General Report

Chirurgia (2016) 111: 379-392
No. 5, September - October

http://dx.doi.org/10.21614/chirurgia.111.5.379

The Importance of Preoperative Staging of Rectal Cancer Using Multiparametric MRI. A Systematic Review - Part I

Ferdinand Bauer

Director of Radiology Clinics in Kaufbeuren - Landsberg - Füssen, Germany

Rezumat

Importanța stadializării preoperatorii a cancerului rectal cu RMN multiparametric. Referat general - partea I

Stadializarea preoperatorie corectă a carcinomului rectal influențează în mod direct strategia terapeutică a acestuia, rezultând în îmbunătățirea considerabilă a ratei de supraviețuire și a calității vieții după tratament. Este vorba de opțiunea de a face radiochimioterapie preoperatorie sau nu înaintea exciziei totale de mezorect (TME). Avansul tehnic în domeniul rezonanței magnetice face posibile examinările multiparametrice (mp RMN) cu aparate de performanță suficient de ridicată (3T sunt din ce în ce mai des întâlnite) pentru a obține imagini de o calitate excelentă, care permit efectuarea diagnosticului corect al extensiei tumorale locale. Aceste examinări multiparametrice includ atât secvențe T2 multiplanare și T1, care oferă informații morfologice valoroase datorită rezoluției înalte a structurilor anatomice, cât și secvențe funcționale DWI, cu rol decisiv în depistarea tumorilor reziduale după radiochimio-terapia preoperatorie. Examinarea funcțională cu DWI este singura metodă diagnostică neinvazivă cu acuratețe ridicată care după RCT poate diferenția între fibroză și resturi tumorale vitale. Examinarea dinamică cu substanță de contrast (DCE) în combinație DWI și volumetrie poate da informații suplimentare privind răspunsul complet sau incomplet la RCT și este eficientă în detectarea recidivei locale după TME. De asemenea, RMN este singura metodă de diagnosticare care are acuratețea necesară evaluării fasciei mezorectale, reprezentând marginea circumferențială de rezecție (CRM) în cazul TME. Cu RMN putem și măsura cu precizia similară histologiei distanța minimă la fascia mezorectală, esențială în planificarea tratamentului chirurgical și mult mai importantă decât stadializarea T. Aceasta permite selectarea pacienților cu factor prognostic nefavorabil care ar profita de radioterapie sau RCT. Evaluarea altor factori de prognoză precum starea ganglionilor, numărul și localizarea lor precum și invazia venoasă extramurală (EMVI) joacă de asemenea un rol important în strategia terapeutică individualizată.

Cuvinte cheie: carcinom rectal, RMN multiparametric, DWI, TME, CRM, EMVI

Abstract

A correct preoperative stadialization of rectal carcinoma has a direct influence upon its therapeutic strategy, resulting in a significant improvement of the survival rate and life quality after the treatment. The therapeutic strategy refers to the option of undergoing or not preoperative radiochemotherapy before the total mesorectal excision (TME). The technical advances in the magnetic resonance domain makes possible the multiparametric examinations (mp MRI) with medical equipments (3T models are common) good enough to obtain images

Corresponding author: Ferdinand Bauer, MD
Radiology Specialist
Director of Radiology Clinics in Kaufbeuren - - Landsberg - Füssen, Germany
E-mail: Ferdinand.Bauer@radiologie-kaufbeuren.de

having an excellent quality, which allow a correct diagnosis of the local tumour spread. These multiparametric examinations include T2 multiplan sequences and T1 sequences, which offer valuable morphological information due to the high resolution of anatomic structures and DWI functional sequences, with a decisive role in tracing residual tumours after post-surgery radiochemotherapy. The functional examination using DWI is the only highly accurate noninvasive diagnostic method which can differentiate the fibrosis from vital tumoral remnants. The dynamic contrast-enhanced examination (DCE) combined with DWI and volumetry can give supplementary information as to the complete and incomplete response to RCT, and is efficient in detecting a local recurrence after TME. Also, MRI is the only diagnostic method which has the necessary accuracy to assess the meso-rectal fascia, which represents the circumferential resection margin (CRM) in the case of TME. With the help of MRI we can measure with a precision similar to histology the minimal distance to the mesorectal fascia, essential in planning the surgical treatment, and more important than the T stadialization. This allows the selection of patients with an unfavourable prognosis factor who would benefit from radiotherapy or from RCT. The evaluation of other prognostic factors as the condition of nodes, their number and primary site, and the extramural venous invasion (EMVI) have an important role in the individualized therapy.

Key words: rectal carcinoma, multiparametric MRI, DWI, TME, CRM, EMVI

Introduction

Colorectal carcinoma is one of the most frequent malignant tumours, with 70000 new cases and approximately 30000 deaths every year in Germany (1). It is the second most frequent oncologic disease (16%) and the second most frequent cause of death by cancer, with a frequency up to 14% (2). The incidence of colon cancer increased in the last three decades. The risk of developing cancer increases with the age of 50 years old. The average age of illness is in the 7th decade of life (1). Approximately 40-50% of the total cases of colorectal carcinoma are in the rectum. 85-90% of these malignant tumours are adenocarcinomas. The drastic decrease of the local recurrence rate, obtained in patients with rectal carcinoma who underwent TME surgery, can be significantly improved by adding the treatment with radiochemo-therapy (RCT) (3). According to the updated S3 Guideline regarding colorectal carcinoma, the patients with T3 and T4 carcinoma and/or positive nodes benefit from this advantage (1,4,5). A more reduced rate of local recurrence was registered for radio-, namely for neoadjuvant radiochemotherapy, being much better tolerated and respected than the one post-surgery (6). Different studies regarding radiochemotherapy show that 18-30% of the patients treated were over-diagnosed and over-treated afterwards (7).

This is the reason why, the correct pre-therapeutic stadialization of rectal carcinoma is essential for selecting the patients who would benefit from preoperative therapy, and for whom a potential toxic overtherapy could be avoided (2).

Staging modalities

Staging modalities used for rectal carcinoma include colonoscopy and rectoscopy performed with a rigid instrument, and also the endorectal ultrasound (EUS), computed tomography (CT), PET - CT and magnetic resonance imaging (MRI).

Endorectal endoscopic ultrasound (EUS)

The studies regarding local stadialization with EUS did not reach a consensus about the exactness of the general diagnosis (69-90%). The EUS is adequate in the early stages (T_1 and T_2) for local stadialization, due to the very good local resolution of the mucous membrane and the submucosa - (sensibility of 94% and specificity of 98%). (8,9,10) In the advanced stages (everything over T_2), the accuracy significantly decreases. Also, with EUS one cannot visualize and assess the mesorectal fascia (*Fig. 1*), the visualization field is narrow and it does not allow nor the stadialization of an advanced T_3 and T_4 disease nor the assessing of extra-mesorectal lymph nodes. It is a real-time examination, so it does not suit the surgical or the radiotherapy planning, and surely it is not good for assessing stenotic tumours with proximal primary site. To conclude, EUS is the imagistic method of choice used for differentiating between T_1 and T_2.

CT

Because of the weak local resolution and contrast, the CT can be used only for M stadialization, this means for excluding liver and distal pulmonary metastases (11). (*Fig. 2*)

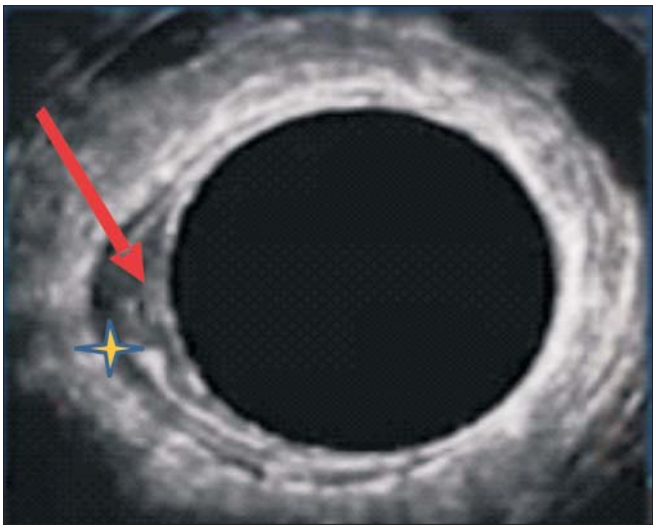

Figure 1. *EUS image of the rectum showing muscularis propria (star) and a rectal carcinoma ar 9 o'clock (arrow). The mesorectal fascia is not visible.*

Figure 2. *CT image of the rectum Low contrast, the mesorectal tumoral invasion is not visible, neither the relation of the tumour with the mesorectal fascia. A rectal carcinoma can be observed on the left (arrow).*

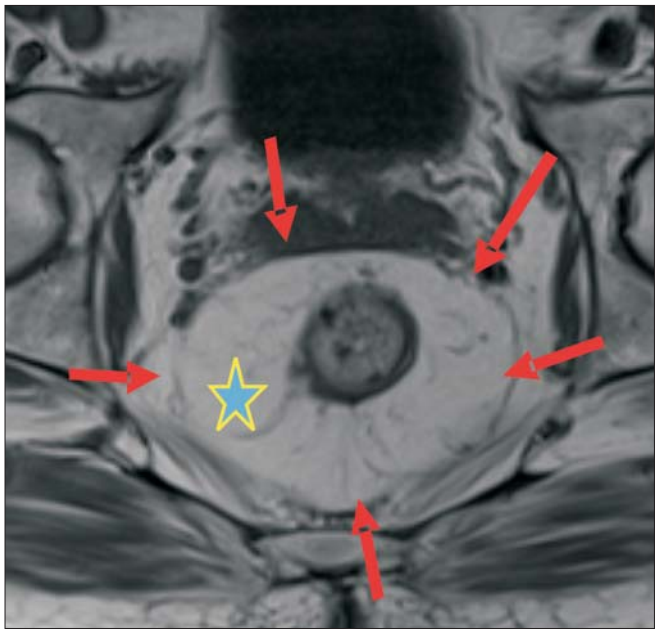

Figure 3. *MRI of the rectum. The mesorectum (star) and the mesorectal fascia (MRF) (arrows) are excellently visualized.*

PET/CT

PET/CT is the method of choice for detecting local recurrence or distant metastases in the clinical routine.

