used. From each muscle the measurement on its largest portion was considered in order to avoid misdiagnosing it thinner than real. Measurements were performed on the left and right side of the sphincter complex; each side was separately evaluated. Sex-related differences and interobserver variation in measurements were assessed using Mann-Whitney test. Age-related variation was evaluated using Pearson's correlation. A P-value below 0.05 was considered to indicate statistical significance.

Results

The endoluminal device was well tolerated by all volunteers. The quality of the MRI images was good in 91%, moderate in 7% and poor in 2% of the cases. In the last two cases motion artifacts occurred.

1. MR Anatomy

The anatomical structures described were visible in all three directions but a certain plane was often particularly useful to demonstrate a certain feature. The coronal plane offered usually a good general overview, the sagittal plane helped to elucidate the morphology at the anterior side, and finally the more detailed axial slices allowed assessment of potential pitfalls.

1.1. Anatomic appearance on T2w TSE sequences in the coronal plane (Fig. 1-3).
The anal sphincter surrounds the most distal part of the digestive tract, the anal canal. At the dentate line, the mucosa and submucosa of the rectum change into squamous epithelium and subepithelium. The mucosa - which becomes more caudal the epithelium - has relatively high signal intensity and the submucosa - which becomes more caudal subepithelium - has relatively low signal intensity. At the anorectal junction the muscularis propria of the rectum changes: the inner, circular layer thickens and becomes the internal sphincter. The smooth muscle internal sphincter has high signal intensity. The outer, longitudinal layer of the muscularis propria becomes the longitudinal muscle of the anal canal. The striated longitudinal muscle appears as relatively hypointense. First external anal sphincter, then puborectalis muscle and, at the anorectal junction, the most inferior part of levator ani muscle surround from caudal to cranial the longitudinal muscle. These striated muscles have low signal intensity. The external sphincter consists of a subcutaneous, a superficial and a deep part. These three bundles are better separately visible in males and are more compact in females. In the coronal plane the subcutaneous bundle of the external sphincter presents with a characteristic "J" shape curved medially (Fig.1). There are overlapping areas between the former described bundles. The internal sphincter and the longitudinal muscle begin above the subcutaneous part of the external sphincter. The puborectalis muscle overlaps at the caudal end with the deep external sphincter. At its cranial end the puborectalis muscle is attached to the levator ani muscle which anchors the sphincter complex to the inner side of the pelvis. The sphincter complex is embedded in the fat containing ischioanal space, which is relatively hyperintense.

1.2. Anatomic appearance on T2w TSE sequences in the sagittal plane (Fig. 4,5).
The tree different bundles of the external sphincter are well visible (Fig. 4). The superficial bundle is attached to the coccyx by the anococcygeal ligament. The external sphincter is shorter anteriorly in females than in males (Table 1) and has a more horizontal orientation in females. In females the

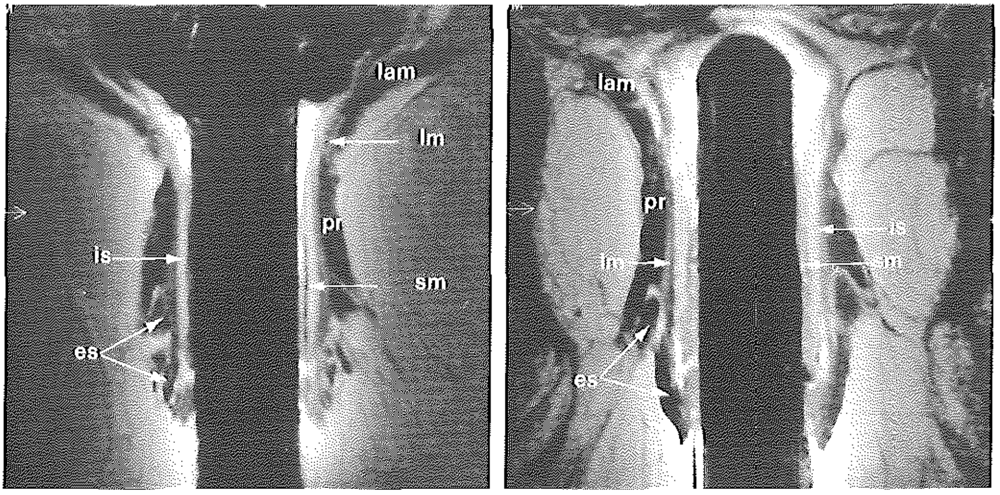


Figure 1a. Mid coronal T2w TSE **Figure 1b.**
1a. Female anatomy: external sphincter (es), internal sphincter (is), puborectalis (pr) and levator ani muscles (lam), longitudinal muscle (lm), submucosa (sm).
1b. Male anatomy: external sphincter (es), internal sphincter (is), puborectalis (pr) and levator ani muscles (lam), longitudinal muscle (lm), submucosa (sm).

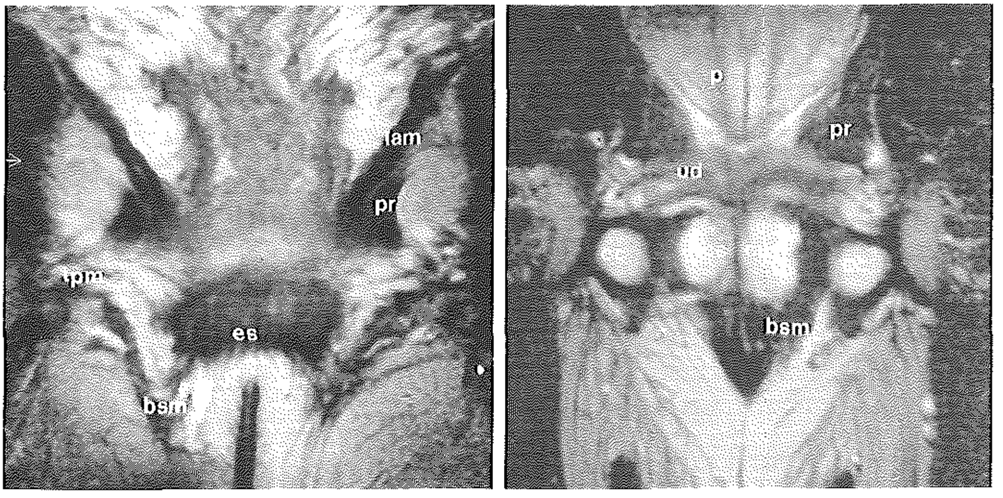


Figure 2a. Anterior coronal T2w TSE **Figure 2b.**
2a. Female anatomy: external sphincter (es), puborectalis (pr) and levator ani muscles (lam), superficial transverse perineal muscle (tpm), bulbospongiosum muscle (bsm).
2b. Male anatomy: endoanal MRI, anterior coronal T2w TSE. Prostate (p), puborectalis muscle (pr), urogenital diaphragm (ud), bulbospongiosum muscle (bsm), corpus spongiosum (cs), corpus cavernosum (cc).

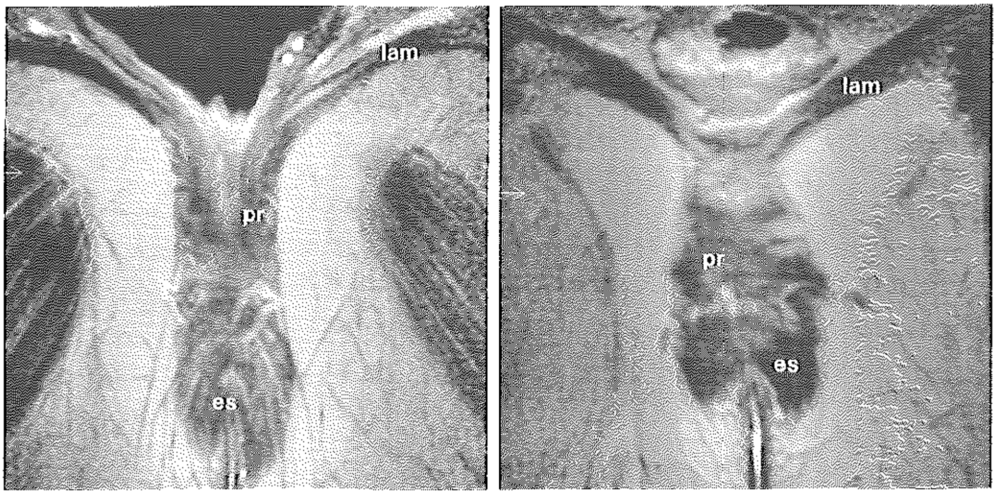


Figure 3a. Posterior coronal T2w TSE **Figure 3b.**
3a. Female anatomy: external sphincter (es), puborectalis (pr) and levator ani muscles (lam).
3b. Male anatomy: external sphincter (es), puborectalis (pr) and levator ani muscles (lam).

longitudinal muscle terminates just cranial to the external sphincter, whereas in males it extends to the caudal part of the external sphincter. The superficial transverse perineal muscle is close to the external sphincter, and their relation in the cranio-caudal direction is different between sexes. In females the superficial transverse perineal muscle is directly superior to the external sphincter, often with some overlap (Fig. 4). At first sight, this close relationship can give the impression of one muscle in the midsagittal image. In males the superficial perineal muscle is directly anterior to the external sphincter. The central perineal tendon is the insertion common to all the striated muscles, which anchors the anal sphincter to the surrounding structures (superficial transverse perineal muscle, bulbospongiosus muscle, urogenital diaphragm).

In men this structure is more like a central point whereas in women this insertion is larger and the imbrication of the muscle fibers more pronounced, therefore often described as the perineal body (Fig. 4). Anterior to the perineal body is the urogenital diaphragm (deep transverse perineal muscle and fascia).

1.3. Anatomic appearance on PDw GRE sequences in the axial plane (Fig. 6-8).

In the axial plane, the superficial part of the external sphincter and the puborectalis muscle have a posterior musculotendineous extensions to the coccyx: anococcygeal ligament. Most fibers of the superficial and deep parts of the external sphincter are anterior in contact with the central tendon of the perineum, but especially in males some fibers may continue forward and insert in the perineal raphe. The first axial slices do not contain internal sphincter and longitudinal muscle as those begin cranial to the level of the subcutaneous external sphincter.

These anterior and posterior insertions create an open elliptical shape of this part of the external sphincter, which can be misdiagnosed as anterior or posterior defects (Fig.8). Posterior the puborectalis muscle slings around the upper part of the sphincter (Fig.7).

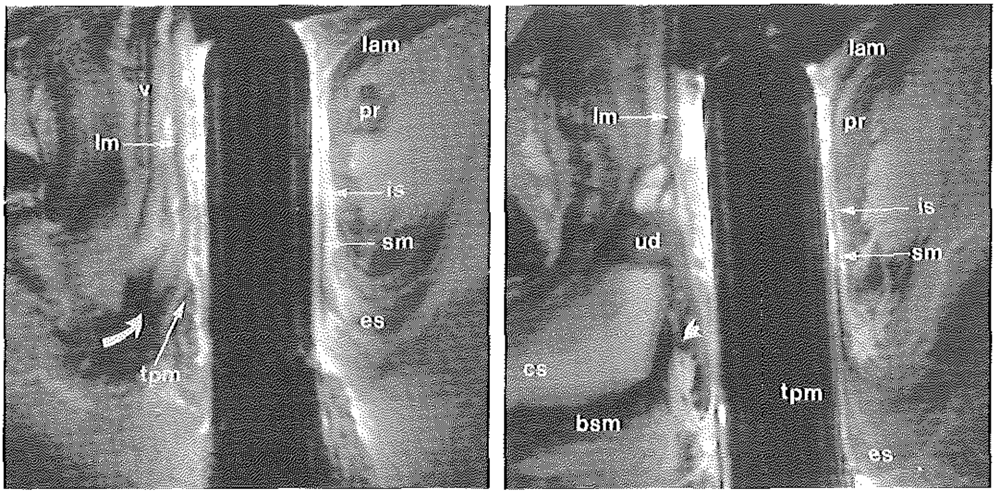
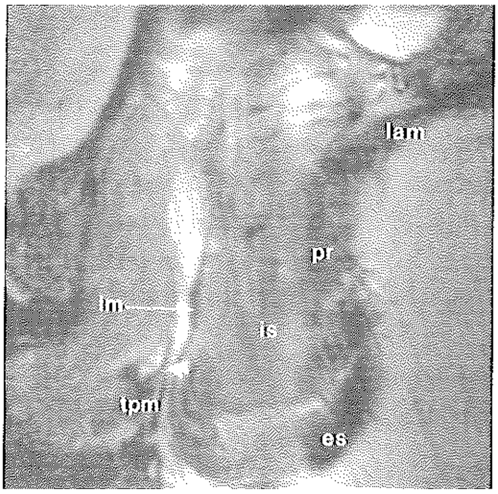


Figure 4a. Mid sagittal T2w TSE **Figure 4b.**

4a. Female anatomy: external sphincter (es), internal sphincter (is), submucosa (sm), puborectalis (pr) and levator ani muscles (lam), vagina (v), longitudinal muscle (lm), superficial transverse perineal muscle (tpm). Central perineal tendon (curved arrow).

4b. Male anatomy: external sphincter (es), internal sphincter (is), submucosa (sm), puborectalis (pr) and levator ani muscles (lam), urogenital diaphragm (ud), longitudinal muscle (lm), superficial transverse perineal muscle (tpm), corpus spongiosum (cs), bulbospongiosum muscle (bsm). Central perineal tendon (curved arrow).



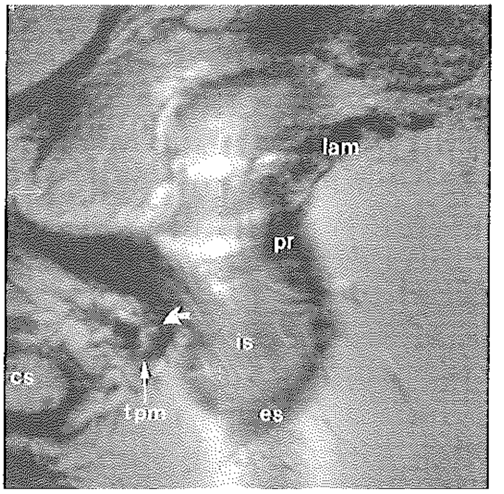
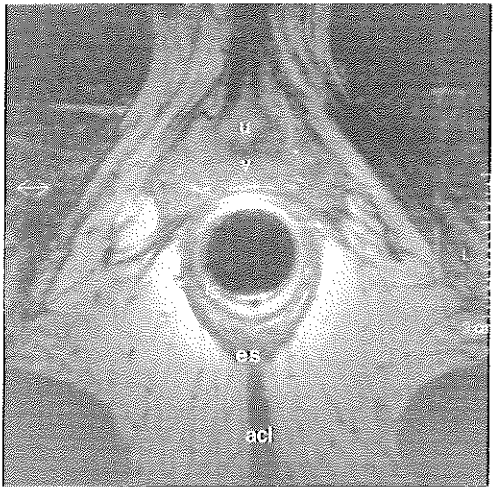


Figure 5a. Lateral sagittal T2w TSE. **Figure 5b.**
5a. Female anatomy: external sphincter (es), internal sphincter (is), puborectalis (pr) and levator ani muscle (lam), longitudinal muscles (lm), superficial transverse perineal muscle (tpm). Central perineal tendon (curved arrow).
5b. Male anatomy: external sphincter (es), internal sphincter (is), puborectalis (pr) and levator ani muscles (lam), superficial transverse perineal muscle (tpm), corpus spongiosum (cs). Central perineal tendon (curved arrow).



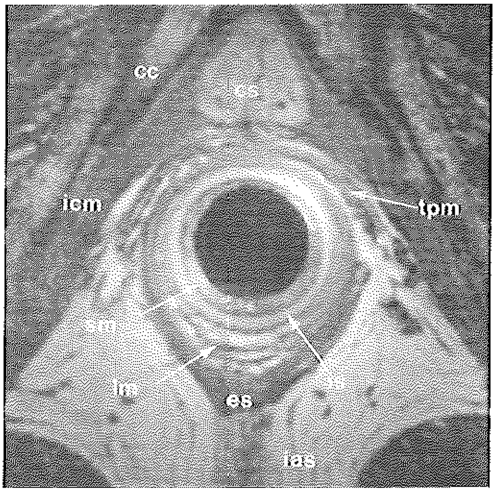
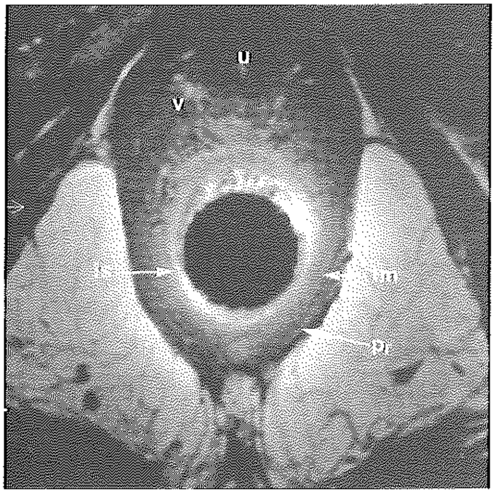


Figure 6a. Axial PRw GRE in mid anal canal **Figure 6b.**
6a. Female anatomy: internal (is) and external (es) sphincter, vagina (v), urethra (u), anococcygeal ligament (acl), submucosa (sm).
6b. Male anatomy: internal (is) and external (es) sphincter, submucosa (sm), superficial transverse perineal muscle (tpm), corpus spongiosum (cs), corpus cavernosum (cc), ischiocavernosum muscle (icm), ischioanal space (ias), longitudinal muscle (lm).