MRI

MRI is undeniably the imaging method with the highest contrast for soft tissues (12,13). MRI is the best diagnostic method used for the staging of primary tumours and for restaging after radiochemo-therapy (14). According to Wietek there is no consensus regarding the intensity of the minimum T (Tesla) necessary (1.5 T vs. 3.0 T) (2). There is no doubt that with 3T the resolution is far better than with 1.5T, which is very useful in assessing the mesorectal invasion and the stratifying of T3 tumours (*Fig. 3*). The use of an endorectal probe is not necessary, an external coil may be used instead. The MRI protocol does not exceed 25 minutes.

Therapeutic options

Surgery

The anatomic position of the rectum inside the pelvis and the proximity with some anatomic structures, especially the sphincter muscles, is a challenge for surgeons, regardless of the surgical technique used. The surgical treatment of rectal cancer is a difficult oscillation between minimizing the risk of local recurrence and maintaining the anorectal and genitourinary functions. (12)

Total mesorectal excision (TME)

The introduction of standardized TME (15) brought a considerable enhancement in the prognosis of patients diagnosed with cancer in the middle or lower thirds of the rectum. This surgical technique supposes the resection of the rectum together with all surrounding lymphatic pathways, lymph nodes, the mesorectal fat and mesorectal fascia, whereas the parietal pelvic fascia and the pelvic splanchnic nerves are spared (*Fig. 4*). The introduction of TME at a large scale has considerably reduced the rate of abdominoperineal surgeries for rectal cancer without maintaining the continence. TME is the best surgical treatment if the resection margin IS NOT infiltrated. (12)

Local excision

Local excision is an option for patients having small tumours, well to moderately differentiated, limited to the mucous membrane and the submucosa. The techniques used for local excision are transanal excision surgery and the endoscopic microscopic tumour ablation. Only a few patients are candidates for local excision (approximately 5%), and they must be carefully chosen.

Circumferential resection margin (CRM) and local recurrence

The rate of local recurrence after curative surgery ranges between 3% and 32% (16). Some studies report net rates under 10% for TME (17,18,19). The lateral circumferential spread of the tumour is a much more important prognostic factor for local

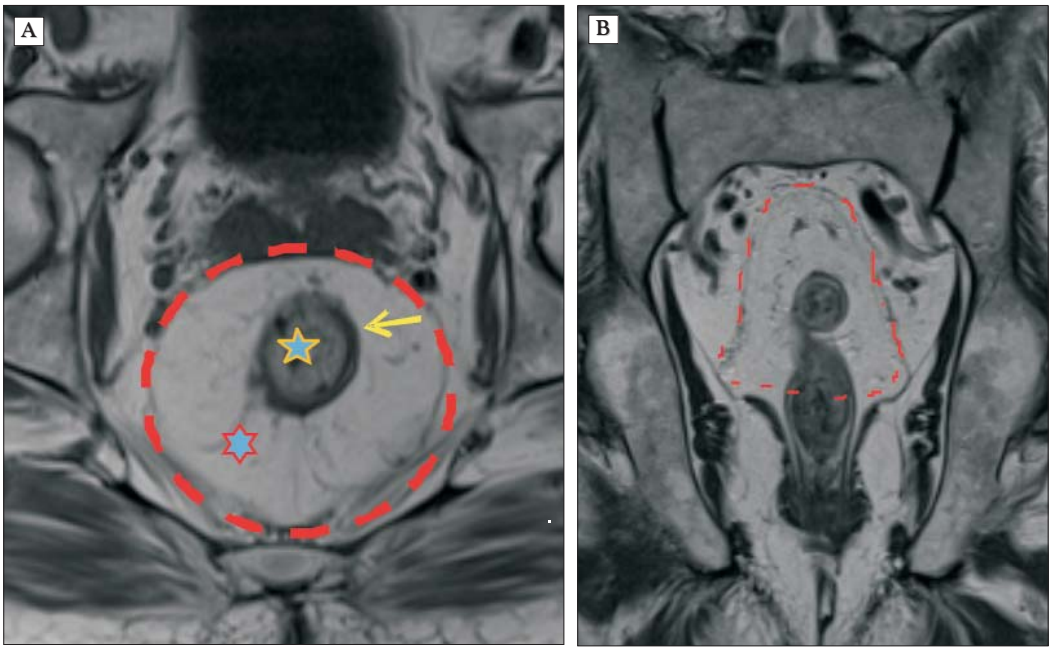

Figure 4. *MRI sequence in T1 with sections (**A**) paraxial and (**B**) paracoronal. The circumferential resection margin (CRM) is the mesorectal fascia, marked with a discontinuous line. We can see the rectal wall (arrow), a tumour (yellow star) and the mesorectum (red star).*

recurrence than the longitudinal tumour size. Currently, the incomplete resection of lateral margins is considered to be the most important cause of local recurrence (12).

Quirke et al. reported 83% patients with positive CRM who had a local recurrence (20). Consequently, the topographic relation of the tumour with the mesorectal fascia, which has the role of a natural barrier and anatomical landmark for TME, is the most important criterion for local tumor staging when choosing a therapeutic solution. (*Fig. 5*)

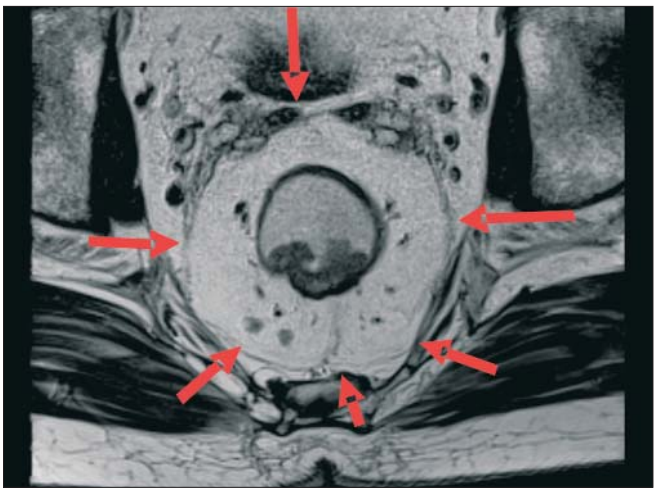

Figure 5. *The mesorectal fascia (MRF) (arrows) is the circumferential resection margin (CRM) when performing a total mesorectal excision (TME).*

MRF = CRM = TME

Adjuvant / neoadjuvant therapy

The purpose of adjuvant and neoadjuvant therapy is to facilitate total tumour resection, even for advanced stages, to prevent local recurrence and to minimize the risk of distant metastases. The adjuvant or neoadjuvant therapy leads to down staging the tumor in terms of its T and N categories (21,22), and 20% of patients present even a complete regression of the tumour (sterilization) (23). (*Fig. 6*)

The timing for applying an adjuvant or neo-adjuvant therapy is still controversial. There are tow large important European studies which are in favour of preoperative radiotherapy alone or the combined version of radiochemotherapy in the cases of tumours in the medium or lower rectum. One of these studies (24), performed in Scandinavia, showed that a short cycle of preoperative radiotherapy reduces the rate of local recurrence from 27% to 11%. The second study showed that preoperative radiotherapy offers advantages also for patients with TME, this procedure being associated with a more reduced rate of recurrence than other surgical approaches (25). The preoperative irradiation significantly reduced the rate of local recurrence compared to the group treated by TME only. In the United States, patients with T3 and / or N1 tumours receive an adjuvant therapy consisting of postoperative radiochemotherapy (26).

Hereinafter we will present the actual stage of MRI diagnosis and its significance for the evaluation of the most important prognostic factors, in order to enhance the treatment and the prognosis for patients with rectal carcinoma.

The MRI anatomy of the rectum and the anorectal complex in an anatomopathological context

The knowledge of the MRI anatomy is essential for correct preoperative local staging. Being localized in the lesser pelvis, the rectum is an ideal organ for MRI examinations. Here, there are no peristaltic or respiratory movements, or vascular pulsations, but we can find fat, the mesorectum, which is the best friend of the radiology physician, because it gives a powerful signal in T1 and T2 sequences. In fact, in this area

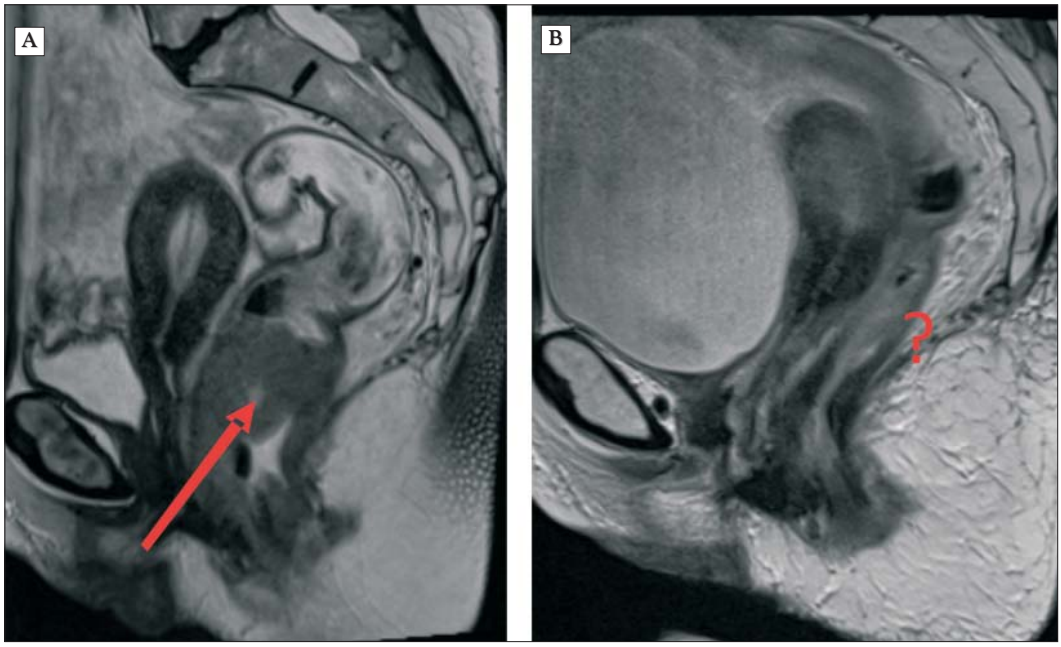

Figure 6. *Sagittal MRI of the rectum (**A**) Before RCT we observe a rectal tumour (arrow), (**B**) after RCT the tumour is no longer visible.*

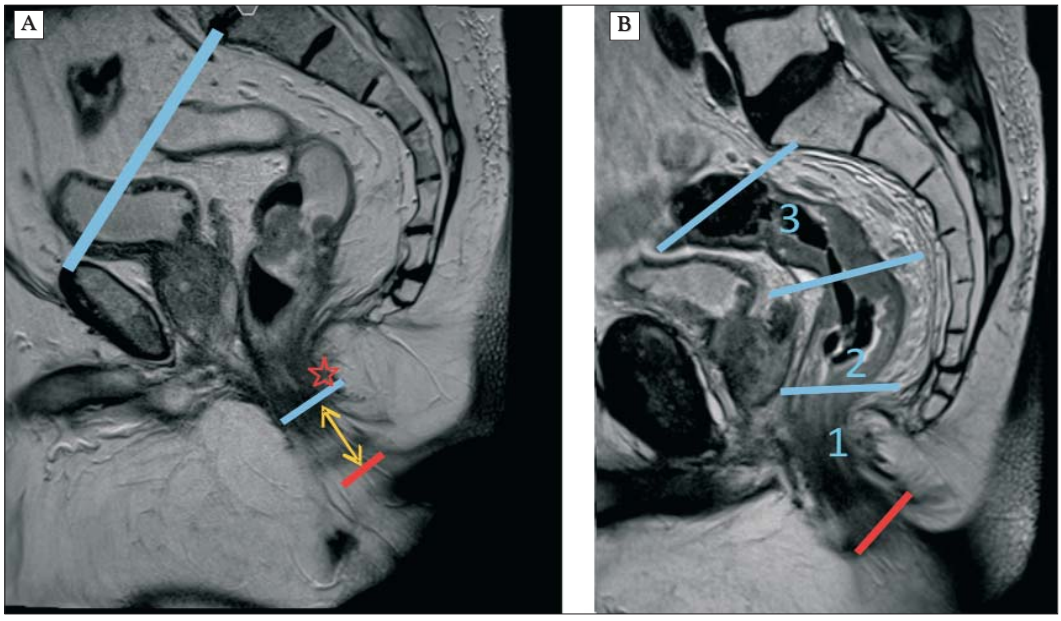

Figure 7. *Sagittal T2 MRI of the rectum (**A**) The rectum is the final straight portion of the large intestine (between the blue lines). It begins at the rectosigmoid junction (end of the sigmoid colon), at the level of the sacral promontory. It ends at the level of the puborectalis sling (star) and it is followed by the anal canal (arrow). (**B**) The anal verge (red line) marks the furthest point of the anal canal It is easy to identify in the physical examination and it is a surgical reference point. Also, the distance to the inferior tumour limit must be included. The distance to the anal verge divides rectal cancers in 1 - low rectal cancers (< 5 cm), 2 - mid rectal cancers (5-10 cm) and 3 - high rectal cancers (10-15 cm).*

we can visualize any pathological process and we can measure exactly the lateral tumour extension.

1. Anterior peritoneal reflection (APR)

The upper third of the rectum is almost completely covered by the peritoneum. The peritoneum also covers the anterior middle third of the rectum and forms the peritoneal recess. The lower part of the rectum is entirely situated in the extraperitoneal space. The anterior peritoneal reflection divides the rectal intra and extraperitoneal portions. The axial images show the so called "seagull sign" (v. *Fig. 8 A*) which visualizes this phenomenon. The sagittal images present the peritoneal reflection as a low-intensity linear structure, that extends over the surface of the bladder, and which can be traced posteriorly to its insertion point on to the rectum. The typical appearance is a V or Y (*Fig. 8 B*). The invasion of APR is considered to be a T4a, the infiltration of the visceral peritoneum is associated with a high risk of subsequent peritoneal carcinomatosis. It is important to remember that the peritoneal membrane is not the resection margin since there are no adjacent organs (27). Consequently, if the tumour extends 1 mm in the peritoneum, the resection margin does not need to be considered involved, even if the margin of the specimen could be involved. (27,28)

2. Normal rectal wall

The normal rectal wall is made out of inner mucosal layer, concentrically covered by the submucosa and by the muscularis propria, comprising an inner circular layer and an outer longitudinal one. Between the two muscular layers there is the myenteric plexus, fixed in a thin layer of connective tissue. The mucosal layer appears in the MRI images as a delicate low-signal intensity line, whereas the submucosal layer appears as a thicker higher-intensity structure. Muscularis propria can be seen sometimes in high-quality images as two distinct layers of circular and longitudinal muscle. The outer muscle layer often has an irregular appearance, because of the blood vessels entering the rectal wall. The perirectal fat has a high intensity, contrasting well with the low-signal of muscularis propria. (29) (*Fig. 9*)

3. Mesorectum

The mesorectum, which we visualize very well, is a natural barrier of the local tumoral extension, where the initial dissemination of cancer occurs. (*Fig. 10*) It is a local tumoral filter. This spread can take place in the lymph nodes or it can be produced vascularly, through the extramural venous invasion EMVI. EMVI means systemic spread, even if it is local from an anatomical point of view.

In the axial MRI images, the mesorectum appears as a high-signal intensity package (similar to fat) which surrounds the rectal wall and contain blood vessels and lymphatic tissue. The mesorectal lymph nodes have the appearance of high-signal intensity ovoid structures. (29) (*Fig. 10*)

4. Presacral fascia

The presacral fascia (*Fig. 11*) appears in the sagittal MRI images as a low-signal intensity linear structure covering the presacral vessels. It is a thick parietal fascia placed posteriorly the mesorectal fascia, which covers the presacral veins and fat. It fuses with and covers the muscles and vessels of the pelvic floor, which contains a lymph node agglomeration situated in a compartment separated from the mesorectum. Consequently, the nodes of the lateral pelvic floor are seen only if during the surgery for rectal cancer the surgeon opens this compartment through the presacral or parietal fascia (28).