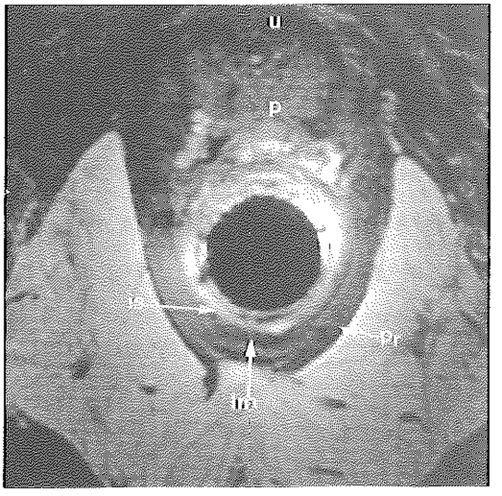
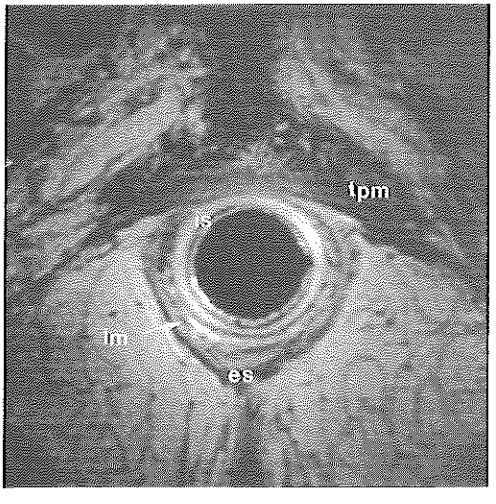


Figure 7a. Axial PDw GRE in the high anal canal **Figure 7b.**

7a. Female anatomy: internal sphincter (is), puborectalis muscle (pr), vagina (v), urethra (u), longitudinal muscle (lm).

7b. Male anatomy: internal sphincter (is), puborectalis muscle (pr), prostate (p), urethra (u), longitudinal muscle (lm).



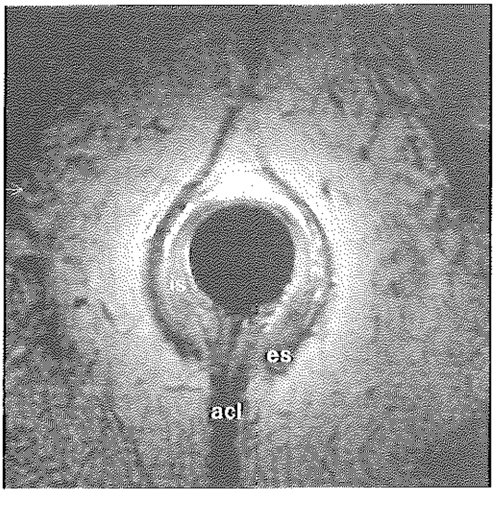


Figure 8a. Pitfalls, axial PDw GRE **Figure 8b.**

8a. Female anatomy in mid anal canal: internal sphincter (is), external sphincter (es), longitudinal muscle (lm), superficial transverse perineal muscle (tpm).

8b. Male anatomy in the low anal canal: internal (is) and external (es) sphincter, anococcygeal ligament (acl). Open elliptical shape of the external sphincter. Inferior border of the internal sphincter.

2. Sphincter Measurements

The differences between the measurements of the two radiologists were not statistically significant ($p>0.05$ Mann-Whitney).

2.1. Sex-related variation (Table 1)

A. Measurements of length

The external sphincter is significantly shorter in females than in males both lateral (mean 27.1 ± 5.4 mm versus 28.6± 4.3 mm, $p<0.05$, Mann-Whitney) and anterior (mean 14±3 mm versus 27 ± 5 mm, $p<0.01$, Mann-Whitney). The mean length of the anal canal was 56.6 ± 8.7 mm in females versus 55.5 ± 8.6 mm in males.

Table 1. Sex-related variation in healthy volunteers

Measured item	Females (50)	Males (50)	Significant* difference Females/Males
A. Measurements of length			
Anal canal	56.6 ± 8.7	55.5 ± 8.6	no
External sphincter lateral part	27.1 ± 5.4	28.6 ± 4.3	p<0.05
External sphincter anterior part	14.0 ± 3.0	27.0 ± 3.0	p<0.01
Puborectalis muscle	29.3 ± 8.1	27.7 ± 6.0	no
B. Measurements of thickness			
External sphincter	4.09 ± 0.11	4.02 ± 0.1	no
Internal sphincter	2.92 ± 0.06	2.83 ± 0.06	no
Longitudinal muscle	2.57 ± 0.05	2.58 ± 0.05	no
Puborectalis muscle	5.66 ± 0.13	5.54 ± 0.1	no
Levator ani muscle	4.76 ± 0.11	4.76 ± 0.13	no

* Mann-Whitney test

The mean length of the puborectalis muscle was 29.3 ±8.1 mm in females versus 27.7 ± 6 mm in males. No significant sex-related differences in length of the anal canal and puborectalis muscle were found.

B. Measurements of thickness

The measurements of thickness of sphincter muscles were done left and right on mid coronal images. There was a very high correlation (Pearson's correlation higher than 0. 880, $p < 0.001$) between left and right measurements at the same level. Therefore, for each subject, a mean muscle thickness (left plus right/2) was calculated; this is the value referred here as "muscle thickness" of a subject. The mean muscle thickness of all subjects was also calculated; this is the value referred here as "mean muscle thickness" of all subjects. There was no significant difference between the female and male group in the thickness of the sphincter muscles ($p>0.05$, Mann-Whitney).

Table 2. Age-related variation in healthy volunteers

Measured item	Pearson's correlation with age			
	Females (50)	Significant	Males (50)	Significant
A. Measurements of length				
Anal canal	-0.056	no	−0.121	no
External sphincter lateral part	-0.054	no	−0.091	no
Puborectalis muscle	+0.101	no	−0.239	no
B. Measurements of thickness				
External sphincter	−0.220	no	−0.582	p<0.01
Internal sphincter	+0.450	p<0.01	+0.508	p<0.01
Longitudinal muscle	−0.359	p<0.05	−0.395	p<0.01
Puborectalis muscle	−0.070	no	−0.146	no
Levator ani muscle	−0.197	no	−0.157	no

2.2. Age-related variation (Table 2)

A. Measurements of length

No significant age-related differences in length of the anal canal, external sphincter and puborectalis muscle were found.

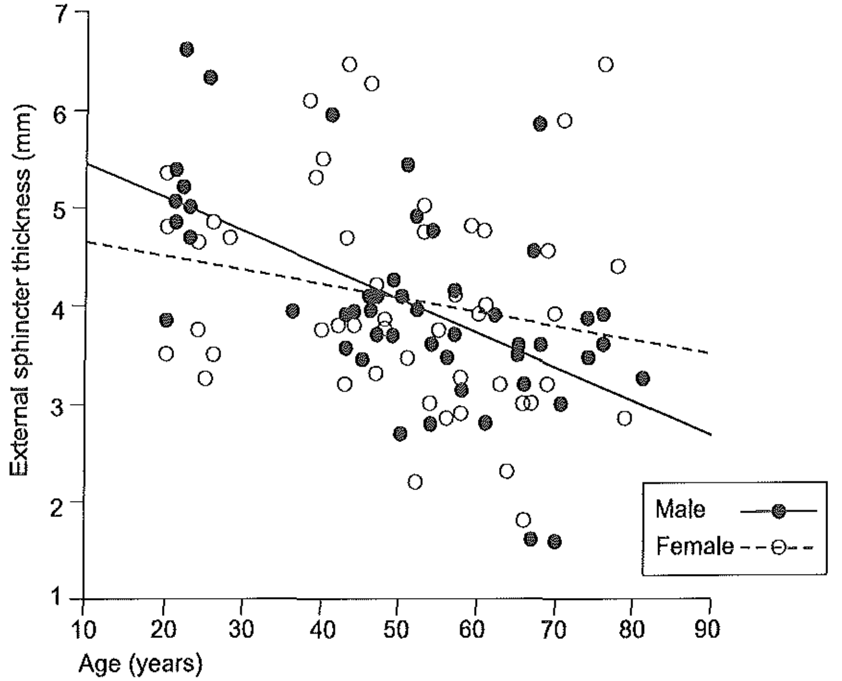
B. Measurements of thickness

Females

The thickness of the longitudinal muscle significantly decreased with age (Pearson's correlation, $p<0.01$), the thickness of the internal sphincter significantly increased with age (Pearson's correlation, $p<0.01$), and the thickness of the external sphincter, levator ani and puborectalis muscle decreased with age but not significantly (Pearson's correlation, $p>0.05$).

Males

The thickness of the external sphincter and of the longitudinal muscle significantly decreased with age (Pearson's correlation, $p<0.01$). The thickness of the internal sphincter significantly increased with age (Pearson's correlation, $p<0.01$).



Graphic 1. Variation of external sphincter thickness with age.

The thickness of levator ani and puborectalis muscle did not correlate with age (Pearson's correlation, $p>0.05$).
The difference between females and males was that the thickness of the external sphincter in males decreased significantly with age and in females it was a not statistically significant decrease. The variation of thickness with age was evaluated as presented in Graphic 1.

Considering only the young subjects (younger than 35 years) the thickness of the external sphincter in young females was significantly lower than in young males (4.32±0.7 mm versus 5.21±0.8 mm, Mann-Whitney, $p<0.05$). In males the muscle bundles were better delineated and more homogeneous than in females. With increasing age there was a thickness decrease in both females and males but more pronounced in males. This resulted in a smaller difference between the thickness of the external sphincter in the older group (above 65) which was however not statistically significant (mean 3.9±1.4 mm in females versus 3.45 ±1.1 mm in males, Mann-Whitney, $p>0.05$). This was probably due to the large spread of values in the female group.

Discussion

The anal sphincter is part of the complex anatomy of the pelvic floor. There have been many contradictory and often confusing views of the anatomy of this region. Debates on this subject persisted because there was little scientific information to define the morphology of anal muscles. Anal ultrasonography is the imaging technique currently used for visualization of this region and has proved superior to conventional body coil MRI without endoluminal device (3,10). A study using endoanal ultrasonography (11) found similar thickness and suggested variation with age of the internal and external sphincter. However, the authors state that thickness of external sphincter was "difficult to define with endoanal sonography", the results were based on a small number of subjects (15 women and 11 men) and no age-distribution of the studied subjects was mentioned. Other studies demonstrated that endoanal MRI is more accurate than endoanal sonography in characterizing the external sphincter and can detect also external sphincter atrophy (12,13). Studies using endoanal MRI (4,5) found similar thickness of the sphincter muscles but were based on no more than ten subjects and did not assess age and sex related variation. It is possible that the measured thickness of the sphincter can be influenced by the distension grade of the sphincter determined by the thickness of the coil. Nevertheless, the measured sex- and age-related variation of the muscle thickness is a value statistically independent from the coil thickness. The role of phased array coil MRI has not been yet evaluated, but the local spatial resolution of this technique is inferior to endoluminal techniques and does in our opinion not allow enough delineation of pelvic muscles to accurately detect sphincter defects and atrophy. Endoanal MRI facilitates the understanding of the anal anatomy by providing multiplanar, high-resolution demonstration in vivo and was therefore the chosen technique to perform this study.

As a result, we found that the major variation of the anatomy is visible on the anterior part of the anal sphincter in males and females. The central perineal tendon is in males a central insertion point. In females, it is not a point, but more an insertion area with woven muscular fibers, consequently allowing more elasticity and being called perineal body.

The superficial transverse perineal muscle is in females superior to the external sphincter. In males, this muscle is directly anterior to the external sphincter reinforcing this part of the anal sphincter.

Quantitative differences are shorter external sphincter in females (almost half than in males) and thinner external sphincter in young females. Those features make it less resistant to pressure. This is important during vaginal delivery when the anterior part of the external sphincter closely related to the vagina should allow wide extension. In women, this region is the most common location of external sphincter lacerations (14,15). Lesions of the anal sphincter are the most common etiology of fecal incontinence and are commonly treated by surgical anterior anal repair. Exact visualization of the sphincter anatomy with endoanal MRI before planning surgery is therefore mandatory (12,16).

External sphincter atrophy was observed in patients with late-onset fecal incontinence several years after childbirth and explained as having both neurological and ischemic etiology (5). It can only be visualized by endoanal MRI and represents a negative predictive factor for the success of anterior anal repair (13). If prospective studies will confirm this findings, patients with anterior external sphincter lacerations and external sphincter atrophy may be preferable selected for other types of surgical treatments like dynamic gracilis plasty (17). Then, preoperative selection can only be performed using endoanal MRI. Although atrophy of the external sphincter is visible in all planes, the coronal plane gives the easiest evaluation as the volume of all sphincter muscles can be compared.

In the young population, "complete continence" is a common state, but in elderly, the prevalence of fecal incontinence was reported as 18% and estimated to be much higher. Because requiring healthy, "completely continent" aged subjects in our study, a careful selection took place. Based on our experience of visualizing fecal incontinence with endoanal MRI we think the general, unselected, old population, where a certain degree of incontinence is quite common, has even thinner sphincter muscles. Further research is directed to assess the scientific basis of this difference and to detect below which level the thinning of anal muscles manifest itself clinically. Nevertheless the radiologist should be aware that with aging, thinning of the external sphincter and longitudinal muscle and thickening of the internal sphincter occur in normal, continent subjects.

The thinning of external sphincter and longitudinal muscle in elderly should be seen as physiological and differentiated from severe atrophy as it occurs in incontinent patients.

Conclusion

Detailed knowledge of anatomical variations among sexes, ages and individuals is crucial for a correct evaluation of pelvic floor morphology. High-resolution endoanal MRI provides a very fine demonstration of deformity and integrity of pelvic floor structures and earlier studies proved it as being an excellent tool in the preoperative diagnosis and for surgical planning (9,11). As the general population lives longer, the number of incontinent patients increases and there is a growing demand for imaging in patients with fecal incontinence. Accurate assessment is therefore extremely important to support successful treatment and hereby increase the quality of life in the elderly.

Acknowledgements

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CHAPTER 4

FECAL INCONTINENCE: ENDOANAL US VERSUS ENDOANAL MR IMAGING

Introduction

Fecal incontinence, the inability to voluntarily control the anal sphincter, may severely affect a person's quality of life and eventually lead to social isolation (1). The prevalence reported in a number of studies ranged from three to ten cases per thousand but may actually be much higher (2,3). The most common causes include traumatic sphincter defects (obstetrical, surgical), neurogenic dysfunction of the pelvic floor musculature and rectal prolapse (4,5). The main cause of fecal incontinence in women is childbirth which can lead to mechanical or neurologic injury to the anal sphincter (6) and especially of the external anal sphincter. After vaginal delivery only 0.7% of women have clinically overt sphincter damage (7). Sultan et al. revealed that 35% of the primiparous women have occult sphincter damage after vaginal delivery and one third of them also directly have disturbances of anal continence (8). Occult sphincter defects may precipitate overt symptoms later, in the middle age, as menopause (9), neuropathy and muscle loss cumulate their effect (10).

In treating fecal incontinence the physician can choose from several modalities (11). Patients with sphincter damage may benefit from surgical repair (12). The choice of an optimal therapy is based on accurate imaging of the anal sphincter complex. Currently, endoanal sonography is the preferred diagnostic technique and has replaced the invasive electromyography (13,14). Recently endoanal magnetic resonance imaging (MRI) was introduced and was shown to be accurate in depicting the anatomy of the sphincter complex (15-19).

The aim of this study was to determine the preferable imaging technique by assessing the agreement between endoanal sonography and endoanal MRI in mapping external sphincter defects as validated by surgery.

This chapter is adapted from: Rociu E, Stoker J, Eijkemans MJ, Schouten WR, Laméris JS.
Fecal incontinence: endoanal US versus endoanal MR imaging. Radiology 1999;212(2):453-458.

Materials and Methods

Twenty-two consecutive unselected female patients (median age 49 years, range 22-74) with fecal incontinence that underwent surgical sphincter repair were retrospectively studied. Informed consent was obtained from all patients and the medical ethics committee approved the research. All the patients were parous (median 3 deliveries, range 1-8). The degree of fecal incontinence according to Parks (20) was II (incontinence only for flatus) in three cases, III (incontinence for liquid stool at any time) in eight cases, or IV (incontinent for solid stool) in eleven cases. The subjects had become incontinent after childbirth (19 patients), anorectal surgery (two patients) or rape (one patient). Following the standard procedure in our hospital all patients were at the same day assessed with endoanal ultrasound and endoanal MRI. Before sonography the patients underwent limited rectal cleaning. The mean and median interval between imaging and surgery was 189 days. The same surgeon treated all patients.

Endoanal sonography

Endoanal sonography (Fig. 1) was performed on a Brüel&Kjaer (Naerum, Denmark) scanner with a rotating probe providing 360° image. A 7-MHz transducer with a minimum beam width of 1.1 mm and a focal length of 3 cm was used. The transducer was covered with a hard, plastic cone 18 mm in diameter. This cone was filled with degassed water for acoustic coupling and covered with a condom after lubricant was applied to both surfaces.

The probe was inserted in the rectum with the patient in left lateral position, rotated so that 12 o'clock was anterior and then withdrawn until the high reflectivity puborectalis sling was seen and used as main landmark. Hard copies of axial images of the puborectalis muscle, internal and external anal sphincter were made at four levels in the anal canal. The internal sphincter presents as a symmetrical ring of low reflectivity and any break in the continuity of this ring is abnormal and implies direct trauma (21,22). The external anal sphincter classically shows a fibrillar pattern of fine parallel lines that becomes more homogeneous at lower levels. Tears are defined by interruption of the fibrillar echotexture. Scarring is recognized by loss of the normal architecture, with an area of amorphous texture, usually of low reflectivity.

The sphincter muscles may also show local thickening or thinning. Generalized external sphincter thinning: atrophy, is difficult to appreciate because of the vague contours of the muscle ring.