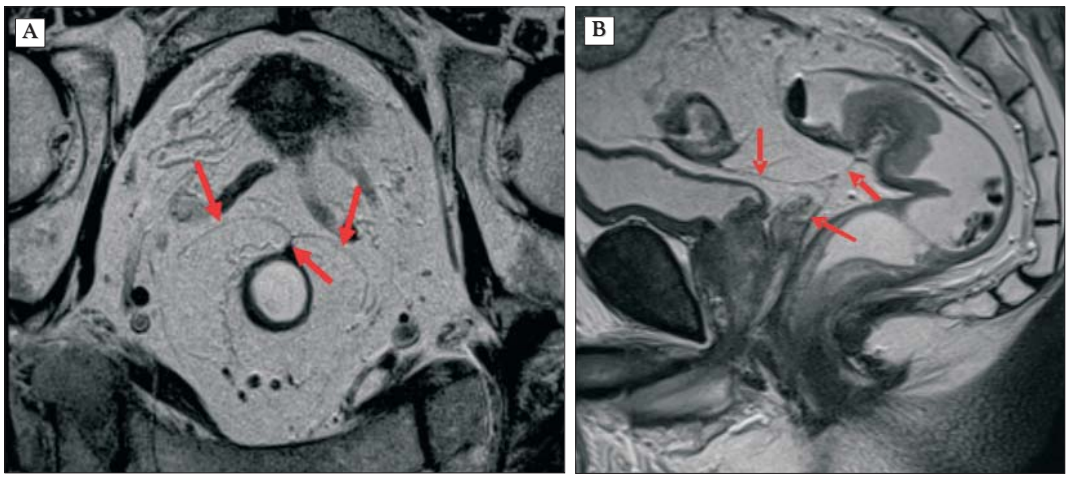

Figure 8. *T2 MRI images (**A**) axial and (**B**) sagittal showing the peritoneal reflection (arrow). (**A**) one can observe in the axial plane the typical morphology "seagull sign" and in the sagittal plane (**B**) the fine linear structure above the bladder and prostate which extends to the rectum in a V or Y shape.*

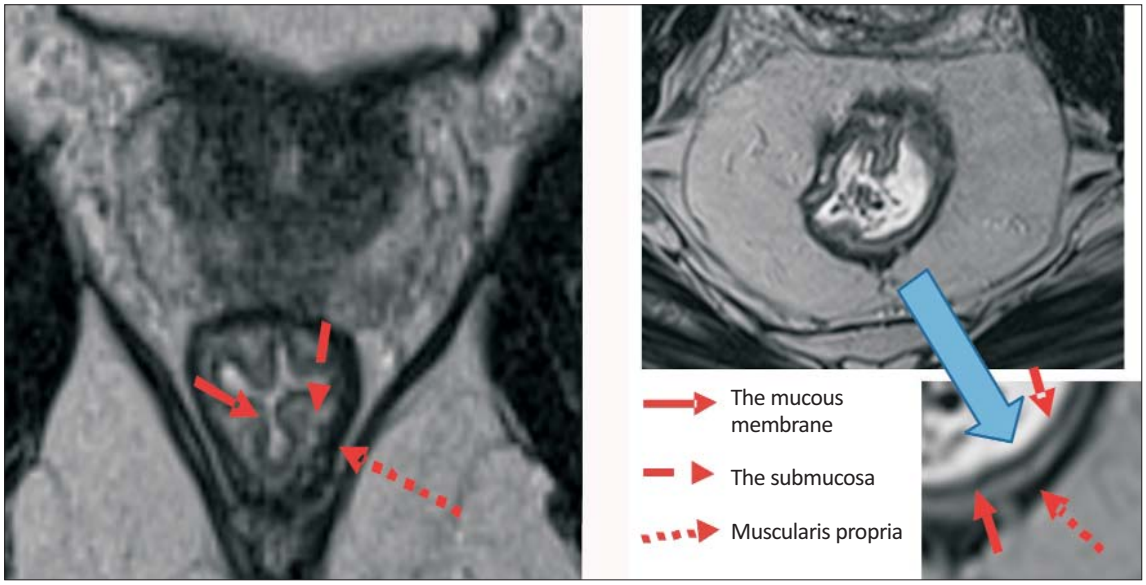

Figure 9. *Oblique paraxial plane T2-weighted FSE image (TSE) of the pelvis showing the layers of the rectal wall. We can see the mucous membrane (closed fine line, red arrow) and the submucosa (interrupted arrow) like an outstreched strip. The muscularis propria is the hypointense "black strip" (interrupted arrow).*

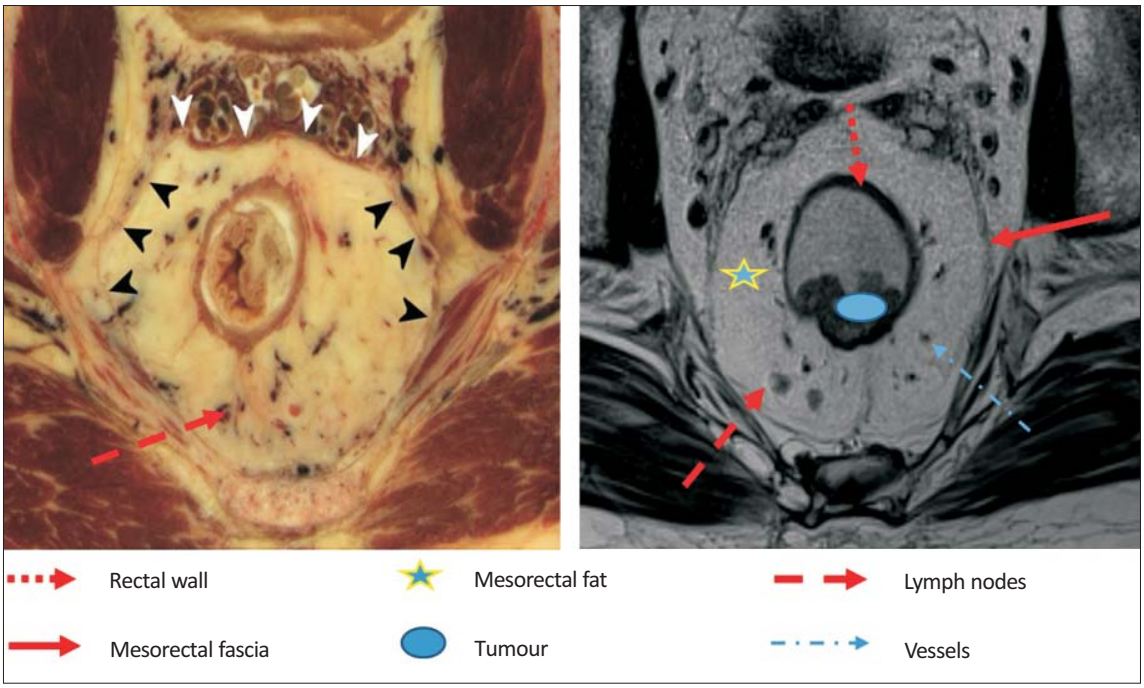

Figure 10. ***(A)*** *Anatomical preparation. We see the mesorectal fascia as a delicate line (triangles) covering the mesorectal compartment with the rectum, the mesorectal fat, the blood and lymphatic vessels and the lymph nodes. (**B**) The axial plane T2-weighted FSE image (TSE) corresponding to the anatomical preparation.*

5. Mesorectal fascia

The mesorectal fascia (*Fig. 12*) which surrounds the meso-rectal fat is the most important anatomical landmark for evaluating the possibility of TME.

It is best observed in the axial images, where it can be seen as a low-signal intensity linear structure which surrounds the mesorectum (*Fig. 10*). This layer fuses in the lower part with the endopelvic fascia situated above the levator muscles, in the anterior upper part with the peritoneal reflection and in the

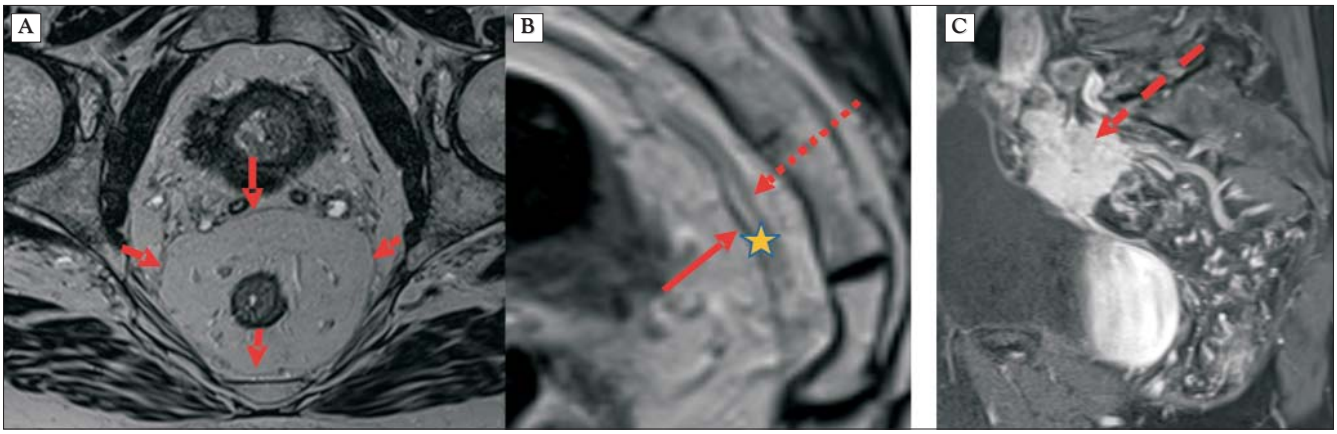

Figure 11. *MRI presenting (**A**) the mesorectal fascia (arrows), (**B**) the clear avascular space (yellow star) where TME is performed, between the mesorectal fascia (normal arrow) and the pelvic fascia (interrupted arrow) and (**C**) a tumour (interrupted arrow) which invades the retrorectal space with the pelvic fascia and the presacral vessels, which means that TME is not possible.*

posterior part with the parietal fascia.

The space between the mesorectal and pelvic fascia, the "holy plane" of Bill Heald, represents the avacular space where the surgeon actions, the space where TME is performed (*Fig. 11 B*, the yellow star). This plane has to be clear for an optimal TME to be performed (*Fig. 11* C). Thus, the mesorectal fascia is our reference point, being the circumferential resection margin (CRM) for TME. All therapeutic decisions have to do with this fascia: if it is clear, periclitated or infiltrated. The distance between the tumour and CRM became an important prognostic factor, being associated with the risk of pelvic recurrence. A CRM of 1 mm or less has a higher risk of local recurrence and distance metastasis.