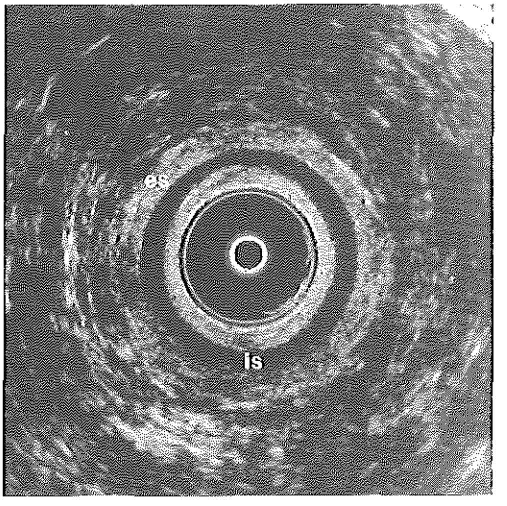


Figure 1. Axial endoanal sonography showing a normal sphincter complex: external sphincter (ES), internal sphincter (IS).

Endoanal MR imaging

Endoanal MR imaging (Fig. 2) was performed at 1.5 T (Gyroscan ACS-NT, Philips Medical Systems, Best, The Netherlands) without bowel preparation.

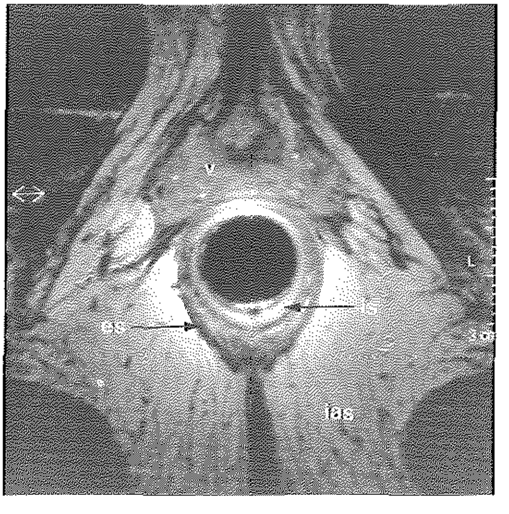


Figure 2. Axial endoanal proton density gradient-echo MRI (30/13) showing a normal sphincter complex: external sphincter (ES), internal sphincter (IS), ischioanal space (IAS), vagina (V).

Before imaging, 1ml butyl-scopolamine bromide (Buscopan, 20mg/ml; Boehringer Ingelheim KG, Ingelheim, Germany) was injected intramuscularly to reduce bowel motion. The endoanal coil (Philips Medical Systems, Best, The Netherlands)(Fig. 3) with a diameter of 19 mm was covered with a condom and lubricant was applied to the surface.

An axial, proton density, three-dimensional gradient-echo sequence (acquisition time 6.5 min., repetition time (TR) 30 msec, echo time (TE) 13 msec, flip angle 60°, field of view (FOV) 140 mm x 112 mm, imaging matrix 205x256, section thickness 2mm, contiguous slices, 2 excitations) was performed perpendicular to the long axis of the endoanal coil. For sagittal and coronal images, T2-weighted turbo spin-echo (T2wTSE) sequences were performed (acquisition time 5.0 min., TR 2800 ms, effective echo time 120 ms, echo train length 10, echo spacing 21.8 ms, FOV120 mm x 90 mm, imaging matrix 186 x 256, section thickness 4.0 mm with an intersection gap of 0.4 mm, 8 excitations). The coronal and sagittal sections were parallel to the long axis of the endoanal coil. A sphincter defect was defined as a discontinuity of the muscle ring. Scarring was defined as a hypointense deformation of the normal pattern of the muscle layer due to replacement of muscle cells by fibrous tissue.

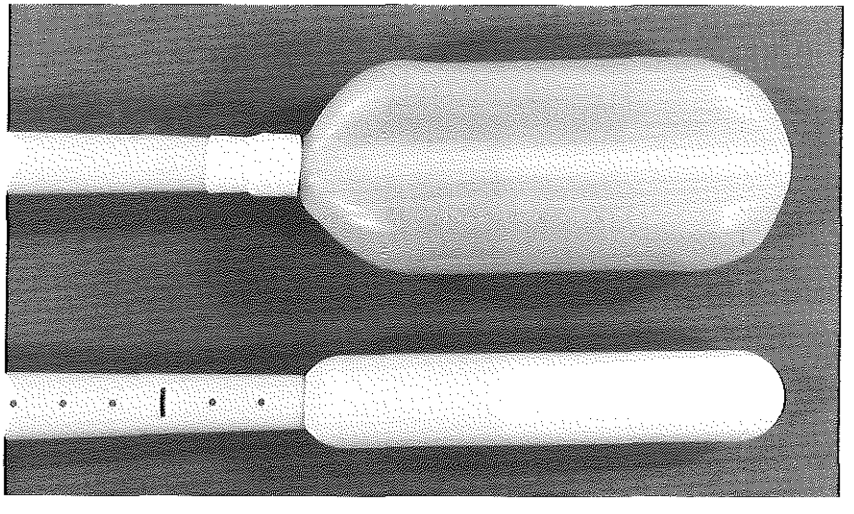


Figure 3. Endorectal coil (top, with a balloon) and the rigid endoanal coil (bottom) both manufactured by Philips Medical Systems, Best, The Netherlands.

Local thinning and atrophy -defined as an extreme generalized thinning of sphincter muscles -were scored on MRI.

Image analysis

Before operation two radiologists evaluated the images separately: one radiologist evaluated the sonography and the other the MRI, blind to the other technique. The decision to perform surgery was taken by the surgeon based on medical history, physical examination and the existence of any kind of lesions of the external sphincter on MRI or sonography.

Because atrophy of the sphincter is not visible with endoanal sonography this was not considered in the correlation with the MR imaging.

The quality of the images (good/moderate/poor), the presence, location and the type of lesions were thoroughly examined and recorded. The results of the imaging methods were compared with the detailed description of the surgical findings by the same surgeon.

Statistical analysis

Differences in quality of images between sonography and MRI were tested with a chi-square test.

The categorical agreement between sonography, MRI and surgery was assessed by calculating the unweighted kappa values. The agreement was considered: poor for $K \leq 20$, fair for $K \in (21\text{-}40)$, moderate for $K \in (41\text{-}60)$, good for $K \in (61\text{-}80)$ and very good for $K \in (81\text{-}100)$.

In this retrospective study, all the patients underwent surgery because a lesion was detected by imaging. There may exist patients with a lesion, which was not detected by imaging and consequently not operated. Therefore the positive predictive value (PPV) of the imaging techniques was considered more appropriate than the sensitivity. The operation revealed only those parts of the sphincter, which required repair. Undamaged parts were not dissected in order to avoid consequent iatrogenic incontinence. This makes the negative predictive value (NPV) more appropriate than the specificity. Therefore the positive and negative predictive values in detecting damage for both sonography and MRI were calculated.

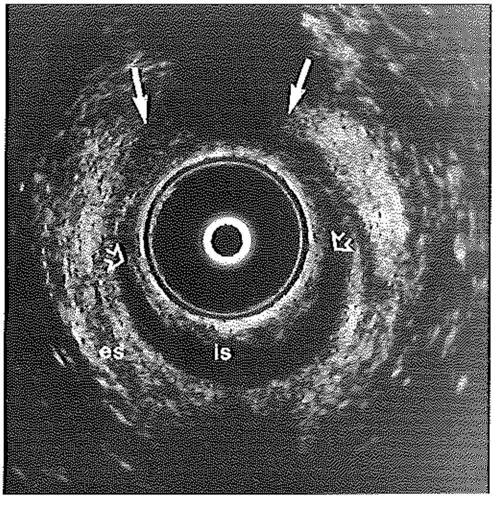
Results

The quality of the sonography images was good in 77% (17/22) of the cases, moderate in 9% (2/22) and poor in 14% (3/22) of the cases. The quality of the MRI images was good in 82% (18/22) of the cases, moderate in 14% (3/22) and poor in 4% (1/22) of the cases. The differences between sonography and MRI were not statistically significant. (Chi-square test p=0.5, chi-square test for trend p=0.6). No significant artifacts occurred.

External sphincter

Surgery detected an external sphincter defect in 13 patients, isolated scarring in 4 patients, local thinning of the sphincter in 2 patients while 3 patients had a normal sphincter.

Endoanal sonography correctly assessed 73% (16/22) cases showing a moderate agreement with surgery (k=0.53) (Fig. 4a). Endoanal MRI correctly assessed 91% (20/ 22) cases, showing a very good agreement with surgery (k=0.85) (Fig. 4b). One defect was seen on a different position and was



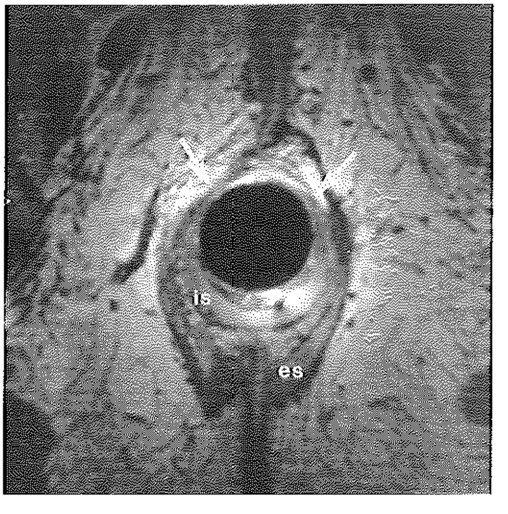


Figure 4a **Figure 4b**

4a. Axial endoanal sonography of a 53 years old female patient with fecal incontinence showing a defect (arrows) of external sphincter (ES) and a defect (open arrows) of the internal (IS) anal sphincter.

4b. Axial endoanal proton density gradient-echo MRI (30/13) of the same patient showing also a defect (arrows) of both external (ES) and internal (IS) anal sphincter.

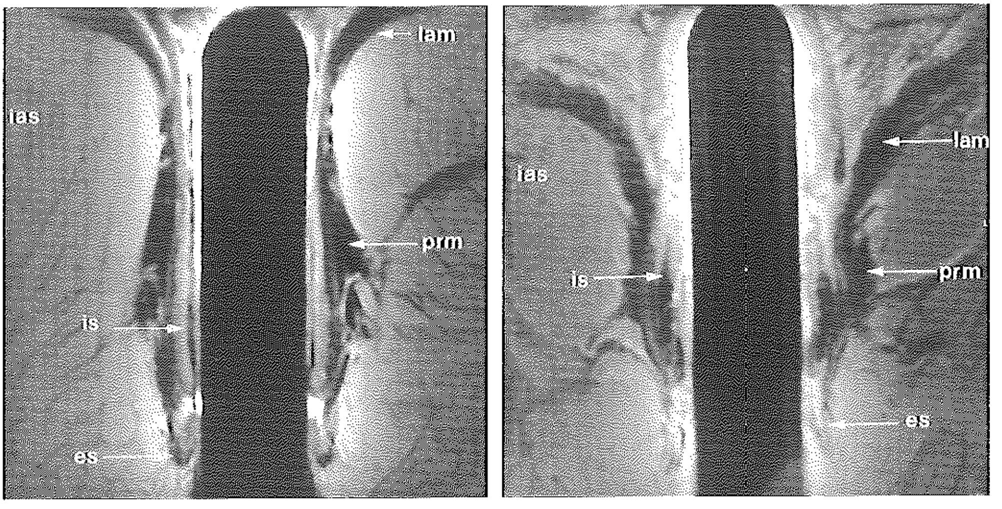


Figure 5a **Figure 5b**

5a. Coronal T2wTSE (2800/120) in a 46 years old female with a normal anal sphincter. The external sphincter (ES), internal sphincter (IS), puborectalis muscle (PRM) and the levator ani muscle (LAM) are demonstrated. Ischioanal space (IAS).

5b. Coronal T2wTSE (2800/120) in a 61 years old female patient with atrophy of the external anal sphincter. The external sphincter (ES), internal sphincter (IS), puborectalis muscle (PRM) and the levator ani muscle (LAM) are demonstrated. Ischioanal space (IAS). Scarring causes low signal intensity of the internal sphincter.

considered incorrectly reported. External sphincter atrophy was only detectable with MRI, and was seen in 9 patients and was confirmed by surgery (Fig. 5a,b).

The surgeon did not find external sphincter atrophy in any patient in whom atrophy was not detected in MR images. The distribution of reported and correct diagnosis for the imaging techniques is shown in Table 1.

In this retrospective study, the decision to perform surgery was based on the existence of any kind of lesion of the external sphincter (defect, scar or thinning), as seen on MRI or sonography. In this regard MRI had no false negative and only one false positive result (Fig.6). Sonography had three false negative and two false positive results.

If MRI had been considered alone it would have lead in 95% (21/22) of cases to a correct decision while sonography alone only in 77% (17/22) of cases.

Table 1. Endoanal sonography, endoanal MRI and surgery diagnosis of external sphincter conditions

	Diagnosis by sonography		Diagnosis by MRI		Diagnosis by surgery
External sphincter	reported	correct	reported	correct	
Defect	13	11	13	12	13
Scarring	5	4	5	4	4
Thinning	0	0	2	2	2
Normal	4	1	2	2	3
Total	22	16	22	20	22

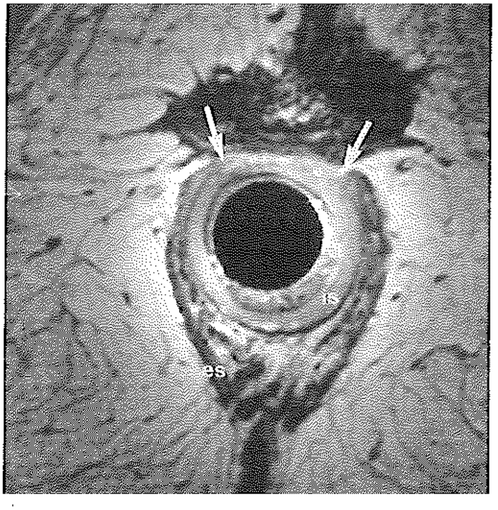


Figure 6. Endoanal axial proton density gradient-echo MRI (30/13) of a 40 years old female patient with fecal incontinence showing subtle decrease of the signal intensity and altered texture (arrows) of the external sphincter (ES) which was diagnosed as scarring. The surgery did not validate this finding. Internal sphincter (IS).

Internal sphincter

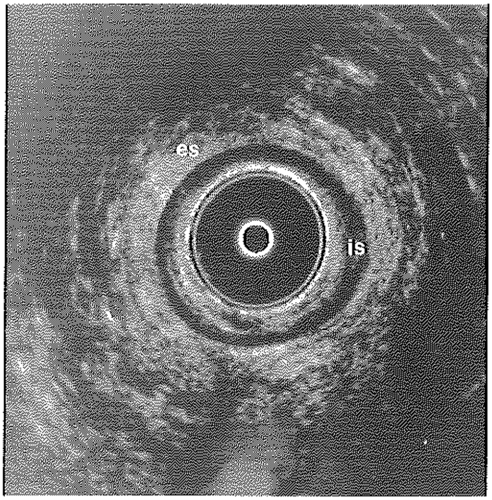
Surgery reported an internal sphincter defect in 12 cases, local thinning in 5 cases, isolated scarring in one case and 4 patients with normal sphincter. Endoanal sonography detected one thinning correctly and interpreted three thinnings as normal and one as a defect. All thinnings found by surgery were seen by MRI. Three additional thinnings were reported by MRI but not validated by surgery. Endoanal sonography indicated a correct diagnosis in 68% (15/22) of patients (Fig. 4a). The agreement with surgery was moderate (k=0.49). Endoanal MRI indicated a correct diagnose in 77% (17/22) of patients showing a good agreement with surgery (k= 0.64) (Fig. 4b). The distribution of reported and correct diagnosis of the imaging techniques is shown in Table 2.

TABLE 2. Endoanal sonography, endoanal MRI and surgery diagnosis of internal sphincter conditions

	Diagnosis by sonography		Diagnosis by MRI		Diagnosis by surgery
External sphincter	reported	correct	reported	correct	
Defect	12	10	11	10	12
Scarring	2	1	1	1	1
Thinning	2	1	8	5	5
Normal	8	3	2	1	4
Total	22	15	22	17	22

Agreement between endoanal sonography and MRI

In diagnosing the external sphincter (defects, scarring, thinning and normal), endoanal sonography corresponded with endoanal MRI in 14 of 22 (64%) cases showing a fair to moderate agreement (k= 0.38) (Fig.7a, b). In mapping internal sphincter damage the two imaging techniques



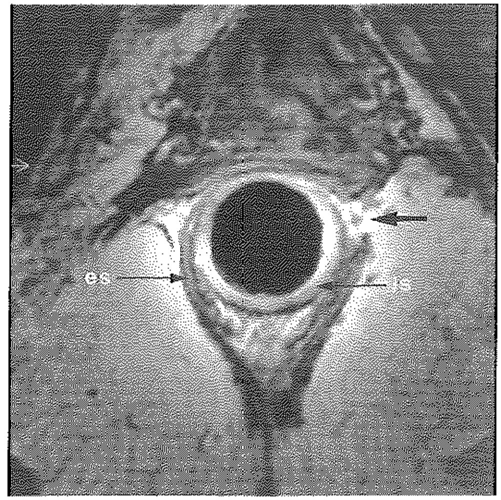


Figure 7a **Figure 7b**

7a. Axial sonography in a 41 years old female patient with fecal incontinence showing no evident lesions of the external (ES) of internal (IS) anal sphincter. At surgery, an external sphincter defect was found.

7b. Endoanal axial proton density gradient-echo MRI (30/13) of the same patient showing the defect (arrow) of the external sphincter (ES) as it was found at surgery. The internal sphincter (IS) is normal on MRI and this was confirmed at surgery.

coresponded in 13 of 22 (59%) cases also indicating a fair to moderate agreement (k=0.39). Endoanal sonography could not correctly detect atrophy or thinning of the sphincter.

The positive and negative predictive values of each diagnostic method for detecting damage (without atrophy or thinning) of the external and internal sphincter are given in Table 3. Concerning the external sphincter MRI showed a combination of very good positive and negative predictive values, both higher than the results of sonography. Concerning the internal sphincter the imaging techniques had rather comparable results.

The positive predictive values for detecting any damage of the anal complex (in the external or internal sphincter) were 89% (32/36) for sonography and 95% (38/40) for MRI. In the same regard the negative predicting values were 25% (2/8) for sonography and 100% (4/4) for MRI. Endoanal MRI showed a good agreement with surgery (k=0.75) while endosonography showed a moderate agreement (k= 0.52).

TABLE 3. Predictive values of US and MRI imaging for demonstration of damage to the external and internal sphincters

Sphincter and Value	US				MR imaging			
External								
Positive Predictive Value	15	of	18	(83)	18	of	20	(90)
Negative Predictive Value	1	of	4	(25)	2	of	2	(100)
Internal								
Positive Predictive Value	12	of	14	(86)	16	of	20	(80)
Negative Predictive Value	3	of	8	(38)	1	of	2	(50)

Note. Number in parentheses indicates the percentage.

Discussion

The selection of patients with fecal incontinence who may benefit from surgical therapy is based on the detection and type of sphincter damage. In order to perform optimal surgery an accurate description of the position, extent and type of lesion is necessary. In previous studies endoanal sonography as validated by surgery has been shown to be more accurate then electromyography and manometry in diagnosing fecal incontinence (22). Other authors revealed that endoanal sonography was also superior to MR imaging using a body coil in the evaluation of the sphincter anatomy (23). However the limitation of endoanal sonography is the poor inherent contrast which causes cumbersome identification of the external anal sphincter. Deliveries or surgery often damages this anal muscle of major importance in the continence. Recently introduced endoanal MRI has high inherent contrast and high spatial resolution and enables the detailed demonstration of normal sphincter anatomy and pathology (muscle tears, abscesses, fistulous tracks, scars, atrophy and hypertrophy) (24). In a study on 7 patients with obstetrical sphincter trauma, endoanal MRI as validated by surgery, provided an 100% accurate description of the site and extent of the sphincter tears (25).

Our aim, therefore was to select the best imaging technique for the work up in patients with sphincter defects and to our knowledge this is the first study which directly compares endoanal MRI and endoanal sonography as related to the surgery findings in patients with fecal incontinence. In our study all but three of the sphincter lesions were caused by childbirth. Therefore, their position was anterior. In the other three patients the position of the lesion was also anterior. The performed surgical technique (anterior anal repair) allowed a good description of the lesion and it was used as the reference standard for the comparison between the two methods.

Lesion detection

In detecting lesions MRI showed a very good agreement with surgery concerning the external sphincter and a good agreement concerning the internal sphincter. Sonography only showed a moderate agreement with surgery in detecting lesions of both external and internal sphincter. The correlation between MRI and sonography was moderate. The negative predictive value of both techniques was relatively low. This can be explained by the fact that our study had a low number of patients without lesions detectable either on MRI or sonography. If, for instance, MRI had correctly detected one additional patient, this would have doubled its negative predictive value. A further study, on a higher number of patients will be more accurate in calculating the negative predictive value. Nevertheless, concerning the external sphincter MRI presented a combination of high positive and negative predictive values, which selects it as a very good preoperative diagnostic method for anterior sphincter repair.

Lesion characterization

Sonography and MRI were comparable when characterizing damage of the internal sphincter. However, in characterizing damage of the external sphincter, endoanal MRI provided a good distinction between different types of tissue (muscle, scar, fat). This allowed an accurate detection of local thinning which was not possible with sonography and a more precise description of the extent and structure of complex lesions. A recent study demonstrated that external sphincter thinning and atrophy as seen on endoanal MRI can predict the outcome of anterior sphincteroplasty (26).

Surgical decision making

In the surgical decision making, the two imaging techniques were in our study complementary. The advantage of sonography is that it is a cheaper, more widely available and quicker technique than MRI. Nevertheless, if only one technique is to be used then MRI will provide the optimal decision in more cases than sonography. This could save unnecessary operations and may make MRI cost-effective. In order to assess all the presented aspects a prospective study is now being conducted. Endoanal MRI demonstrates to be superior to endoanal sonography in deciding the optimal therapy.

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CHAPTER 5

EVALUATION OF EXTERNAL SPHINCTER LESIONS: ENDOANAL MRI VERSUS ENDOANAL SONOGRAPHY AS VALIDATED BY ULTRASOUND GUIDED ELECTROMYOGRAPHY

Introduction

Fecal incontinence is a progressively disabling condition very common in elderly and after pelvic floor injuries caused by vaginal delivery, anorectal surgery and accidental trauma (1).

Classically, digital examination, anorectal manometry (resting and squeezing pressures), electromyography (EMG) and endoluminal imaging techniques of the pelvic floor support the clinical assessment of fecal incontinence (2). It is important to determine whether there are lesions of the striated external anal sphincter in such patients, as these are amenable to surgical repair with good results (3).

The technique of EMG using concentric needle electrodes is an established part of the physiological investigation of striated muscle activity (4). Lesions are demonstrated by a complete loss or marked reduction of normal electrical activity (5). An accurate mapping of the external sphincter implies serial needle insertion making this technique very painful for the patient. By allowing the painless mapping of the lesions in their depth and radial extent, endoluminal imaging techniques became an indispensable tool in diagnosing diseases of the pelvic floor. The first and most widely available endoluminal technique to demonstrate the anal sphincter complex was endoanal sonography (5,6). It is accurate in diagnosing the internal sphincter, while the detection and interpretation of lesions in the external anal sphincter is difficult and requires EMG confirmation before surgical repair (7). The high inherent contrast and high spatial resolution of the endoanal MRI allows insight into pelvic floor anatomy and pathology in a

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This chapter is adapted from: Rociu E, Meulstee J, Stoker J, Eijkemans MJC, Laméris JS. Evaluation of external sphincter lesions: endoanal MRI versus endoanal sonography as validated by ultrasound guided electromyography. (Submitted article).

more precise way (8-11). All the muscle layers and the adjacent structures can easily be inspected. This results in improved detection of presence and type of sphincter defects (12) and allows the visualization of a crucial finding: external sphincter atrophy (13), which is not possible with endoanal sonography (14).

Comparative studies between EMG and endosonography have shown a good correlation between acoustic and electric defects in the external anal sphincter (7). To our knowledge, no evaluation of the electrical activity in areas where endoanal MRI shows lesions or apparently normal tissue was related with the same findings on endosonography.

In our study, ultrasound guidance was used for EMG needle placement in sonographical normal and abnormal areas within the external sphincter. Then the correlation between MRI findings and sonographical findings was evaluated, using EMG as gold standard.

The aim of this study was to determine the optimal diagnosing modality endoanal sonography or endoanal MRI for detecting external sphincter lesions as validated by EMG.

Subjects and Methods

Seventeen consecutive patients (two males, fifteen females) with fecal incontinence were studied. The median age of the patients was 54 years (range 34-76). All the female patients were parous (median 2 deliveries, range 1-4). The degree of fecal incontinence according to Parks was II (incontinence only for flatus) in one case, III (incontinence for loose stool at any time) in four cases, or IV (incontinent for solid stool) in twelve cases. The subjects had become incontinent after childbirth (11 patients), anorectal surgery (4 patients) or accidental trauma (two patients).

After informed consent was obtained, all patients underwent endoanal MRI, followed by endoanal sonography and ultrasound guided electromyography. Endoanal MR imaging was performed at 1.5 T (Gyroscan ACS-NT, Philips Medical Systems, Best, The Netherlands) without bowel preparation. Before imaging, 1ml butyl-scopolamine bromide (Buscopan, 20mg/ml; Boehringer Ingelheim KG, Ingelheim, Germany) was injected intramuscularly to reduce bowel motion. The rigid endoanal coil (Philips Medical Systems) with a diameter of 19 mm was covered with a condom and lubricant was applied to the surface. An axial, proton density weighted, three-dimensional gradient-echo sequence (acquisition time 6.5 min., repetition time (TR) 30 msec, echo time (TE) 13 msec, flip angle 60°, field of view (FOV) 140 mm x 112 mm, imaging matrix 205x256, section thickness 2mm, contiguous slices, 2 excitations) was performed perpendicular to the long axis of the endoanal coil. For sagittal and coronal images, T2-weighted turbo spin-echo sequences were performed (acquisition time 5.0 min., TR 2800 ms, TE 120 ms, turbo factor 10, FOV120 mm x 90 mm, imaging matrix 186 x 256, section thickness 4.0 mm with an intersection gap of 0.4 mm, 8 excitations). The coronal and sagittal sections were parallel to the long axis of the endoanal coil.

Endoanal sonography was performed on a B&K scanner (Naerum, Denmark), with a rotating probe (10 MHz) providing 360° image. The 10 MHz transducer was covered with a hard, plastic cone 18 mm in diameter. This cone was filled with degassed water for acoustic coupling and covered with a condom after lubricant was applied to both surfaces. The probe was inserted in the rectum with the patient in left lateral position, rotated so that 12 o'clock was anterior and then withdrawn until the high reflectivity puborectalis sling was seen and used as main landmark. Hard copies of axial images of the sphincter muscles were made at four levels in the anal canal, starting with level zero at the lower extremity of the external sphincter and moving longitudinal in the cranial direction with 1 cm per level (level 1, 2, 3). In the transversal plane, the circular image of the coil or of the transducer (which have almost the same diameter) was divided in 360 grades. This allowed a description of the position of the needle insertion in the axial images. The same levels were considered on the MRI hard copies (starting also with level zero at the lower extremity of the external sphincter) and findings were similarly recorded and evaluated.

Two radiologists evaluated separately the findings of these methods. The quality of the images (good/moderate/poor), the presence, location and the type of lesions were thoroughly examined and recorded. Concentric needle EMG under endoanal ultrasound guidance was then performed. In each patient, a radiologist inserted the needle in both endosonographically normal (17 recordings) and pathological (17 recordings) external anal sphincter and the needle tip was clearly visualized on the screen. The results were displayed on a Viking IV Nicolete EMG apparatus (Biomedical Instruments,

Madison, WI, USA). A neurologist who was not aware of the imaging findings recorded the electrical activity of each site during straining and at rest. In order to reduce artifacts the ultrasound transducer was switched off during the EMG recordings. The neurologist used headphones so the radiologist was not aware of the sound of the electrical signal. The results of MRI and sonography were compared using EMG as a gold standard.
In the statistical analysis the categorical agreement between sonography, MRI and EMG was assessed by calculating the unweighted kappa values. The agreement was considered: poor for $K \leq 20$, fair for $K \in (21\text{-}40)$, moderate for $K \in (41\text{-}60)$, good for $K \in (61\text{-}80)$ and very good for $K \in (81\text{-}100)$.

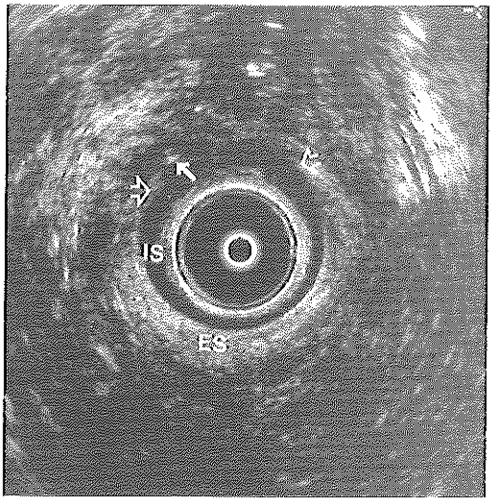
Results

The quality of MRI images was in 88% (15/17) good and 12% (2/17) moderate. The quality of sonography images was in 88% (15/17) good, in 6% (1/17) moderate and in 6% (1/17) poor.

Correlation between endoanal sonography and endoanal MRI
Endoanal sonography reported a sphincter defect in all patients (Table 1). Endoanal MRI agreed with sonography in all the 17 external sphincter defects (Fig. 1).

Table 1. Correlation between sonography and MRI

		MRI		
		Lesions	Normal	Total
Sonography	Lesions	17	0	17
	Normal	6	11	17
Total		23	11	34



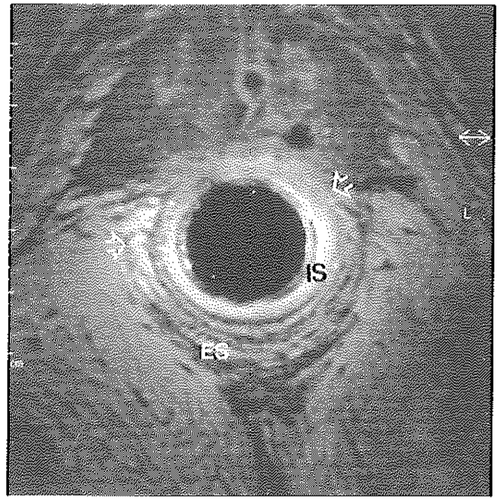
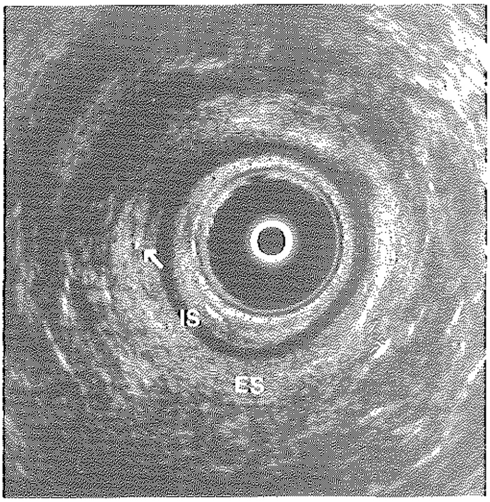


Figure 1a 44-year-old women with fecal incontinence after childbirth **Figure 1b**
1a. Endoanal ultrasound guided electromyography (arrow) in an "acoustic defect"(open arrows) of the external sphincter (ES). Internal sphincter (IS).
1b. Axial proton density weighted GRE endoanal MRI showing the same defect (open arrows) of the external sphincter (ES). Internal sphincter (IS).

Table 2. Correlation between sonography and EMG

		Sonography		
		Lesions	Normal	Total
EMG	Lesions	14	6	20
	Normal	3	11	14
Total		17	17	34

The findings of endoanal sonography and MRI differed in six patients: MRI detected one additional sphincter defect and in five cases atrophy of the external sphincter (Fig. 2). Those lesions were not reported by endosonography. EMG confirmed the MRI findings in those six patients.



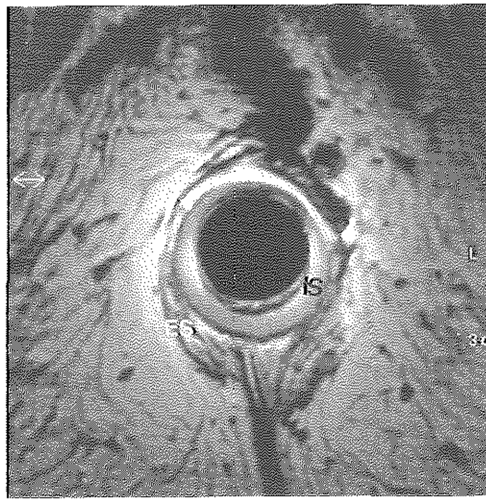


Figure 2a 63-year-old woman with fecal incontinence after childbirth **Figure 2b**
2a. Endoanal ultrasound guided electromyography (arrow) in an "acoustic normal" external sphincter (ES). Internal sphincter (IS).
2b. Axial proton density weighted GRE endoanal MRI showing generalized atrophy of the external sphincter (ES). Internal sphincter (IS).

The agreement between sonography and MRI in detecting sphincter lesions was good (k=0.65).

Correlation between endoanal sonography and EMG

Fourteen of the 17 defects reported by endoanal sonography showed no electromyographical activity (Table 2). From the 17 registrations in acoustic normal muscle (Fig. 2a), electromyography confirmed normal muscular activity in 11 cases. The agreement between sonography and electromyography was moderate (k=0.47).

Correlation between endoanal MRI and EMG

Endoanal MRI reported 23 lesions (18 defects and 5 generalized atrophy) of the external sphincter. Electromyography showed no electrical activity in 20 of the 23 lesions and normal electrical activity in all the cases reported as normal by the MRI (Table 3). The agreement between endoanal MRI and electromyography was very good (k=0.81).
The positive and negative predictive values were lower for endoanal sonography than for endoanal MRI as shown in Table 4.

Table 3. Correlation between MRI and EMG

		MRI		
		Lesions	Normal	Total
EMG	Lesions	20	0	20
	Normal	3	11	14
Total		23	11	34

In detecting sphincter lesions, endoanal MRI showed a sensitivity of 100% and a specificity of 79%. Endoanal sonography showed a sensitivity of 70% and a specificity of 79%. The calculated sensitivity and specificity of sonography are possibly biased (higher then real) as the place of EMG needle insertion was chosen using sonography. Therefore, these findings for sonography were not taken into account.

Table 4. Positive and negative predictive value of sonography and MRI

	PPV *	NPV **
Sonography	82%	65%
MRI	87%	100%

* PPV = positive predictive value
** NPV = negative predictive value

Discussion

In a study (15) on 96 nulliparous Allen et. al, concluded that vaginal delivery causes neurological injuries of the pelvic floor in 80% of women having their first baby. Eventually, when the effect of age and menopause is added, this may lead to external sphincter atrophy. In our study atrophy of the external sphincter was found in five of the 17 (30%) of the patients. All of them were female and had become incontinent after childbirth. In a retrospective study on 15 patients (14), the presence of external sphincter atrophy proved to be an important predictor of the negative outcome of surgical anal repair. For this reason, an imaging technique that is able to detect sphincter atrophy is of great importance.

Endoanal sonography is a cheap and fast method to detect sphincter defects. However, this technique is not able to detect external sphincter atrophy. Previous studies (5,16) comparing endoanal sonography with electromyography found a good correlation between the two methods in the detection of sphincter defects but did not considered atrophy as this was not seen by ultrasound.

The introduction of endoanal MRI provided a visualization of the sphincter complex, which is superior to endoanal sonography by its multiplanar capabilities and higher resolution (17,18). This allowed a precise inspection of the external sphincter, which was not possible with endoanal sonography. In a study on 22 patients, comparing imaging results to surgical findings, endoanal MRI was more accurate than endoanal sonography in detecting sphincter lesions (12).