The assessment of the mesorectal fascia involvement has a crucial importance, because currently, the quality of the mesorectal total excision determines the prognosis of rectal cancer (30,31). The surgeon's focus is on the periphery, namely the mesorectal fascia, and not the centre - which is the rectal wall. Consequently, the attention of the radiologist must focus on this fascia, not on the rectal wall.

The mesorectal fascia is considered to be involved if the distance between the tumour and the mesorectal fascia is under 1 mm, jeopardized if the distance is between 1 - 2 mm and it is free if the distance is greater than 2 mm.

The smallest distance between the tumour and the mesorectal fascia is the most important prognostic factor as to the local recurrence, and this is why it is mandatory to report it in mm, according to the S3 surgery guideline. (32,33)

5a. Special attention: T3 CRM -, SAFE vs. UNSAFE

A T3 tumour crosses the layers of the intestinal wall reaching the perirectal fat. In the case of this tumour, it is important to determine the involvement of the mesorectal fascia.

The tumour on the left (*Fig. 14*), T3 CRM, invades just a little the mesorectal fat, corresponding to T3 a and b stages. There is a great resection margin surrounding the tumour and there are no lymph nodes adjacent to the mesorectal fascia. This tumour is "safe" for TME. In the Netherlands, as in the majority of European countries, the patient will be treated in this case with a short preoperative radiochemistry treatment of 5x5 Gy followed by TME (14).

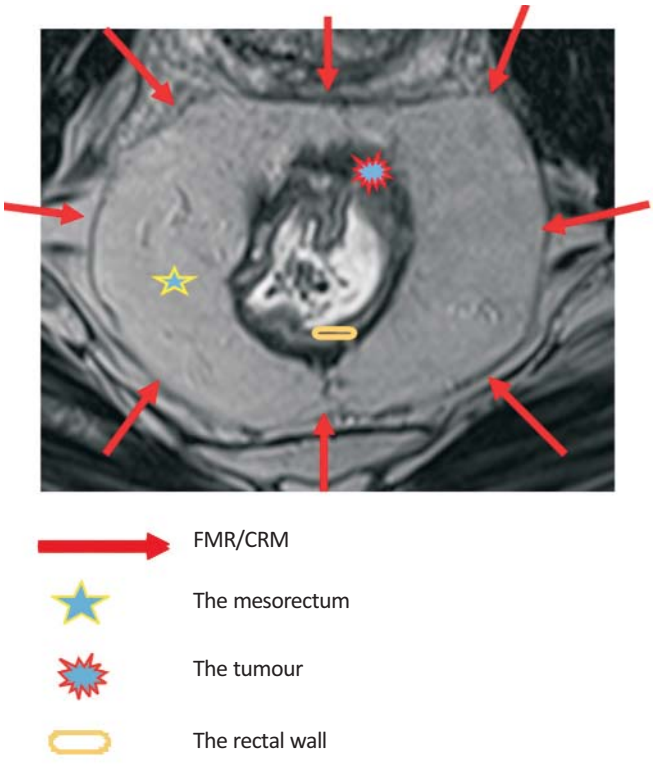

Figure 12.

The tumour on the right (*Fig. 14*), T3 CRM+, strongly invades the mesorectal fat, and the resection margin is jeopardized or even infiltrated. This tumour corresponds to T3 c, d MRF+ „unsafe“ stages. The patient undergoes in this case a long RCT preoperative stage. If the treatment is successful resulting in the restaging at MRI, this will be followed by TME.

Attention! In both cases we are dealing with the same T3

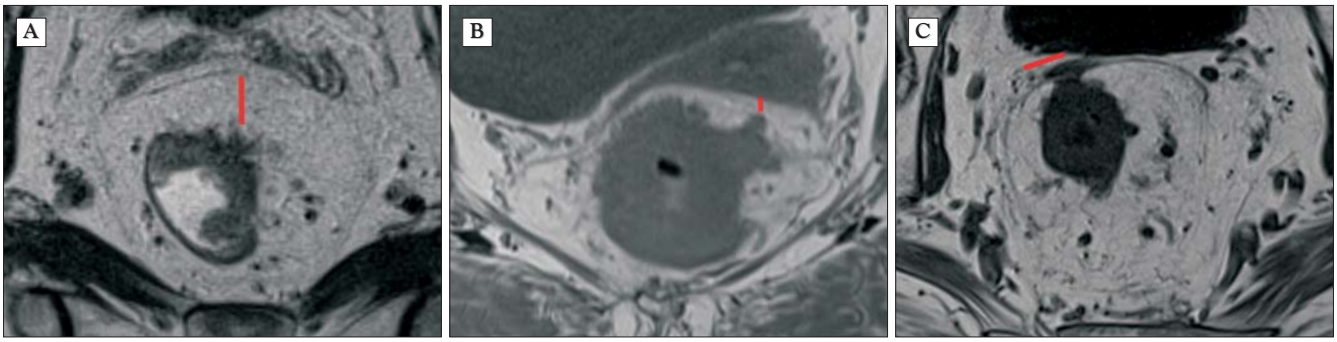

Figure 13. *(**A**) Dorsal wall can be very well seen between 9 and 6 o'clock positions as the intact black strip. Between 11 and 5 o'clock the tumoral formation destroys the black strip / muscularis propria and infiltrates the mesorectum; the great distance to the mesorectal fascia indicates that it is free. TME only can be performed, the risk of local recurrence being minimal. (**B**) Large scale tumor invasion of the mesorectum between 2-3 o'clock; there is a small distance to the mesorectal fascia, it being thus jeopardized. In this situation we recommend preoperative radiochemotherapy for down-staging, to decrease the possibility of a local recurrence after surgery. (**C**) Clear invasion of the mesorectal fascia between 11-12 o'clock. Preoperative radiochemotherapy is mandatory in order to clear this space where the surgery is performed.*

Figure 14. *Schematic representation of the actual classification of rectal tumours.*

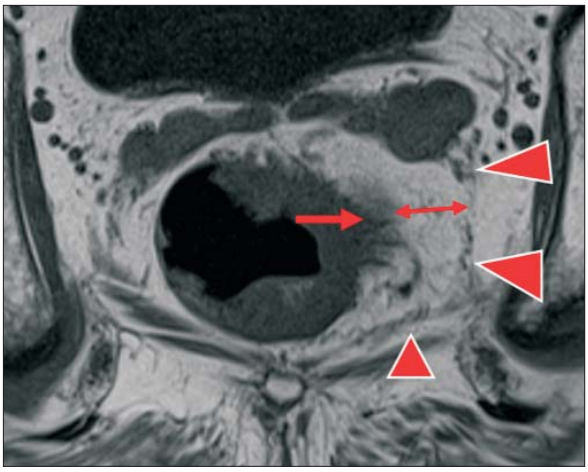

Figure 15. *T3 a,b, CRM-*
T2 weighted FSE image (TSE) A T3 rectal cancer passed through the muscularis propria (arrow) and invaded the mesorectum. The tumour does not touch the mesorectal fascia (triangles). One can hope at a free CRM. The risk of local recurrence is minimal.

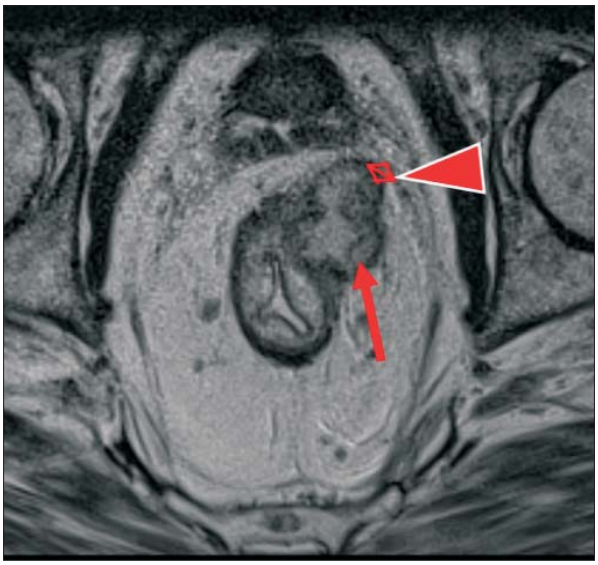

Figure 16. *T3 c,d CRM+*
Paraaxial T2 weighted FSE imaging (TSE) A rectal cancer widely invades the mesorectum. The tumour expansion (arrow) is situated immediately near the mesorectal fascia (triangle). One cannot obtain a free resection margin.

stage. However, treatment and prognosis are totally different! Therefore, the subdivision of T3 tumours is decisive for an individualized treatment.

T3 a, b CRM - tumours (*Fig. 15*) are tumours at the beginning of the extramural expansion, still placed at a very large distance of the mesorectal fascia. In this case a R0 surgery can be performed, obtaining a free CRM. Like in the case of T2 tumours, TME can be performed without radiochemotherapy. The risk of local recurrence is minimal.

T3 c, d CRM+ tumours invade a great part of the mesorectum (*Fig. 16*), being so close to the mesorectal fascia that one cannot obtain a free resection margin. We

have in this case a high risk of R1 resection, associated with a high risk of local recurrence. Consequently, radiochemotherapy will be performed before TME with the purpose of clearing the resection margin.