In our study, the findings of the two imaging methods correlated in all but one patient in the detection of sphincter defects. The correlation between MRI and EMG was higher than between sonography and EMG. The positive and negative predictive values were also higher for MRI than for sonography. These differences are mainly caused by the fact that sonography is not able to detect external sphincter atrophy while endoanal MRI found generalized external sphincter atrophy in five patients where no or minimal electrical activity was registered.

It should be noted that in three cases MRI and sonography found partial defects and EMG recorded no changes in the local activity. Previous studies raised the question whether EMG and imaging techniques provide the same information or whether the limits between normal and pathological findings of these techniques are different between the techniques (16). It is possible that the visualized changes of muscle structure are not or not yet functionally relevant.

EMG is the gold standard but only a very dense EMG mapping, implying many needle insertions, will provide the same topographical information as the imaging methods (16). Ultrasound guidance is necessary to avoid sample errors. EMG is also a very painful, lengthy procedure while endoanal sonography and endoanal MRI are painless methods. Endoanal sonography is more widely available then endoanal MRI but remains operator dependent. Endoanal MRI is able to detect sphincter lesions with 100% sensitivity and negative predictive value, a specificity of 80% and a positive predictive value of 87%. Therefore, we consider it more accurate than endoanal sonography and we recommend it as the method of choice in the diagnostic work-up of patients with fecal incontinence.

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CHAPTER 6

EXTERNAL ANAL SPHINCTER ATROPHY ON ENDOANAL MRI ADVERSELY AFFECTS CONTINENCE AFTER SPHINCTEROPLASTY

Introduction

Childbirth is the most common cause of fecal incontinence (1). Following primary gynecological repair of perineal tears, persistent defects can be demonstrated in 85 percent of patients (2). A substantial part of patients with an occult sphincter defect will become incontinent with increasing age. The incidence of occult sphincter damage after childbirth was unknown until Sultan et al. studied a consecutive group of 202 pregnant women. On endoanal ultrasound, 35% of primiparae who delivered vaginally developed a sphincter defect involving one or both muscles, which persisted at 6 months (3). Although sphincter defects due to obstetric trauma can be restored adequately by overlapping sphincteroplasty, incontinence persists in a substantial number of patients. The reported failure rates at long term follow-up vary between 44 and 53 % (4,5).

Preoperative evaluation of patients with fecal incontinence usually includes anorectal manometry, evacuation proctography, assessment of pudendal nerve terminal motor latency, and endoanal ultrasound.

The role of these preoperative anorectal function tests in predicting the outcome of sphincteroplasty is still controversial. Reports about the predictive value of these tests are numerous and conflicting. Recently, it has been shown that endoanal MRI enables the detection of external anal sphincter atrophy (6-10) (Figure 1a,b). Using conventional endoanal ultrasound atrophy can not be demonstrated.

This chapter is adapted from:
Briel JW, J Stoker J, Rociu E, JS Laméris JS, Hop WCJ, and Schouten WR. External anal sphincter atrophy on endoanal mri adversely affects continence after sphincteroplasty. Br J Surg 86:11; 1392-1397. 1999.

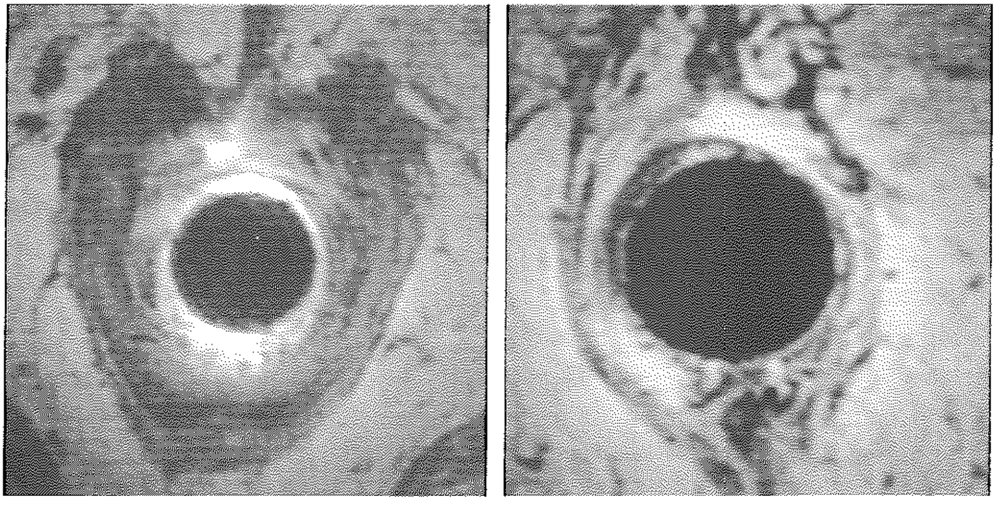

Figure 1a Axial proton density weighted endoanal MRI **Figure 1b**

1a. Patient with an anterior external sphincter defect. Normal width of the external sphincter.
1b. Patient with external sphincter atrophy.

Therefore, we conducted a prospective study in order to investigate the prevalence of external anal sphincter atrophy in female patients with anterior sphincter defects due to obstetric injury. Furthermore, the impact of external anal sphincter atrophy on the outcome of sphincteroplasty was studied.

Patients and Methods

Twenty consecutive female patients (median age: 50 years; range: 28-75) with fecal incontinence due to obstetric trauma were preoperatively assessed with endoanal ultrasound and endoanal MRI. Images obtained with each technique were seperately examined and external anal sphincter atrophy was scored. Within 6 months after the preoperative assessment, all patients underwent anterior anal repair, as described earlier (11). Clinical outcome was evaluated using the grade and frequency of fecal incontinence, the need for pads, the grade of social isolation and patient satisfaction after a median follow-up of one year. Outcome was interpreted without knowledge of the MR and ultrasound images. The decision to perform surgery was based solely on endosonography. The MR imaging was considered additional and did not influence treatment.

Endoanal Sonography

A B&K (Naerum, Denmark) ultrasound scanner with a rotating probe providing a 360°image was used. A 7 MHz transducer with minimum beam width of 1.1 mm and a focal length of about 3 cm, was used. Transversal images were performed, at least at four different levels, through the anal canal.

Endoanal MRI

MR imaging was performed at 0.5 T (Gyroscan T5-II, Philips Medical Systems, Best, The Netherlands). An endoanal coil with a diameter of 19 mm (Philips Medical Systems, Best, The Netherlands) was used (7-9). Axial T2weighted 3D gradient echo and coronal and sagittal T2weighted turbo spinecho sequences were performed.

Determination of atrophy

The extent of external sphincter muscle thinning was qualitated on hard copy by one radiologist (JS). The MR images were also quantatively evaluated using a work station with commercially available software (Gyroview HR, Philips Medical Systems, Best, The Netherlands). In all cases the anterior part of the external anal sphincter could not be identified due to an anterior sphincter defect. External anal sphincter width at the posterior side and at both lateral sides was determined (WIDTH, Fig. 2). Furthermore, the arc of the anterior defect was noted (ARC, Fig. 2). The area of the remaining part of the external anal sphincter was measured (AREA, Fig. 2). All measurements were performed on the MRI-slice located at the mid-level of the anal canal, in each patient. In order to investigate the existence of an interobserver bias, the results of quantative MRI assessment, performed by two investigators (JWB and ER) were compared. Both were blinded to the measurements of the other.

Statistical Analysis

Fisher's exact test was used for the comparison of percentages. Mann-Whitney test was used to compare continuous data between groups.

To determine agreement between measurements of different investigators, intraclass correlation coefficient was used. $P<0.05$ was considered significant.

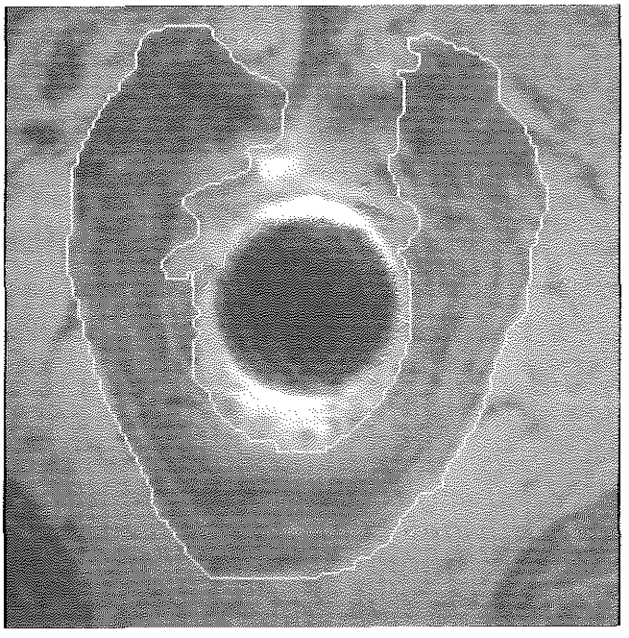

Figure 2. Measurement of external anal sphincter width, arc of external anal sphincter defect, and remaining area of external anal sphincter.

Results

In all patients anterior sphincter defects could be demonstrated both with endoanal ultrasound and MRI. External anal sphincter atrophy could only be demonstrated on endoanal MRI. The prevalence of external anal sphincter atrophy (determined by one of the radiologists) was 40% (8 patients). Continence was restored in 13 patients (65%). Comparing patients with and without atrophy, clinical outcome was significantly better in those without external anal sphincter atrophy (11/12 = 92% versus 2/8 = 25%, P=0.004).

The results of the MRI measurements are listed in Table 1. Determination of external anal sphincter width at the posterior side and both lateral sides showed not to be useful in predicting the outcome of sphincter repair. However, there was a significant relationship between the outcome of sphincteroplasty and the arc of the external anal sphincter defect (ARC, P=0.04). Furthermore, the area of the remaining external anal sphincter was related with the outcome (AREA, P=0.002). In comparing these 2 predictive parameters, the area of the remaining external anal sphincter is the most potent one (Table 1).

Table 1. MRI measurements in patients with and without successful outcome after sphincter repair

	Success		Failure		P-value
Width (mm)					
Posterior	9.3	(2.0 - 23.5)	9.3	(4.7 - 13.1)	0.12
Left	4.3	(1.1 - 8.8)	2.5	((1.1 - 5.6)	0.22
Right	3.9	(1.1 - 9.0)	3.0	(1.1 - 6.0)	0.73
ARC (°)	55	(19 - 146)	85	(51 - 190)	0.04
AREA(mm^2)	393	(121 - 1350)	218	(87 - 360)	0.002

Data given are median values (range)

For AREA the cut-off point for successful outcome was determined. The highest AREA in patients with poor outcome after sphincteroplasty was 360 mm^2 (Fig. 3). In the 10 patients with AREA < 360 mm^2, only 3 had a successful outcome after sphincter repair (30%). In patients with AREA > 360 mm^2, all 10 patients regained continence (100%).
Atrophy, as qualitated by a radiologist, and the quantitative measurement of AREA on MRI, were well related (P=0.001).
Comparing the quantative measurements of the two investigators (JWB and ER), there was no systemic difference (P=0.67). The interobserver agreement was good (intraclass correlation coefficient: 0.91).
Age and surgical outcome were not related. There was also no significant correlation between age versus atrophy. Furthermore, age was not related to any of the MRI measurements (WIDTH, ARC, AREA).

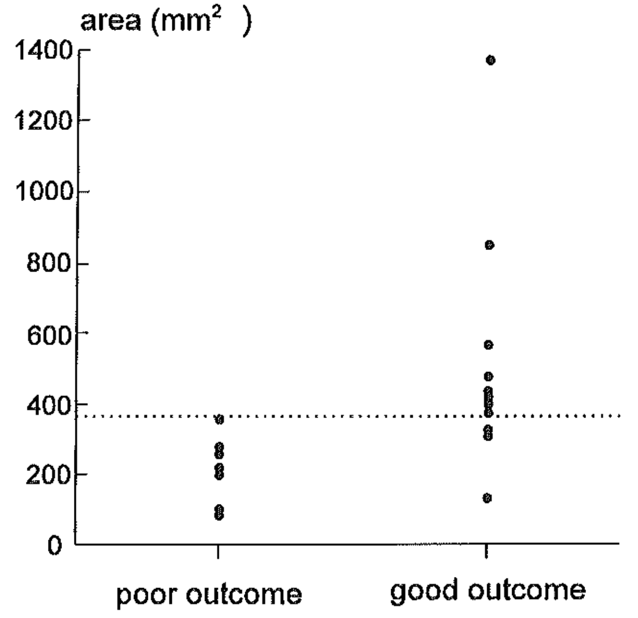

Figure 3. Determination of the cutt off point of AREA in predicting outcome after sphincter repair.

Discussion

The use of conventional whole body MRI in the evaluation of patients with fecal incontinence has been described. It has proven to be of great value in assessing patients with congenital anorectal anomalies (12). However, anal endosonography is the imaging technique of choice for the detection of abnormalities in the region of the anal sphincters, when compared with MRI using a whole body receiver coil (13-15). The spatial resolution of endoanal sonography is superior to body coil MRI. However, a major limitation of anal endosonography is the poor inherent contrast, which is the cause of the difficult identification of the external anal sphincter. Recently, it has been shown that the use of an endoanal coil enables the detection of anal sphincter defects as well as external anal sphincter atrophy on MRI (6,8,9).

In this study anterior sphincteroplasty was found to be successful in 65% of cases. This outcome is in accordance with other series (5,16).

Prevalence of external anal sphincter atrophy was 40%. In 1977, Parks (16) examined biopsies of the external anal sphincter of patients with idiopathic fecal incontinence. The biopsies of all incontinent patients showed histologic evidence of denervation. He therefore suggested that this type of fecal incontinence could be the result of denervation of anal sphincter muscles. This could be the result of entrapment or stretch injury of the pudendal or perineal nerves occurring as a consequence of rectal descent induced during repeated defecation straining in constipated patients (17), or from injuries to these nerves associated with childbirth (18). Nowadays this type of fecal incontinence is called neurogenic.

In patients with fecal incontinence due to obstetric injury both anal sphincter rupture and denervation may coexist (11,19-21). The external anal sphincter is composed of striated voluntary muscle and controlled by the somatic nervous system. The efferent innervation of the external anal sphincter for both tonic and phasic contractions originates in spinal cord segment S-2 and travels through the pudendal nerve (22). Several authors have reported that denervation of the pelvic floor and subsequent failure of surgical repair can be predicted by preoperative electromyography (5,19,23-25). However, detecting and quantification of denervation might be difficult. Denervation of the external anal sphincter and its detection fade in time while the sphincter damage remains. Furthermore electromyography of the pelvic floor is generally considered as distressing.

It seems likely that in patients with both denervation and sphincter defects, denervation of the pelvic floor will persist, regardless of the outcome of repair of the sphincter defect. It has been shown that functional results of sphincter repair in patients with neurogenic fecal incontinence are poor (26). Therefore, in patients with both denervation and sphincter defects, a poor outcome might be expected. If traumatic denervation leads to atrophy of the external anal sphincter, the finding of atrophy of this sphincter muscle influences outcome after surgery. This hypothesis was confirmed by the present study. Comparing patients with and without external sphincter atrophy, outcome was significantly better in those without external anal sphincter atrophy.

The area of the remaining external anal sphincter on endoanal MRI proved to be of significant value in determining patients with favorable outcome. The objective quantitative measurement of this area shows to be of equal value as the rather subjective determination of atrophy on hard copies of MR images by the radiologist: both determinations are well correlated ($P=0.001$).

The arc of the sphincter tear is a predictor of outcome after sphincter repair as well. However, comparing the predictive value of ARC and AREA, the measured area is by far the most important one.
The separate measurements of sphincter width at the posterior side and both lateral sides did not relate with outcome. This might be explained by the rather singularity of the width measurement. The computed area consists of numerous adjacent sphincter widths measurements, thereby ruling out the impact of sphincter irregularity.
Determination of the presence of atrophy on endoanal MRI enables the prediction of outcome after sphincteroplasty. Quantitative assessment of this atrophy by means of the cut-off area (360 mm^2) specifically predicts which patient will benefit from sphincter repair.
Age of the patient and outcome of the anterior anal sphincter repair were not related. Consistently with this finding, there was also no significant correlation between age versus atrophy. Furthermore, age was not related to any of the MRI measurements (ARC, AREA).
Endoanal MRI is the first imaging technique to predict functional outcome after sphincter repair. Moreover, endoanal MRI directly enables the detection of external sphincter atrophy, rather than assuming atrophy by detection of pelvic floor denervation assessed by either electromyography or pudendal nerve terminal motor latencies. Although endoanal MRI is relatively expensive, it is certainly less distressing than electromyography or latency studies, whereas the time needed for the investigation itself is comparable for all tests. Therefore, the authors advocate the implementation of endoanal MRI in the preoperative work-up of patients with fecal incontinence, in predicting the result of surgery in individual patients.
The alternatives for patients with persistent fecal incontinence after sphincteroplasty are either creation of a stoma or dynamic gracilis plasty. Since this dynamic gracilis plasty is technically more feasible in patients without previous attempts to restore continence, i.e. sphincteroplasty, selection of patients is preferable. Therefore, patients with external anal atrophy as seen on endoanal MRI might be candidates for dynamic gracilis plasty in the first place, rather than conventional sphincteroplasty. To confirm this hypothesis, further investigation is needed. Especially, the relation between

current anorectal physiology tests and atrophy as seen on endoanal MRI needs to be investigated.

Conclusions

Until recently, none of the available imaging techniques could predict the outcome of surgical therapy for fecal incontinence. This study demonstrates that external anal sphincter atrophy occurs in almost half of the patients with fecal incontinence due to obstetric trauma. Furthermore, it has been shown that this atrophy adversely affects the outcome of sphincteroplasty. In our opinion, endoanal MRI is a valuable tool in the preoperative assessment of patients with fecal incontinence.

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CHAPTER 7

ENDOANAL MRI OF THE ANAL SPHINCTER IN FECAL INCONTINENCE

Introduction

Fecal incontinence is the inability to voluntarily control defecation. The prevalence of fecal incontinence ranges from three to ten per thousand but may actually be much higher (1). Most affected persons do not seek help for fecal incontinence. This is chiefly because of embarrassment or because they are not aware that help is available. This chronic disability has serious emotional impact with increased risk for behavioral problems and social isolation. Women are more often affected than men especially as a consequence of childbirth (2).

Initially fecal incontinence was thought to be caused by neurogenic dysfunction of the anal complex. Therefore, diagnostic techniques mostly focused on functional information. The development of imaging techniques using endoluminal devices: endoluminal sonography and endoluminal MRI resulted in a good visualization of the anal sphincter. This made possible a better understanding of the pathology by showing that sphincter lesions are the main cause of fecal incontinence (3,4). Consequently, detailed sphincter imaging became extremely important in the diagnosis and treatment of the disease.

Besides the main pathology confined to the anal sphincter, less often, the causes of fecal incontinence can be located higher in the digestive tract, like chronic diarrhea and rectal prolapse (5). Fecal incontinence caused by rectal prolapse is imaged by defecography (6), which allows the visualization of the pelvic floor morphology during defecation and will not be part of this paper. As the most frequent cause of fecal incontinence is anal sphincter pathology, the purpose of this paper is to discuss the value of endoanal MRI in imaging the anal sphincter in patients with fecal incontinence.

This chapter is adapted from: Rociu E, Stoker J, Zwamborn AW, Laméris JS. Endoanal MR imaging of the anal sphincter in fecal incontinence. Radiographics 1999, 19:171-177.

Endoanal MRI

Technique

MR imaging with a special dedicated coil was developed in the last five years (7,8). Endoanal MRI has multiplanar capabilities and high inherent contrast resolution. In our study imaging was performed at 1.5 T (Philips, Gyroscan ACS-NT, Best, The Netherlands) with a dedicated endoanal coil (diameter of 19 mm). Axial, proton density weighted , 3D GRE (TR 30 msec, TE 13 msec, flip angle 60°, FOV 140x112 mm, imaging matrix 205x256, slice thickness 2mm) and sagittal and coronal T2wTSE (TR 2800 ms, TE 120 ms, ETL 10, FOV 120x90 mm imaging matrix 228x256, slice thickness 4mm) scans were performed.

Endoanal MRI enables detailed demonstration of normal sphincter anatomy and pathology.

The hyperintense internal sphincter (Fig. 1) is visible as a continuation of the circular smooth muscle of the rectum. The hypointense external sphinc ter (Fig. 1) surrounds the lower part of the internal sphincter. The puborectalis muscle (Fig. 2) slings the upper part of the external sphincter and is continued cranial by the levator ani muscle.

A sphincter defect (Fig. 3-6) is defined as a discontinuity of the muscle ring. Scarring (Fig. 6,7) is defined as a hypointense deformation of the normal pattern of the muscle layer due to replacement of muscle cells by fibrous tissue. Two external sphincter patterns can be misdiagnosed as defects. The first, a posterior discontinuity of the muscular ring (Fig. 8), is often seen in young male patients. This can be interpreted as a defect but is in fact a normal variant determined by the anococcygeal ligament. On higher scans, the external sphincter fibers will merge posterior reestablishing the common shape. The second, an anterior discontinuity of the external sphincter ring, is often seen in female patients (Fig. 9). This discontinuity is created by the direction of the external sphincter fibers. Most fibers of the superficial and deep parts of the external sphincter insert to the central tendon of the perineum, but some fibers continue forward and insert anteriorly in the perineal raphe.

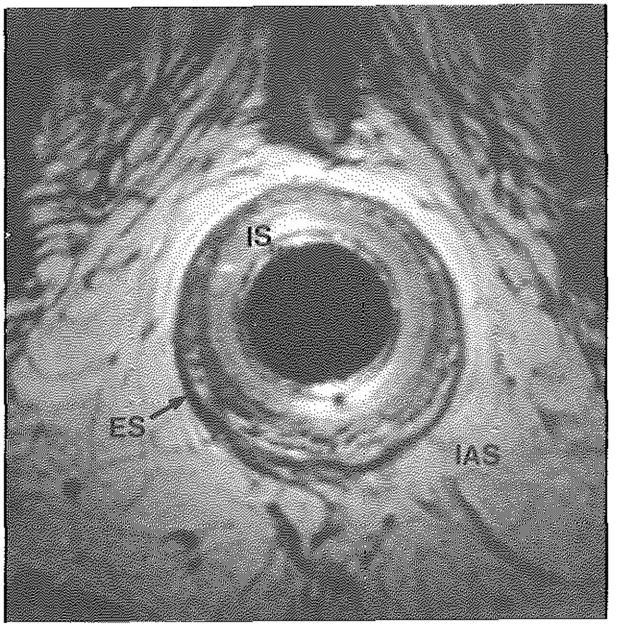


Figure 1. Endoanal MRI, axial proton density weighted GRE, showing a normal internal (IS) and external(ES) sphincter.
Ischioanal space (IAS).

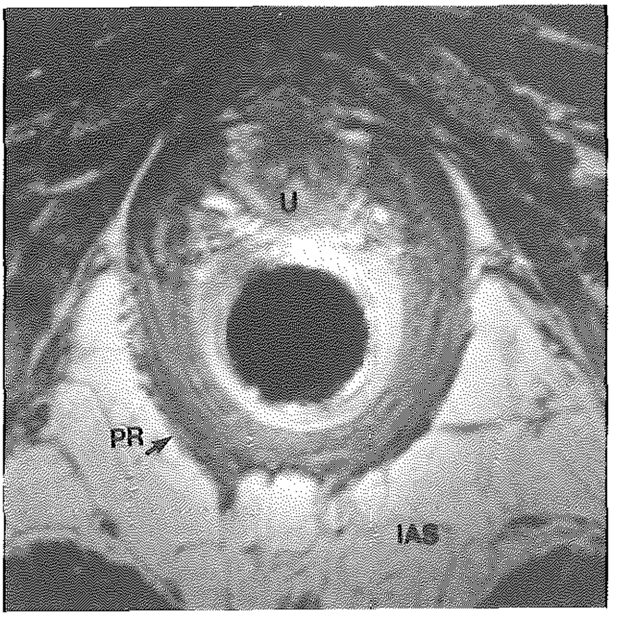


Figure 2. Endoanal MRI, axial proton density weighted GRE, showing a normal puborectalis muscle (PR). Ischioanal space (IAS). Urethra (U).

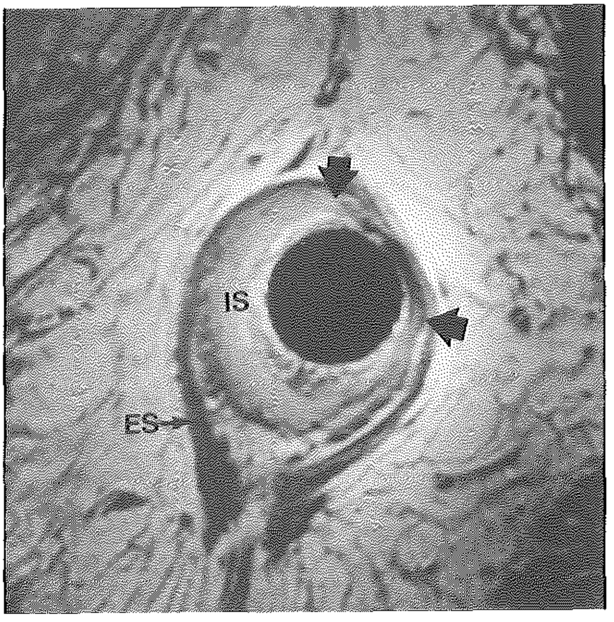


Figure 3. Endoanal MRI, axial proton density weighted GRE showing an internal sphincter (IS) defect (arrows). External sphincter (ES). The patient presented with fecal incontinence after hemorrhoidectomy.

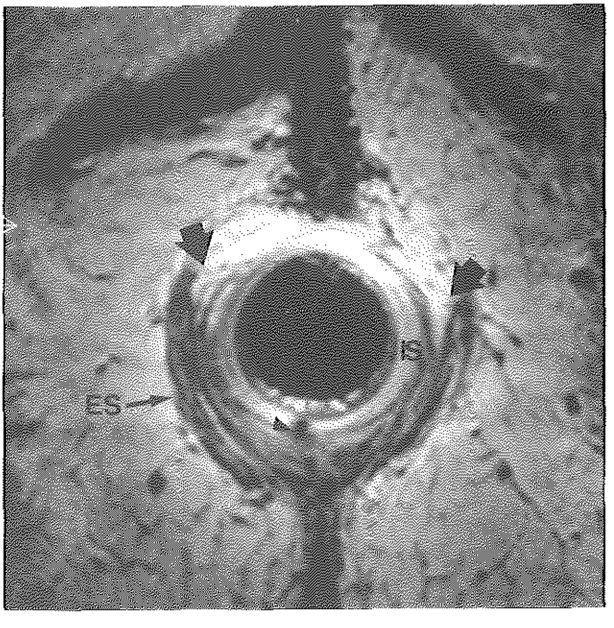


Figure 4. Endoanal MRI, axial proton density weighted GRE showing an external sphincter (ES) defect (arrows). Internal sphincter (IS).
The patient presented with fecal incontinence after delivery. Small coil artifact (arrowhead).

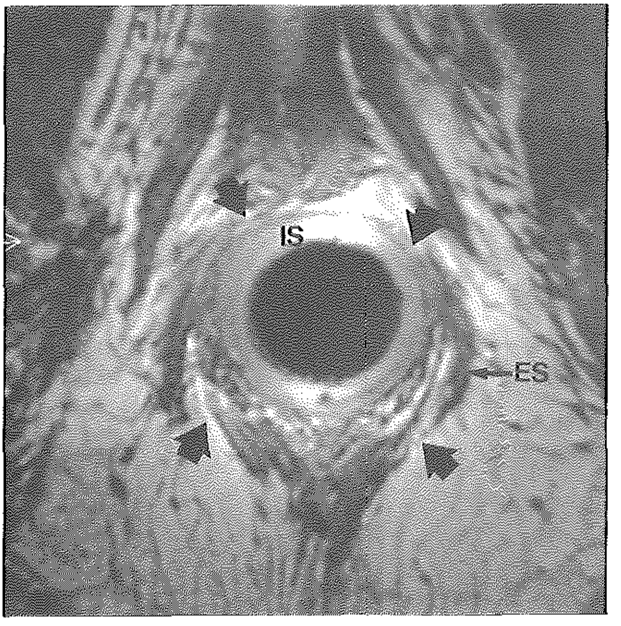


Figure 5. Endoanal MRI, axial proton density weighted GRE showing fragmentation (arrows) of the external sphincter (ES). Internal sphincter (IS). The patient presented with fecal incontinence after rape.

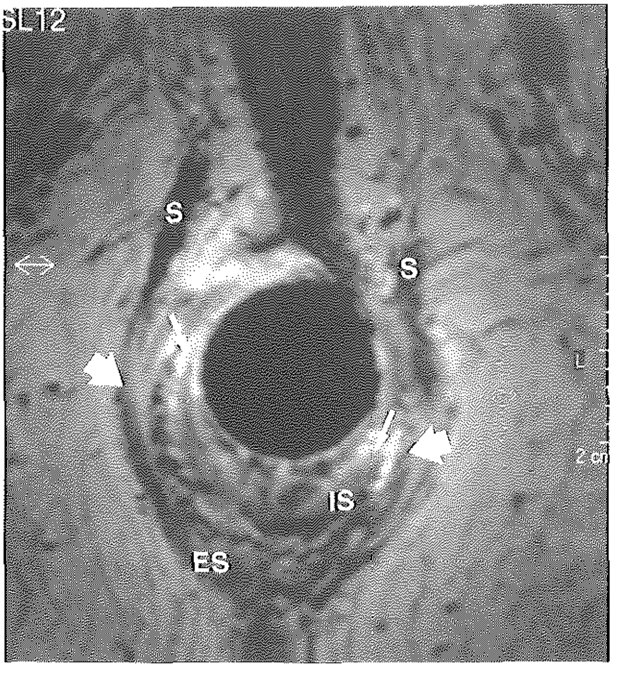


Figure 6. Endoanal MRI, axial proton density weighted GRE showing a complex lesion: external sphincter (ES) and internal sphincter (IS) defect (arrows), scarring (S) and asymmetry of the anal complex.

Especially in women, this insertion can be larger and the imbrication of the muscle fibers more pronounced. The resulting open elliptical shape is in fact a normal variant but can be misdiagnosed as anterior defect.
By providing a fine delineation of the muscular layers, endoanal MRI can also detect local thinning and atrophy of the sphincter muscles. Atrophy of the external sphincter (Fig. 10) defined as an extreme generalized thinning proved to be a predicting factor for negative outcome of sphincter surgery (9). On coronal scans the thickness of all anal muscles can be compared making external sphincter atrophy easy to detect (Fig. 11 a,b). Several studies demonstrated a good correlation between atrophy as seen on endoanal MRI and the findings by surgery and the histopathologic investigation of the biopsy specimens (8,9). Therefore, endoanal MRI is of major importance in the preoperative assessment of patients with fecal incontinence.

Endoanal MRI related to other diagnostic modalities for fecal incontinence

In patients with fecal incontinence, anal sphincter pathology includes neurogenic dysfunction and traumatic sphincter lesions. Several diagnostic techniques give information about the structure and/or function of the anal sphincter. The detection of structural lesions has the most impact as the treatment of sphincter neuropathy often gives disappointing results and only the patients with sphincter lesions can benefit from surgical repair. Sphincter lesions can be caused by deliveries but also by pelvic surgery (for prolapse, hemorrhoids and hysterectomy) and rape.
Digital examination can reveal perianal hypoesthesia, decreased sphincteric resting and squeezing tone or sometimes sphincter defects (3). Anorectal manometry is important for measuring the resting pressure (mainly due to the internal sphincter) and the squeezing pressure (mainly due to the external sphincter) (10). Both resting and squeezing pressures are often reduced in fecal incontinence. Manometry is also important for establishing the presence of the rectoanal inhibitory reflex, which is often reduced or absent in fecal incontinence. Pudendal nerve terminal motor latencies (PNTML) are valuable in the study of the innervation of the external sphincter and are often prolonged in neurogenic fecal incontinence (10).

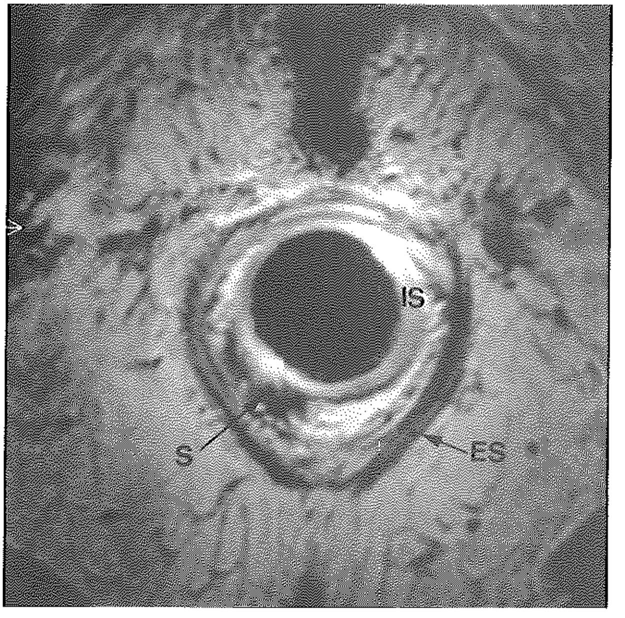


Figure 7. Endoanal MRI, axial proton density weighted GRE showing scar tissue (S) of the internal sphincter (IS) in the intersphincteric space. External sphincter (ES).

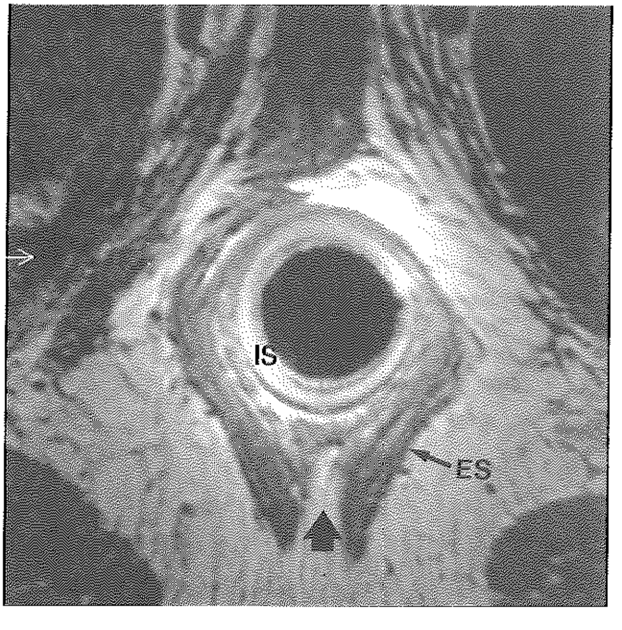


Figure 8. Endoanal MRI, axial proton density weighted GRE showing posterior a discontinuity of the external sphincter (ES) ring (arrow). This can be interpreted as a defect but is in fact a normal variant determined by the anococcygeal ligament. On higher scans, the external sphincter fibers will merge posterior reestablishing the common shape. Internal sphincter (IS).