5b. Special attention: Low rectal cancers (CRM-, CRM+)

Low rectal cancers are very special case concerning CRM. These are defined as tumours whose inferior part is situated at less than 5 cm above the anal verge and represent a third from the total of rectal cancers. We are discussing about them separately because they are a diagnostic and therapeutic challenge. In 20-36% of cases, these tumours invade the CRM, leading to a final worse oncological evolution compared to other rectal cancers. (31)

MERCURY-II, a multicentric European study obtained very good revealing results in this respect. The two purposes of this study were: 1 - validating the high resolution MRI as instrument for the preoperative evaluation of the relation between low carcinomas and the mesorectal fascia, and 2 - establishing a systematic preoperative evaluation of the intersphincteric plane with the purpose of reducing the CRM invasion (34) (*Fig. 17*). In the case of this plane invasion, it is necessary to remove the sphincters and to perform a permanent colostomy in order to obtain a free CRM. The risk of CRM invasion increases 17 times when the intersphincteric plane is invaded. In the recrutment period of the study, 2008 - 2012, 326 patients were included. After the exclusion of 47 cases, there were 279 patient left who were analysed. MERCURY-II study combines the assessment of mesorectal fascia with the one of the intersphincteric plane as decisive criteria for the evaluation of the prognosis concerning CRM invasion risk in low carcinomas:

- „safe“ intersphincteric plane - the tumours do not invade the intersphincteric plane nor the musculus levator ani; (*Fig. 18 A*)
- „unsafe” intersphincteric plane - the tumours extend in the intersphincteric plane, ≤ 1 mm in the direction of musculus sphincter ani externus. (*Fig. 18 B*)

This innovative staging concept was named „MRI low rectal plane“, mrLRP. When a carcinoma jeopardizes the CRM and the intersphincteric plane, mrLRP is considered to be „unsafe“. (*Fig. 19*) In the case of an unfavourable radiological result, namely an unsafe intersphincteric plane, (unsafe CRM, ≥ mrT3c, mrN2, mrEMVI), the patient is proposed for neoadjuvant chemotherapy.

The surgical treatment consisted of an excellent TME, and in the case of carcinomas extended in the intersphincteric plane the extralevatory abdominoperineal excision (ELAPE) was performed.

The MRI examination in the low rectal plane proved to be a reliable diagnostic criteria for the tumoral invasion assessment, and a predictive factor as to the CRM participation in low carcinomas. This new staging system proposed determined the reduction of the CRM invasion rate to 9%, a considerable enhancement compared to the results previously published.

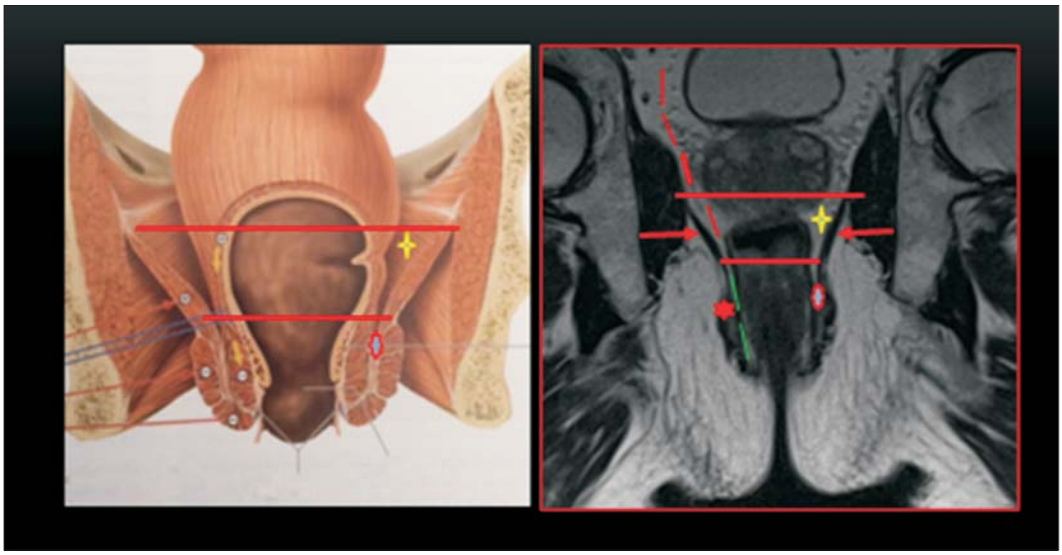

Figure 17. *Inclined coronal plane as longitudinal section through the lower third of the rectum and the anal canal: (**A**) The primary site of low rectal cancers is between the two red lines. The longer line is the top margin of this area, placed at 6 cm from the anal limit, in the area of insertion of levator ani muscle. The shorter line marks the passing from the mesorectal fascia plane (yellow star) to the intersphincteric one (red circle), placed at 1 cm over the puborectalis muscle. **(B)** the red interrupted line (over the right levator) is the plane of the mesorectal fascia, the green interrupted line (under the levator) is the intersphincteric plane. In the case of low rectal carcinoma, the CRM can be involved at the level of both the mesorectal fascia (yellow star) and the intersphincteric plane (red circle).*

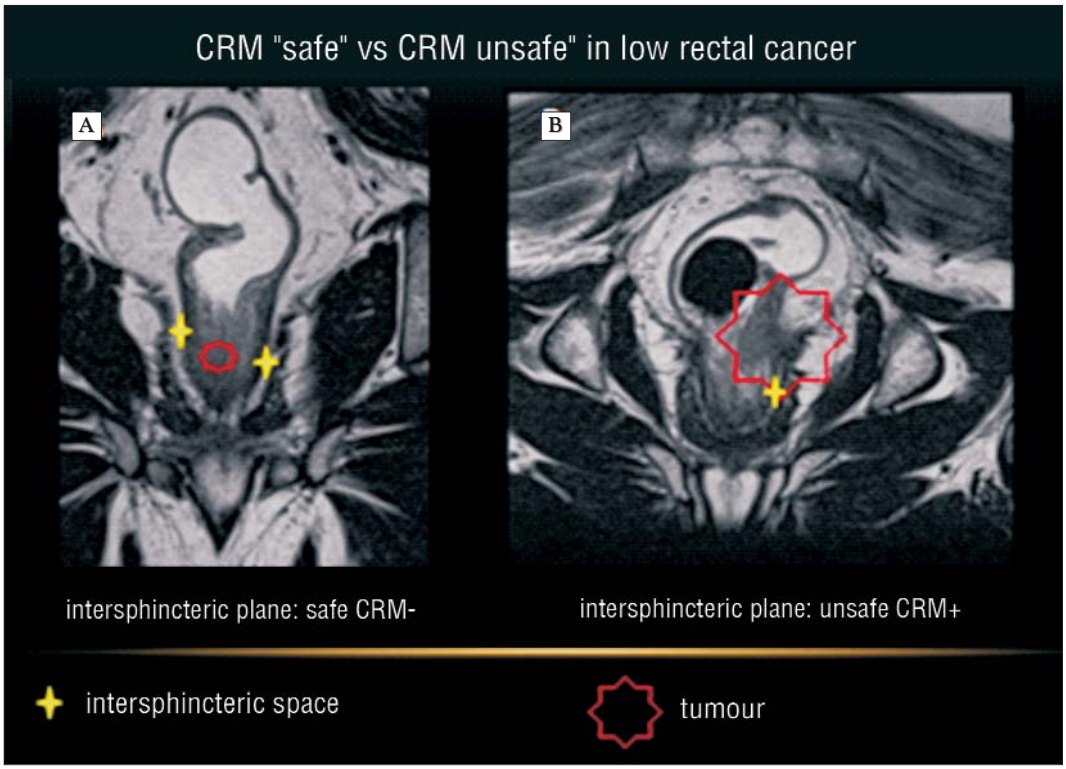

Figure 18. *Tumour in the low rectal segment. (**A**) The exterior margin of muscularis propria (the black strip) is safe in both sides. Hence the intersphincteric space (the yellow star) is safe and a sphincter-preserving resection can be performed. CRM - (**B**) Muscularia propria, the mesorectum and the levator ani muscle on the left side in the 2-3 o'clock position are infiltrated. Consequently, the sphincter cannot be preserved during surgery. CRM +. In exchange, preoperative radiochemotherapy will be performed. If the treatment is successful resulting in the restaging at MRI, this will be followed by TME.*