Electromyography is useful in mapping external sphincter and internal sphincter defects and in studying the fiber density of muscular fibers, which is increased in neurogenic fecal incontinence. This invasive method is now replaced by endoluminal imaging (11). Endosonography is a good method in detecting internal sphincter defects. However, it is limited by the poor inherent contrast, which causes cumbersome identification of the external anal sphincter. Deliveries or surgery often damages this anal muscle of major importance in the continence (2). Endoanal sonography can not delineate the external sphincter and therefore can not detect external sphincter thinning and atrophy. This technique also remains operator dependent. Ultrasound has the advantage of being cheaper, more widely available and quicker than endoluminal MRI. Earlier studies demonstrated that sonography (Fig. 12) or body coil MRI (Fig. 13) without endoluminal device do not result in adequate contrast and spatial resolution (12). The role of phased array coil MRI (Fig. 14) has not been yet evaluated, but the local spatial resolution of this technique is inferior to endoluminal techniques. Endoanal MRI is superior to endosonography by its multiplanar capabilities and higher inherent contrast resolution. This technique was proven to be more accurate than endosonography in detecting anal sphincter lesions (13). Endoanal MRI is not operator dependent but is more expensive than endosonography. A recent study indicated that if only one technique is to be used then MRI would provide the optimal decision in more cases than sonography (13). This could save unnecessary operations and may make MRI cost-effective.

Impact of endoanal MRI in the treatment of fecal incontinence

In treating fecal incontinence, the physician has the choice between several modalities. The conservative approach consists of constipating agents, electrical biofeedback therapy and exercises of the pelvic floor. The most used surgical therapy is anterior anal repair. Unfortunately, it has only 65% success rate. A recent study indicated that external sphincter atrophy detectable only with endoanal MRI could predict a poor outcome of the anterior anal repair (9). In this respect, the use of endoanal MRI may lead to a better selection of the patients and thereby better results. The alternative for patients with persistent fecal incontinence after sphincteroplasty commonly was creation of a stoma. New surgical treatment modalities have been developed. These new and promising modalities include the transposition of striated skeletal muscles combined with implantation of neurostimulators (e.g. dynamic gracilis muscle plasty), artificial sphincters based on the same principle as artificial urinary sphincters, and direct sacral nerve stimulation (14,15).

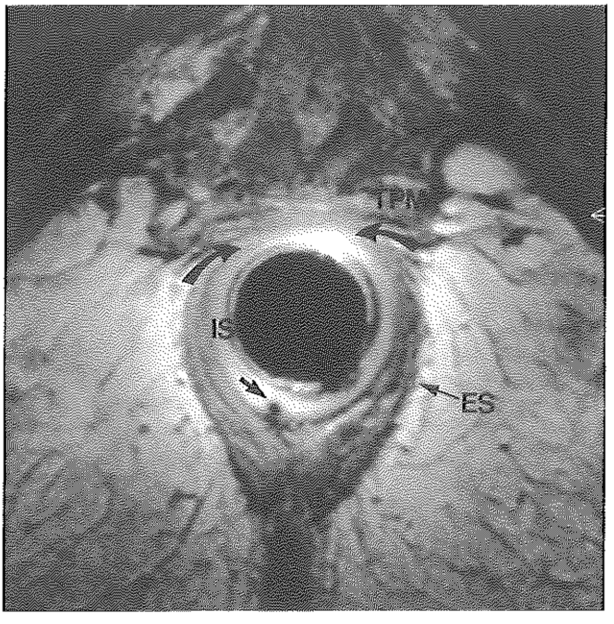


Figure 9. Endoanal MRI, axial proton density weighted GRE showing anterior a discontinuity of the external sphincter (ES) ring (curved arrows). This can be interpreted as a defect but is in fact a normal variant determined by the proximity of the transverse perineal muscle (TPM), which make the external sphincter fibers difficult to delineate. Internal sphincter (IS). Small coil artifact (arrow).

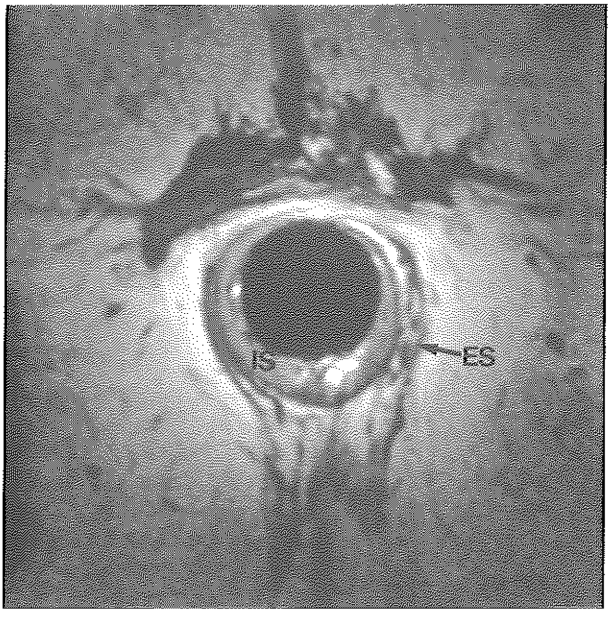


Figure 10. Endoanal MRI, axial proton density GRE showing severe atrophy of the external sphincter (ES). (Compare with Figure 1). Internal sphincter (IS).

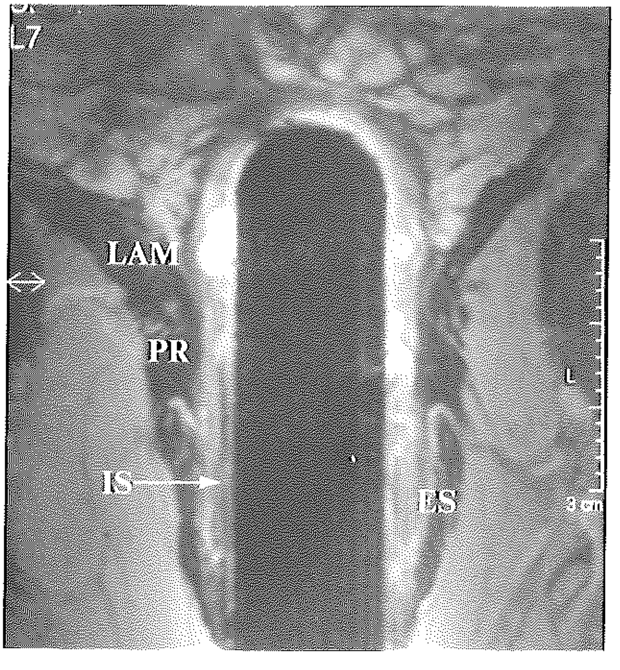


Figure 11a. Endoanal MRI, coronal T2w TSE of a normal sphincter complex. External sphincter (ES). Puborectalis (PR) and levator ani muscles (LAM). Internal sphincter (IS).

Figure 11b. Endoanal MRI, coronal T2w TSE showing atrophy of the external sphincter (ES). Puborectalis (PR) and levator ani muscle (LAM). Internal sphincter (IS).

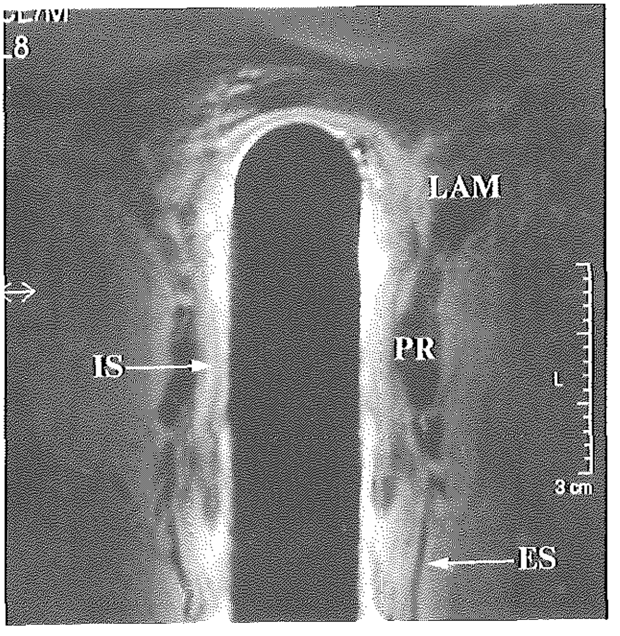
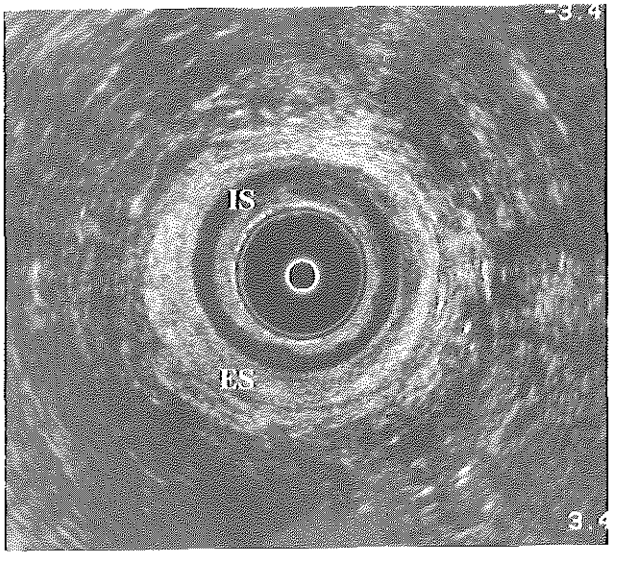


Figure 12. Endoanal sonography showing a normal external (ES) and internal sphincter (IS). Compare with Fig.1.



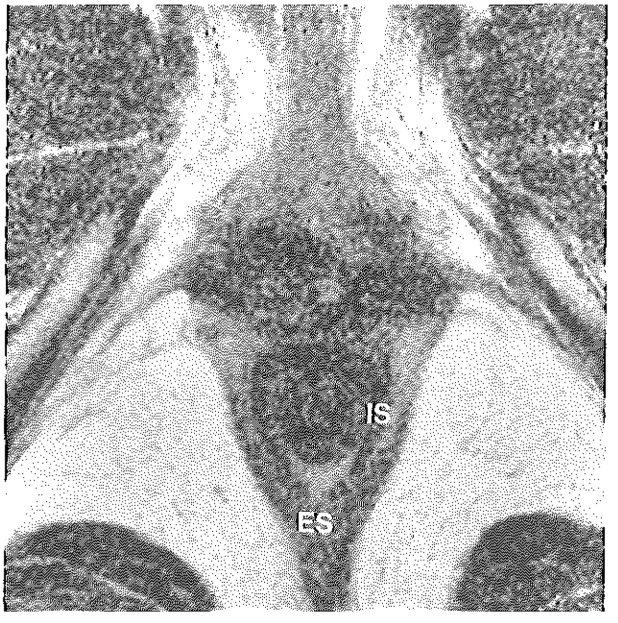


Figure 13. Axial T2w TSE using the body coil. The external sphincter (ES) and internal sphincter (IS) are difficult to delineate. An accurate evaluation of anal sphincter pathology is therefore hardly possible. Compare with fig.1.

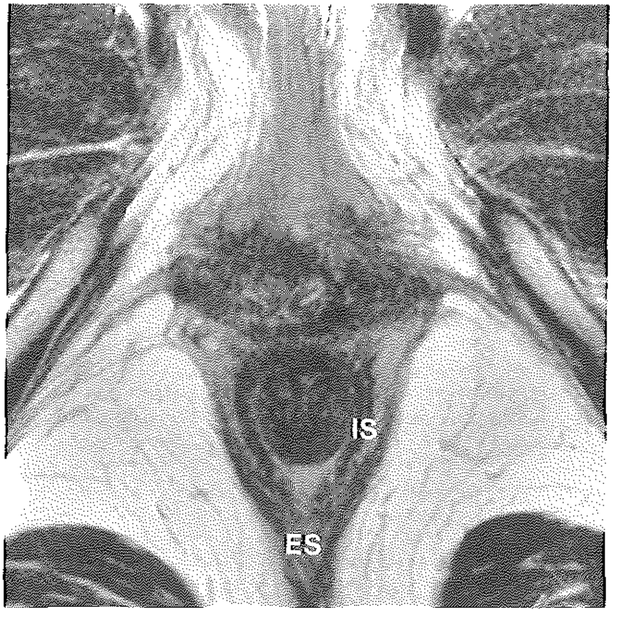


Figure 14. Axial T2w TSE with the use of phased array coil. The anal sphincter muscles are more detailed demonstrated than with the use of the body coil but less accurate than with the use of endoluminal coil. External sphincter (ES). Internal sphincter (IS). Compare with Fig 1.

Conclusion

Careful medical history and physical examination will orient the physician about the etiology of fecal incontinence. Fecal incontinence caused by conditions as: prolapse, enterocele, cystocele and intussusception, can be assessed with defecography.

In the diagnose of fecal incontinence due to anal sphincter pathology after assessing the sphincter function by digital examination, PNTML and manometry, visualisation of the sphincter and detection of sphincter lesions will play an important role. The selection of patients with fecal incontinence who may benefit from surgical therapy is based on the detection and type of sphincter damage. In order to perform optimal surgery an accurate description of the position, extent and type of lesion is necessary. If available, endoanal MRI should be performed instead of endoanal ultrasound. In our experience endoanal MRI is at the moment the most accurate technique in detecting and characterizing anal sphincter lesions and in deciding the optimal therapy.

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SUMMARY

Imaging has become important in the diagnostic work-up of fecal incontinence. The aim of this thesis was to evaluate the role of endoanal MR imaging in the assessment of patients with fecal incontinence.

Chapter 1 Short overview of prevalence, etiology, pathology, current diagnostic and therapeutic modalities of fecal incontinence

Chapter 2 Technique, limitations and pitfalls of endoanal MRI in a larger context: the diagnosis of anorectal diseases

Endoluminal MRI has become important in the diagnostic work up of patients with anorectal diseases. In several aspects this technique is superior to endoluminal sonography and body coil MRI. The spatial resolution of body coil MRI is limited, while endoluminal sonography has a low contrast resolution. Endoluminal MRI combines the strength of the two previous techniques: the high spatial resolution of an endoluminal technique and the high intrinsic contrast resolution of MR imaging. For an optimal endoluminal MRI attention should be paid to adequate patient preparation, imaging protocols and potential pitfalls in interpretation. The advantage of endoluminal MRI over phased array coil MRI is less well substantiated. Current research is directed towards further evaluation of the role of endoluminal MRI in fecal incontinence and towards the comparison of phased array coil MRI to endoluminal MRI and the combination of both coils in several applications.

Chapter 3 Study of the normal anatomy

Knowledge of the normal anatomical features of the anal canal is essential for the diagnosis and treatment of anal diseases. Endoanal MRI is the first imaging technique that provides multiplanar, high-resolution in-vivo demonstration of anal anatomy and fine delineation of all sphincter muscles. The purpose of this study was to analyze qualitative variations of normal sphincter anatomy as seen with high-resolution endoanal MRI. Furthermore quantitative sex- and age-related variations in thickness and length of the anal sphincter were evaluated in order to refine the diagnosis of sphincter atrophy.

Qualitative differences. The major variation of the anatomy was visible on the anterior part of the anal sphincter in males and females. In males the central perineal tendon has the aspect of a central insertion point. In females, it is not a point, but appears as an insertion area with woven muscular fibers, consequently allowing more elasticity and being called perineal body. In females the superficial transverse perineal muscle was located cranial to the external sphincter. In males, this muscle is located directly ventral to the external sphincter reinforcing the anterior part of the anal sphincter.

Quantitative differences.

1. External sphincter in males was almost twice as long as in females.
2. External sphincter in young (under 35) males was significantly thicker than in young females.

These features allow easier stretching of the female external sphincter. This may be important during vaginal delivery when the anterior part of the external sphincter closely related to the vagina should allow wide extension.

3. With aging in normal, continent males and females:
   a) significant thinning of the longitudinal muscle and thickening of the internal sphincter were recorded;
   b) thinning of the external sphincter was recorded, only significant in males.

The thinning of external sphincter muscle in elderly may be physiological and should be differentiated from severe atrophy as it occurs in incontinent patients.

Endoanal sonography was the first method to directly visualize the anal complex. The introduction of endoanal MRI in the last decade generated the question "which is the preferable imaging method for the work-up of patients with fecal incontinence: endoanal sonography or endoanal MRI?" The following two studies tried to answer this question.

Chapter 4 Endoanal sonography versus endoanal MRI as validated by surgery

22 female patients with surgery for fecal incontinence were included in this retrospective study. The findings by surgery were correlated with the pre-operative findings of endoanal sonography and endoanal MRI.

Detecting lesions. In detecting lesions MRI showed a very good agreement with surgery concerning the external sphincter and a good agreement concerning the internal sphincter. Sonography only showed a moderate agreement with surgery in detecting lesions of both external and internal sphincter. The correlation between MRI and sonography was moderate. Nevertheless, concerning the external sphincter MRI presented a combination of high positive and negative predictive values, which selects it as a very good preoperative diagnostic method for anterior sphincter repair.

Characterizing lesions. Sonography and MRI were comparable when characterizing damage of the internal sphincter. However, in characterizing damage of the external sphincter, endoanal MRI provided a good distinction between different types of tissue (muscle, scar, fat). This allowed an accurate detection of local thinning which was not possible with sonography, and a more precise description of the extent and structure of complex lesions.

Deciding surgery. In the surgical decision-making, the two imaging techniques in our study were complementary. The advantage of sonography is that it is a cheaper, more widely available and quicker technique than MRI. Nevertheless, if only one technique is to be used then MRI would have provided the optimal decision in more cases than sonography. This could save unnecessary operations and may make MRI cost-effective. Endoanal MRI demonstrates to be superior to endoanal sonography in the pre-operative work-up of patients with fecal incontinence.

Chapter 5 Endoanal sonography versus endoanal MRI as validated by ultrasound guided electromyography

17 patients with fecal incontinence underwent endoanal MRI, endoanal sonography and ultrasound (US) guided electromyography (EMG). Presence of lesions, location and type were recorded. Ultrasound guidance was used for EMG needle placement in sonographical normal and abnormal areas within the external sphincter. Then the correlation between MRI findings and sonographical findings was evaluated, using EMG as gold standard. The correlation between MRI and EMG was higher than between sonography and EMG. The positive and negative predictive values were also higher for MRI than for sonography. These differences are mainly caused by the fact that sonography is not able to detect external sphincter atrophy while endoanal MRI found generalized external sphincter atrophy in five patients where no or minimal electrical activity was registered. In our opinion, endoanal MRI is the method of choice in the diagnostic work up of patients with fecal incontinence.

Chapter 6 The importance of external sphincter atrophy

20 female patients with fecal incontinence after vaginal delivery were included in this prospective study.
Endoanal MRI was performed before the operation and found :
- in all patients anterior external sphincter defect;
- in 40% (8/20) of patients external sphincter atrophy.

All patients underwent surgical anterior sphincter repair. One year after the operation, the clinical outcome of surgery was evaluated.
Continence was restored in 65% of the patients. The operation was successful in 25% (2/8) of patients with external sphincter atrophy and in 92% (11/12) of patients without external sphincter atrophy ($p<0.05$). Both the subjective determination of atrophy by a radiologist and the objective measurements of the remaining area were significantly correlated with the outcome of surgery.
External sphincter atrophy as seen on endoanal MRI is a predictive factor for negative outcome of anterior sphincter repair.

Chapter 7 The role of endoanal MRI in the work-up of patients with fecal incontinence

Patients with fecal incontinence first undergo physical examination. As a following step, functional tests will complete clinical findings with objective data. At this point, the physician has knowledge of impaired anal function but still limited information on the existence and location of sphincter lesions that can be corrected surgically. Therefore, imaging is mandatory in the preoperative diagnose of fecal incontinence. If available, endoanal MRI should be performed because it enables detailed demonstration of normal sphincter anatomy and pathology. The selection of patients with fecal incontinence who may benefit from surgical therapy is based on accurate detection, type and extent of sphincter lesions. A sphincter defect was defined as a disturbance of the normal architecture with discontinuity of the muscle ring and changes in signal intensity. Scarring was defined as a hypointense deformation of the normal pattern of the muscle layer due to replacement of muscle cells by fibrous tissue. Local thinning and atrophy -defined as an extreme generalized thinning of sphincter muscles and fatty degeneration- can be detected on endoanal MRI. Images with examples of the described lesions are given. In patients with a sphincter tear, operations such as anal sphincter repair or sphincter reconstruction may achieve complete restoration of continence. Coexisting external sphincter atrophy and sphincter tear on endoanal MRI are predictive for a negative outcome of the sphincter repair. In these patients, other options for surgical treatment, like surgical implantation of an artificial sphincter, may be considered. In the work-up of patients with fecal incontinence, endoanal MRI provides essential information for accurate treatment.

CONCLUSIONS

Endoanal MRI provides multiplanar, high-resolution, in vivo visualization of anal region.

The study of normal anatomy with endoanal MRI showed morphologic differences between males and females at the anterior side of the sphincter complex and documented the effects of aging on the caliber of sphincter muscles. With aging, significant thinning of the longitudinal muscle and thickening of the internal sphincter were recorded in normal subjects. Also, thinning of the external sphincter was recorded, only significant in males. The thinning of external sphincter muscle in elderly may be physiological and should be differentiated from severe atrophy as it occurs in incontinent patients.

The study of pathological alterations in fecal incontinence proved two advantages of endoanal MRI when compared with endoanal sonography. First, endoanal MRI is more accurate in detecting and characterizing anal sphincter lesions. Second, only endoanal MRI can detect external sphincter atrophy.

Of great importance is the observation that external sphincter atrophy is a predictor for the negative outcome of anal repair surgery. Prospective research should be conducted to confirm the results of this thesis. The practical consequence for the patients is that, based on imaging, a pre-operative selection should be possible: patients without atrophy will undergo sphincter plasty and patients with external sphincter atrophy and coexisting sphincter rupture will be suitable for other types of surgical treatment like the dynamic gracilis plasty.

In our opinion, endoanal MRI is at the moment, the best imaging technique to study anatomy and to diagnose pathology in fecal incontinence.

SAMENVATTING

Fecale incontinentie is een chronische aandoening met een grote emotionele impact, hetgeen kan leiden tot sociale isolatie. Afbeelding van de anale kringspier is een belangrijk onderdeel geworden van de diagnostiek van fecale incontinentie. Het doel van dit proefschrift is de rol van recent ontwikkelde endo-anale MRI bij de beoordeling van fecale incontinentie te evalueren.

Hoofdstuk 1 Kort overzicht van prevalentie, etiologie, pathologie, huidige diagnostische en therapeutische modaliteiten van fecale incontinentie.

Hoofdstuk 2 Techniek van endo-anale MRI, beperkingen en valkuilen in een bredere context: de diagnose van anorectale afwijkingen.

Endoluminale MRI is belangrijk geworden voor de diagnostiek van anorectale aandoeningen. Deze techniek is in een aantal aspecten superieur ten opzichte van endoluminale echografie en 'body coil MRI'. De spatiële resolutie van body coil MRI is beperkt, terwijl endoluminale echografie een matige contrast resolutie heeft. Endoluminale MRI combineert de sterke eigenschappen van deze beide technieken: de hoge spatiële resolutie van de endoluminale technieken en de hoge intrinsieke contrastresolutie van MRI. Voor een optimale endoluminale MRI moet aandacht besteed worden aan een goede voorbereiding van de patiënt, aan scanprotocollen en aan mogelijke valkuilen bij de interpretatie. Het voordeel van endoluminale MRI boven phased array coil MRI is minder goed aangetoond. Huidig onderzoek richt zich op verdere evaluatie van de rol van endoluminale MRI bij fecale incontinentie, op de vergelijking van phased array coil MRI met endoluminale MRI en op de combinatie van beide spoelen in diverse toepassingen.

Hoofdstuk 3 Studie van de normale anatomie

Kennis van de normale anatomie van het anale kanaal is essentieel voor diagnose en behandeling van anale afwijkingen. Endo-anale MRI is de eerste techniek die in vivo multiplanaire afbeelding van de anale anatomie met hoge resolutie mogelijk maakt, waarbij een duidelijke visualisatie van de kringspier wordt verkregen. Het doel van deze studie is de mogelijke variaties in de normale kringspieranatomie, zoals te zien met endo-anale MRI met hoge resolutie, te analyseren. Verder worden geslachts- en leeftijdsafhankelijke variatie in dikte en lengte van de anale kringspier geëvalueerd, zodat verdere verbetering van de diagnostiek van kringspieratrofie verkregen kan worden.
We constateerden dat er een anatomische verschil bestaat tussen mannen en vrouwen in het anterieure deel van de anale kringspier. De centrale perineale pees is bij mannen een insertiepunt, terwijl het bij vrouwen meer een insertiegebied is, met in elkaar vervlochten spiervezels, wat een grotere elasticiteit tot gevolg heeft. Dit gebied wordt bij vrouwen de 'perineal body' genoemd. Bij vrouwen is de oppervlakkige transversale perineale spier craniaal gelegen ten opzichte van de externe kringspier. Bij mannen bevindt deze spier zich tegen de anterieure zijde van de externe kringspier, waardoor het dit deel van de anale kringspier versterkt.
Een kwantitatief verschil is dat de externe kringspier bij vrouwen bijna twee keer zo kort is als bij mannen. In de subgroep van jonge vrijwilligers (leeftijd < 35 jaar) was de externe kringspier bij vrouwen ook significant dunner dan bij mannen. Door deze eigenschappen laat de kringspier zich bij vrouwen makkelijker oprekken dan bij mannen. Dit kan een rol spelen bij vaginale bevalling, wanneer het anterieure deel van de externe kringspier die dicht tegen de vagina aanligt, fors uitgerekt wordt. Met toenemende leeftijd neemt de dikte van de externe kringspier zowel bij mannen als bij vrouwen af. Deze afname is significant bij mannen maar niet bij vrouwen. Bij beide sexen wordt een statistisch significante, leeftijdsafhankelijke verdikking van de interne kringspier en een afname van dikte van de longitudinale spier gezien. De afgenomen spierdikte van de externe kringspier bij ouderen kan fysiologisch zijn en moet onderscheiden worden van ernstige atrofie, zoals te zien is bij incontinente patiënten.

Endo-anale echografie was de eerste methode waarmee het anale complex direct gevisualiseerd kon worden. In het afgelopen decennium is de endo-anale MRI geïntroduceerd en heeft tot de vraag geleidt: welke afbeeldingtechniek, endo-anale echografie of endo-anale MRI, verdient de voorkeur? De volgende twee hoofdstukken proberen een antwoord op deze vraag te geven.

Hoofdstuk 4 Vergelijking tussen endo-anale echografie en endo-anale MRI, waarbij de chirurgische bevindingen als referentiestandaard dienen.

22 vrouwelijke patiënten geopereerd voor fecale incontinentie waren in deze studie geincludeerd. De chirurgische bevindingen werden met de diagnose bij endo-anale echografie en endo-anale MRI vergeleken.

Detectie van laesies: MRI laat een zeer goede overeenkomst met de chirurgische bevindingen zien wat betreft de externe kringspier en een goede overeenkomst wat betreft de interne kringspier. Echografie laat slechts een matige overeenkomst zien met de chirurgische bevindingen, zowel voor de externe als voor de interne kringspier. De correlatie tussen MRI en echografie is matig. Voor de externe kringspierlaesies heeft zowel een positieve als een negatieve testuitslag van MRI een hoge voorspellende waarde, zodat het een zeer goede pre-operatieve diagnostische methode is voor anterieure kringspier plastiek.

Beschrijving van de laesies: Echografie en MRI zijn vergelijkbaar in het karakteriseren van letsel van de interne kringspier. Endo-anale MRI toont echter een goed onderscheid tussen diverse weefsels (spierweefsel, littekenweefsel, vet). Hierdoor is een nauwkeurige bepaling van lokale afname van kringspierdikte mogelijk - hetgeen met echografie niet mogelijk is – en tevens een preciezere vaststelling van de uitgebreidheid en structuur van complexe laesies.

Besluit tot chirurgie: Voor de beslissing tot chirurgische behandeling zijn de twee afbeeldingtechnieken in deze studie complementair. Het voordeel van echografie is dat het goedkoper is, gemakkelijker beschikbaar en sneller dan MRI. Echter, als slechts één techniek gebruikt zou zijn, zou MRI in meer gevallen tot de beste behandelingsbeslissing hebben geleid dan echografie. Keuze voor MRI zou onnodige operaties kunnen voorkomen en kan betekenen dat MRI kosten-effectief is. Het blijkt dat endo-anale MRI superieur is ten opzichte van endo-anale echografie voor de optimale behandelingskeuze.

Hoofdstuk 5 Vergelijking tussen endo-anale echografie en endo-anale MRI, waarbij echogeleide electromyografie (EMG) als referentiestandaard dient.

17 patiënten met fecale incontinentie ondergingen endo-anale MRI, endo-anale echografie en echogeleide EMG. Aanwezigheid van laesies, locatie en type werden vastgesteld. De EMG naald werd echogeleid in echografisch normaal en abnormaal weefsel van de externe kringspier geplaatst. Vervolgens werd de correlatie tussen MRI- en echobevindingen bepaald, met EMG als gouden standaard. De correlatie tussen MRI en EMG was hoger dan tussen echografie en EMG. De positief en negatief voorspellende waarde waren ook hoger voor MRI dan voor echografie. Deze verschillen werden voornamelijk veroorzaakt doordat echografie geen atrofie van de externe kringspier kan detecteren, terwijl met endo-anale MRI bij vijf patiënten gegeneraliseerde atrofie van de externe kringspier werd aangetoond, waarbij geen of minimale elektrische activiteit werd geregistreerd. Concluderend bevelen we endo-anale MRI aan als methode van eerste keus voor de diagnostiek van patiënten met fecale incontinentie.

Hoofdstuk 6 Invloed van atrofie van de externe kringspier

20 vrouwelijke patiënten met obstetrisch letsel en fecale incontinentie waren in deze prospectieve studie geincludeerd. Deze patienten stonden voor kringspier plastiek operatie gepland. Voor de operatie was de endo-anale MRI diagnose: in alle patiënten een defect van de externe kringspier en in 8

(40%) patiënten atrofie van de externe kringspier. Een jaar na de operatie werd de uitkomst van de kringspier plastiek geanalyseerd.
In 65 % van de patiënten die een kringspier plastiek hadden ondergaan herstelde de continentie zich. De uitkomst was significant beter bij patiënten zonder atrofie van de externe kringspier (92 %) dan bij patiënten met atrofie van de externe kringspier (25 %). De relatief subjectieve bepaling van atrofie op MRI beelden door de radioloog als ook de objectieve kwantitatieve meting van het oppervlak van de overgebleven externe kringspier op werkstation blijken significant gerelateerd te zijn met de uitkomst van de kringspier plastiek. We concluderen dat atrofie van de externe kringspier van invloed is op continentie na kringspier plastiek.

Hoofdstuk 7 De rol van endo-anale MRI in de diagnostiek van patiënten met fecale incontinentie.

Patiënten met fecale incontinentie ondergaan eerst lichamelijk onderzoek, aangevuld door functionele testen. Hierdoor heeft de arts inzicht in de verminderde anale functie, maar nog geen informatie over de aanwezigheid en de locatie van chirurgisch corrigeerbare kringspierlaesies. Daarom is afbeelding van de afwijking noodzakelijk voor pre-operatieve diagnose van fecale incontinentie. Indien beschikbaar verdient endo-anale MRI de voorkeur; het geeft een gedetailleerde afbeelding van normale kringspieranatomie en kringspierpathologie. De selectie van patiënten met fecale incontinentie die baat kunnen hebben bij chirurgische behandeling wordt gebaseerd op accurate detectie, type en grootte van de kringspierlaesie. Een kringspierdefect werd gekenmerkt door verstoring van de normale architectuur met onderbreking van de spierring en verandering in de signaalintensiteit. Littekenweefsel werd gedefinieerd als een hypo-intense deformatie van de normale patroon van de spierlaag ten gevolge van vervanging van spiercellen door fibreus weefsel. Lokale afname van de spierdikte en atrofie – gedefinieerd als een extreme gegeneraliseerde afname van de dikte van de kringspier of vervetting – kan gedetecteerd worden met endo-anale MRI. Voorbeelden van deze laesies worden getoond. Bij patiënten met een externe kringspier laesie kunnen operaties zoals anale kringspier plastiek een compleet herstel van continentie geven. Als met endo-anale MRI echter een combinatie van kringspierscheur en atrofie van de externe kringspier wordt gezien, is de kans op een negatief resultaat van de kringspier plastiek groot. Bij deze patiënten zijn andere technieken, zoals gracilis kringspier plastiek, een optie. Endo-anale MRI verschaft essentiële informatie voor een juiste behandeling van patiënten met fecale incontinentie.

CONCLUSIE

Endo-anale MRI is een techniek die met hoge spatiële resolutie, in vivo multiplanaire afbeelding van de anale regio mogelijk maakt.
De studie van de normale anatomie met endo-anale MRI heeft een anatomische verschil tussen mannen en vrouwen in het anterieure deel van de anale kringspier geconstateerd. Ook de invloed van leeftijd op de dikte van de anale kringspier werd geëvalueerd. Met toenemende leeftijd neemt de dikte van de externe kringspier zowel bij mannen als bij vrouwen af. Deze afname is significant bij mannen maar niet bij vrouwen. Bij beide sexen wordt een statistisch significante, leeftijdsafhankelijke verdikking van de interne kringspier en een afname van dikte van de longitudinale spier gezien. De afgenomen spierdikte van de externe kringspier bij ouderen kan fysiologisch zijn en moet onderscheiden worden van ernstige atrofie, zoals te zien is bij incontinente patiënten.
De studie van pathologische veranderingen bij fecale incontinentie heeft twee voordelen van de endo-anale MRI aangetoond. Eerst, endo-anale MRI is meer accuraat dan endo-anale echografie in detectie en beschrijving van laesies van de anale kringspier. Als tweede, endo-anale MRI kan de atrofie van de externe kringspier bepalen, hetgeen niet mogelijk is met endo-anale echografie. Van groot belang is het feit dat atrofie van de externe kringspier de uitkomst van kringspier plastiek negatief kan beïnvloeden. Prospectieve studies moeten de resultaten van dit proefschrift bevestigen. De praktische consequentie voor de patiënten is dat een op endo-anale MRI gebaseerde

selectie uitgevoerd zou kunnen worden. De patiënten met kringspierdefecten en zonder atrofie van de externe kringspier kunnen met kringspier plastiek behandeld worden. Patiënten met kringspierdefecten en atrofie van de externe kringspier kunnen voor andere operatieve technieken, zoals gracilis plastiek, in aanmerking komen.

Naar onze mening is endo-anale MRI op dit moment de beste afbeeldingtechniek voor de visualisatie van anatomie van de anale kringspier en voor het diagnosticeren van laesies bij fecale incontinentie.

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Elena Rocin

CURRICULUM VITAE

Name	:	Rociu
First name	:	Elena
Date of birth	:	November 21, 1968
Nationality	:	Romanian/Dutch
Education	:	**Medicine**, Carol Davila University, Bucharest, Romania 1987-1993 **Medicine**, University of Utrecht, The Netherlands 1994 - 1996
Training	:	**Ph.D. Research**: January 1997- December 1998, Dept. of Radiology, University Hospital Dijkzigt, Rotterdam, the Netherlands. **Radiology Residency**, started January 1999, Department of Radiology, Academic Medical Center, University of Amsterdam, The Netherlands.
Awards	:	**Certificate of Merit**. Stoker J, Rociu E, Zwamborn AW, Schouten WR, Laméris JS. Endoluminal MR imaging of rectum and anus: technique, applications and pitfalls. 83rd Scientific Assembly and Annual Meeting of the Radiological Society of North America (RSNA). November 30 - Dececember 5, 1997. Chicago, USA. **Certificate of Merit**. Rociu E, Stoker J, Laméris JS. Endoluminal imaging of fecal incontinence. 9th Annual Meeting of European Society of Gastro-intestinal and Abdominal Radiology (ESGAR), Marbella, Spain, May 24-28, 1998. **Magna cum laude**. Rociu E, Stoker J, Zwamborn AW, Laméris JS. Endoluminal MR imaging of anal diseases. Scientific exhibition award European Congress of Radiology (ECR) Vienna, March 5-12, 1999.

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