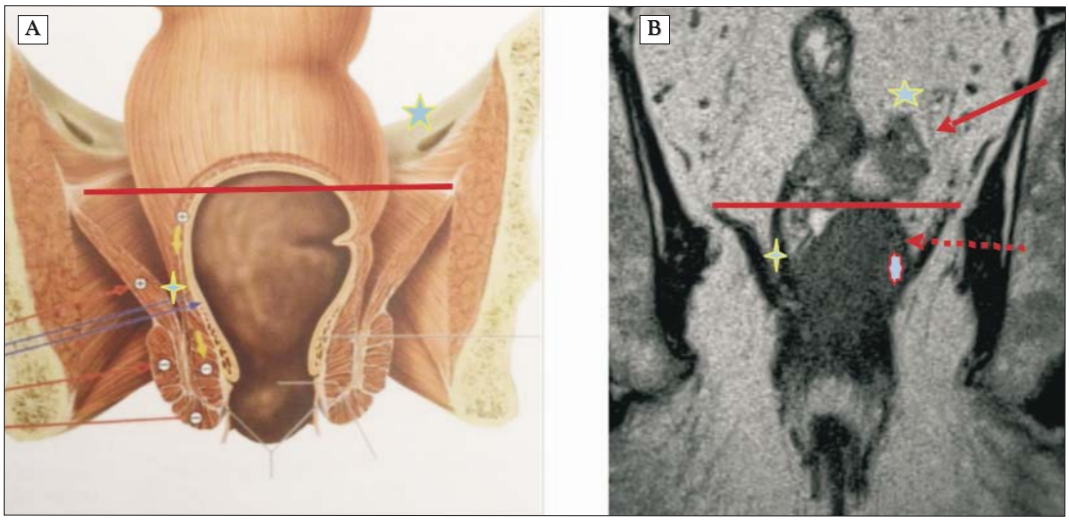

Figure 19. *Low rectal cancer with CRM+ infra- and supra-levator. (**A**) Anatomy. (**B**) T2 paracoronal corresponding to the anatomical preparation. We can observe the invasion of the mesorectum (star) in 2-3 o'clock position, the unsafe mesorectal fascia (red arrow) and the invasion of the intersphincteric plane at 5 o'clock (interrupted arrow, red star), so both planes are unsafe. Preoperative radiochemotherapy is recommended. If the treatment is successful resulting in the restaging at MRI, this will be followed by TME.*

6. Anorectal junction, intersphincteric plane, anal canal

MRI helps us to better visualize the anorectal junction and the anal canal on coronal and paracoronal sections, important for low tumours. (*Fig. 20*) The anal canal comprises an internal and external sphincterian complex, separated by an intersphincteric fat plane. The assessment of the anorectal complex is important for identifying the cases where a sphincter-preserving resection can / cannot be performed.

The low rectal cancer has a higher local recurrence rate. The distal tapering of the mesorectal envelope has as result the fact that the low rectal tumours invade more easily the adjacent structures and that it is more difficult for the surgeon to perform a free resection. (*Fig. 20, 21*)

7. Anal sphincter

The anal sphincter (*Fig. 22*) is composed by an internal musculus sphincter and an external sphincterian complex. The internal sphincter is a continuation of the circular rectal muscle layer, whereas the intersphincteric plane between the internal and external sphincters is the continuation of the longitudinal muscle layer. The external sphincterian complex is composed by the lower extremity of the anal levator muscle, the puborectalis sling and the external sphincterian muscles. The upper margin of the puborectalis sling is the upper limit of the surgical anal canal. The assessment of the relation between the tumour and the upper limit of the puborectalis sling is necessary for the evaluation of the feasibility of a sphincter-preserving resection. This relation is better assessed in the coronal images. The involvement of the anal sphincter complex could necessitate a partial resection of sphincters with colon reconstruction, whereas its important involvement excludes the possibility of sphincter-preserving surgery. (27)

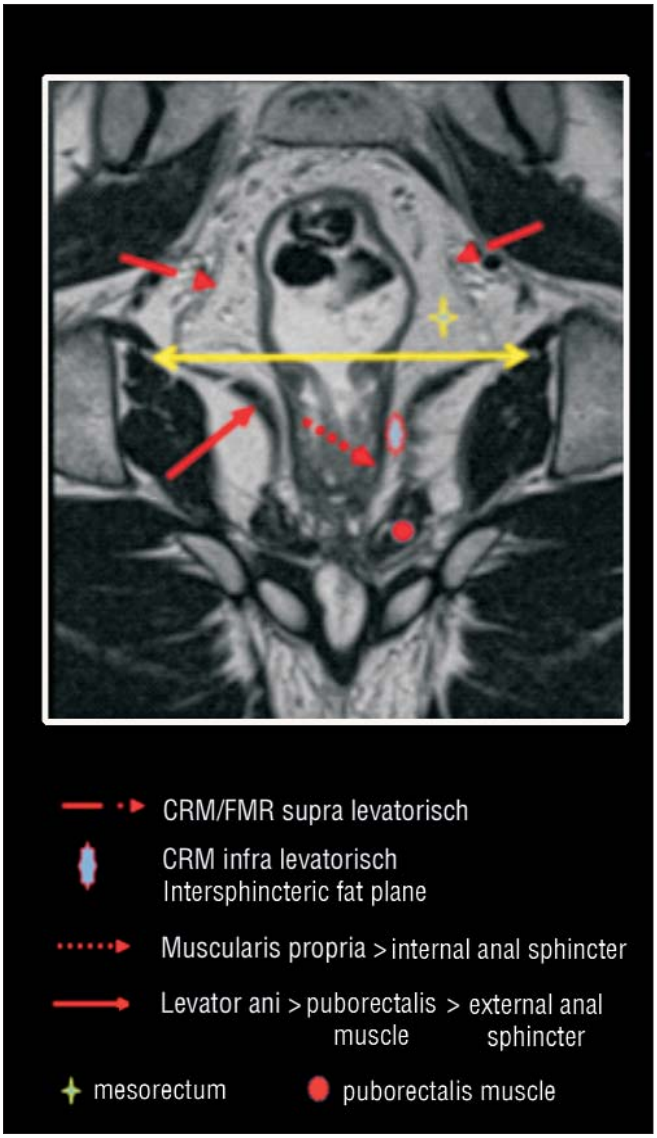

Figure 20. *Paracoronal T2-weighted MRI: muscularis propria, the black strip, passes in the internal anal sphincter, and the anal lifter in the external canal through the puborectalis muscle. Between the black strips there is a white strip, the fat, which is in fact an extension, the end, the mesorectum stalagmite. This intersphincteric space is also very important because it has to be clear in order to perform sphincter-preserving surgery.*

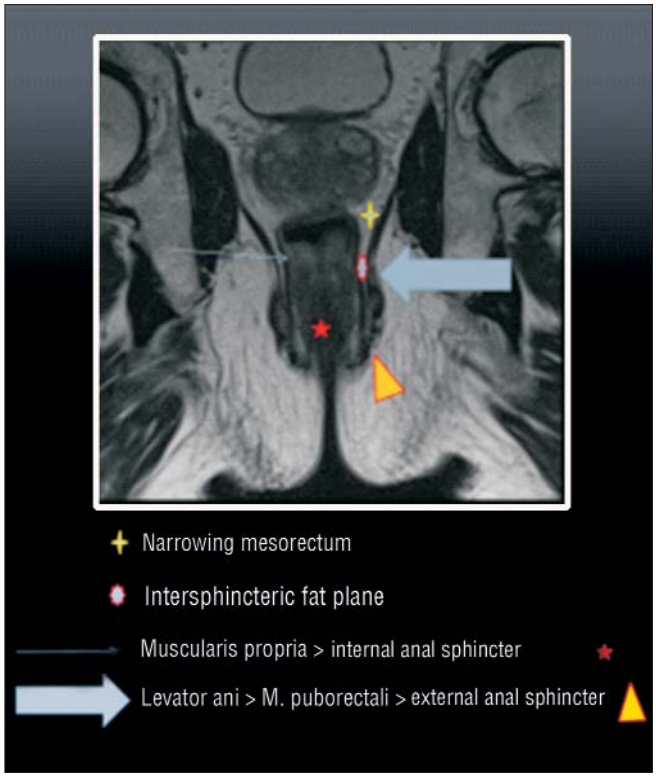

Figure 21. *T2-weighted coronal oblique MRI. The normal anatomy of the anorectal complex can be observed. Observe the fat intersphincteric plane (red circle) and the external sphincter (blue arrow) representing the continuation of the low portion of the anal levator and puborectalis muscles. The black strip (thin blue arrow), namely the muscularis propria passes in the internal anal sphincter (red star).*

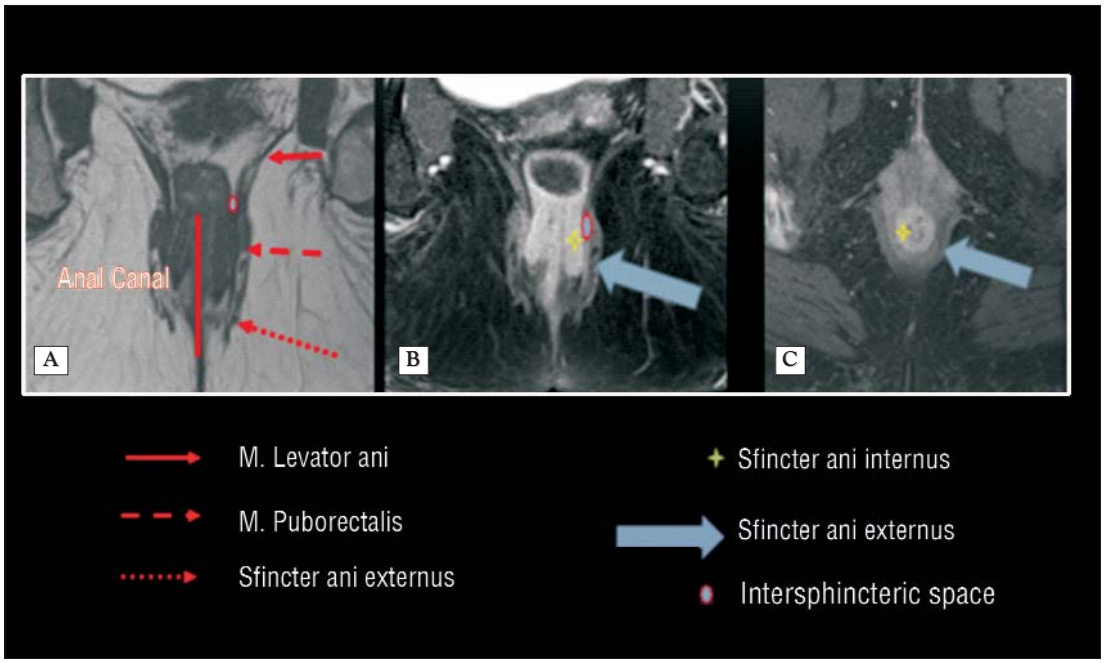

Figure 22. *The anatomy of the anal canal. (**A**) the coronal T1-weighted MRI presents the external anal sphincter composed by the levator ani muscle, the puborectalis muscle and the external anal sphincter. (**B**) the coronal T1-weighted image with fat suppression (FS) after an intravenous contrast media injection: the internal anal sphincter (yellow star) continuing the muscularis propria layer of the rectum. The intersfincterian fat (red circle) the external anal sphincter (blue arrow). The internal anal sphincter (the yellow star) is better visualized after the administration of contrast medium. (**C**) Axial T1-weighted fat suppression after an intravenous injection with contrast medium. We can observe the internal anal sphincter (yellow star) and the external anal sphincter (blue star).*

References

1. Schmiegel W, Reinacher-Schick A, Arnold D, Graeven U, Heinemann V, Porschen R, et al. Update S3-guideline "colorectal cancer" 2008] Z Gastroenterol. 2008;46(8):799-840. doi: 10.1055/s-2008-1027726. German
2. Wietek BM, Kratt T. Current MRI staging of rectal cancer Rofo. 2012;184(11):992-1001. doi: 10.1055/s-0032-1313051. Epub 2012 Aug 14. German
3. Colorectal Cancer Collaborative Group. Adjuvant radiotherapy for rectal cancer: a systematic overview of 8,507 patients from 22 randomised trials. Lancet. 2001;358(9290):1291-304.
4. Akasu T, Iinuma G, Fujita T, Muramatsu Y, Tateishi U, Miyakawa K, et al. Thin-section MRI with a phased-array coil for preoperative evaluation of pelvic anatomy and tumor extent in patients with rectal cancer. AJR Am J Roentgenol. 2005;184(2):531-8.
5. Burt RW, Barthel JS, Dunn KB, David DS, Drelichman E, Ford JM, et al. NCCN clinical practice guidelines in oncology. Colorectal cancer screening. J Natl Compr Canc Netw. 2010; 8(1):8-61.
6. Valentini V, Aristei C, Glimelius B, Minsky BD, Beets-Tan R, Borras JM, et al. Multidisciplinary Rectal Cancer Management: 2nd European Rectal Cancer Consensus Conference (EURECA-CC2). Radiother Oncol. 2009;92(2):148-63. doi: 10.1016/j.radonc.2009.06.027.
7. Bosset JF, Bosset M, Nguyen F et al. Defining preoperative treatment strategies in T3 rectal cancer. Gastrointestinal Cancer Res 2008; 2: S54–S57.
8. Garcia-Aguilar J, Pollack J, Lee SH, Hernandez de Anda E, Mellgren A, Wong WD, et al. Accuracy of endorectal ultrasonography in preoperative staging of rectal tumors. Dis Colon Rectum. 2002;45(1):10-5.
9. Puli SR, Bechtold ML, Reddy JB, Choudhary A, Antillon MR, Brugge WR. How good is endoscopic ultrasound in differentiating various T stages of rectal cancer? Meta-analysis and systematic review. Ann Surg Oncol. 2009;16(2):254-65. doi: 10.1245/s10434-008-0231-5. Epub 2008 Nov 19.
10. Kauer WK, Prantl L, Dittler HJ, Siewert JR. The value of endosonographic rectal carcinoma staging in routine diagnostics: a 10-year analysis. Surg Endosc. 2004;18(7):1075-8. Epub 2004 May 27.
11. Ward J, Robinson PJ, Guthrie JA, Downing S, Wilson D, Lodge JP, et al. Liver metastases in candidates for hepatic resection: comparison of helical CT and gadolinium- and SPIOenhanced MR imaging. Radiology. 2005;237(1):170-80. Epub 2005 Aug 26.
12. Klessen C, Rogalla P, Taupitz M. Local staging of rectal cancer: the current role of MRI. Eur Radiol. 2007;17(2):379-89. Epub 2006 Sep 29.
13. Araujo B, Costa FR, Correia R, Cunha RG. MR Imaging in rectal cancer - an essential and preferably universal tool in loco-regional staging. Congress: ESGAR 2015,e-Poster: EE-072

14. Beets-Tan RG, Beets GL, Vliegen RF, Kessels AG, Van Boven H, De Bruine A, et al. Accuracy of magnetic resonance imaging in prediction of tumour-free resection margin in rectal cancer surgery. Lancet. 2001;357(9255):497-504.
15. Heald RJ, Husband EM, Ryall RD. The mesorectum in rectal cancer surgery - the clue to pelvic recurrence? Br J Surg. 1982; 69(10):613-6.
16. Sagar PM, Pemberton JH. Surgicalmanagement of locally recurrentrectal cancer. Br J Surg. 1996;83(3):293-304.
17. Heald RJ, Ryall RD. Recurrenceand survival after total mesorectal excisionfor rectal cancer. Lancet. 1986;1(8496): 1479-82.
18. Enker WE. Potency, cure, and local control in the operative treatment of rectal cancer. Arch Surg. 1992;127(12):1396-401; discussion 1402.
19. MacFarlane JK, Ryall RD, Heald RJ. Mesorectal excision for rectal cancer. Lancet. 1993;341(8843):457-60.
20. Quirke P, Durdey P, Dixon MF, Williams NS. Local recurrence of rectal adenocarcinoma due to inadequate surgical resection. Histopathological study of lateral tumor spread and surgical excision. Lancet. 1986;2(8514):996-9.
21. Williamson PR, Hellinger MD, Larach SW, Ferrara A. Endorectal ultrasound of T3 and T4 rectal cancers after preoperative chemoradiation. Dis Colon Rectum. 1996;39(1): 45-9.
22. Chari RS, Tyler DS, Anscher MS, Russell L, Clary BM, Hathorn J, et al. Preoperative radiation and chemotherapy in the treatment of adenocarcinoma of the rectum. Ann Surg. 1995;221(6):778-86; discussion 786-7.
23. Minsky BD. Conservative treatment of rectal cancer with local excision and postoperative radiation therapy. Eur J Cancer. 1995;31A(7-8):1343-6.
24. [No authors listed] Improved survival with preoperative radiotherapy in resectable rectal cancer. Swedish Rectal Cancer Trial. N Engl J Med. 1997;336(14):980-7.
25. Kapiteijn E, Marijnen CA, Nagtegaal ID, Putter H, Steup WH, Wiggers T, et al. Preoperative radiotherapycombined with total mesorectalexcision for resectable rectal cancer. N Engl J Med. 2001;345(9):638-46.
26. [No authors listed] NIH consensus conference. Adjuvanttherapy for patients with colon andrectal cancer. JAMA. 1990;264(11): 1444-50.
27. Brown G, How P. Magnetic resonance imaging staging of rectal cancer. In „Manual of Total Mesorectal Excision". Edited by Brendan Moran, R.J. Heald; 2013. p. 59-61.
28. Heald RJ. Manual of Total Mezorectal Excision. CRC Press, Taylor&Francis Group. 2013.
29. Brown G, Richards CJ, Newcombe RG, Dallimore NS, Radcliffe AG, Carey DP, et al. Rectal carcinoma: thin-section MR imaging for staging in 28 patients. Radiology. 1999;211(1): 215-22.
30. Bonfill M, Garcia E, Eugena A, Oliva A, Garcia-Lorente F, Fonoll M. A practical approach to rectal cancer by MRI. Congress: ESGAR 2015, e-Poster: EE-071.
31. Schäfer AO. Local imaging of rectal cancer--update 2015: MRI as imaging biomarker. Radiologe. 2015;55(11):1015-26; quiz 1027-8. doi: 10.1007/s00117-015-0030-5. German
32. Merkel S, Mansmann U, Siassi M, Papadopoulos T, Hohenberger W, Hermanek P. The prognostic inhomogeneity in pT3 rectal carcinomas. Int J Colorectal Dis. 2001;16(5):298-304.
33. Pox C, Aretz S, Bischoff SC, Graeven U, Hass M, Heußner P, et al. S3-guideline colorectal cancer version 1.0. Z Gastroenterol. 2013;51(8):753-854. doi: 10.1055/s-0033-1350264. Epub 2013 Aug 16. German
34. Battersby NJ, How P, Moran B, Stelzner S, West NP, Branagan G, et al. Prospective validation of a low rectal cancer magnetic resonance imaging staging system and development of a local recurrence risk stratification model: the MERCURY II study. Ann Surg. 2016;263(4):751-60.