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Rectal tumour staging: MR imaging using pelvic phased-array and endorectal coils vs endoscopic ultrasonography

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Abstract. The aim of this study was to compare MR imaging and endoscopic ultrasonography (EUS) for the local staging of rectal tumours. Forty-nine patients were examined on a 1.5-T MR unit using either a pelvic phased-array coil ($n = 37$) alone or combined with an endorectal coil ($n = 12$). Sagittal and axial sequences with T2-weighted fast spin-echo and axial T1-weighted spin-echo techniques were employed. The EUS technique was performed using a flexible endosonoscope. The results were compared with findings at histopathological sectioning of the specimen. The T-stage on MR correlated with histopathology in 32 of 49 patients and on EUS in 29 of 49 patients. The N-stage on MR correlated with histopathology in 22 of 49 patients and on EUS in 26 of 49 patients. Tumour penetration of the rectal wall was predicted by MR with 86 % sensitivity and 65 % specificity, and by EUS with 89 % sensitivity and 33 % specificity. Preoperative radiotherapy was administered to 40 of the patients after the examinations which may explain some of the overstaging by MR and EUS. Three patients with surgically and histopathologically confirmed invasion of neighbouring organs in the pelvis were detected preoperatively on MR but none on EUS. Tumour penetration of the rectal wall and local lymph node metastases cannot accurately be predicted with MR or EUS. Magnetic resonance, however, seems to be more useful for preoperative identification of clinically occult advanced disease.

Key words: Rectum – Neoplasms – MR imaging – Ultrasonography – Comparative studies

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Introduction

In rectal cancer staging, both transrectal ultrasonography (TRUS), CT and MR imaging have all been evaluated for assessing both tumour infiltration in the bowel wall and loco-regional lymph node metastases [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21]. Despite initial promising results and subsequent technical developments of the methods, the overall results in large series of patients indicate that presently routine staging of rectal cancer cannot be justified, because the accuracy to predict tumour penetration and lymph node metastases is limited [22, 23, 24, 25]. With MR technology, such as phased-array coils and endorectal surface coils, image quality is considerably improved [14, 26]. Transrectal ultrasonography, which is currently the most commonly used method for staging of rectal cancer, has several limitations and cannot reach the entire rectum due to stiffness of the device [27]. Some stenotic tumours cannot be investigated and the ultrasound examination is not satisfactory since the tumour can be viewed only from the anal side. However, with a flexible endoscope equipped with an ultrasound probe, the majority of rectal tumours can be examined.

The aim of this study was to prospectively assess the accuracy of MR, performed with phased-array surface coils and endorectal coils, and endoscopic ultrasonography (EUS) in the local staging of rectal cancer in patients who either after preoperative radiotherapy or not, are surgically treated. The results were compared with those obtained by a detailed histopathological examination of the surgical specimens.

Materials and methods

The MR and EUS techniques were performed in 49 consecutive patients admitted to the surgical department. Patients with tumours situated 0–15 cm from the anal verge (median 9 cm), verified by rigid rectoscopy

Table 1. Magnetic resonance imaging examination protocol. *PPA* pelvic phased array; *FSE* fast spin echo; *SE* spin echo; *FOV* field of view; *TR* repetition time; *TE* echo time

Imaging plane	Coil	Sequence	TR/TE (ms)	FOV (mm)	Slice thickness (mm)	Interslice gap (mm)	Matrix
Sagittal	PPA	T2 FSE	4000–5000/102–120	240	5	0	512 × 256
Axial	Endorectal	T2 FSE	3480–5860/119–126	120	4	0	256 × 128
Axial	Endorectal	T1 SE	400–700/9–12	120	4	0	256 × 128
Axial	PPA	T2 FSE	3000–4620/119–126	160	5	0	256 × 192
Axial	PPA	T1 SE	360–700/8–11	160	5	0	256 × 160
Coronal/oblique coronal	PPA	T2 FSE	2500–4000/102–130	240	5	0–1.5	512 × 256

and judged clinically as primarily resectable by the surgeon, were included in the study. The examinations were performed between February 1996 and December 1997. There were 31 men and 18 women (age range 42–86 years, median age 70 years).

Informed consent was obtained from all patients and the study was approved by the local ethics committee.

Magnetic resonance imaging was performed on a 1.5-T superconductive unit (Signa, General Electric, Milwaukee, Wis.). An intramuscular injection of 1 IU of glucagon (Novo Nordisk) was administered before scanning in order to decrease artefacts due to bowel peristalsis.

After localiser scans, a sagittal sequence with a pelvic phased-array coil, using T2-weighted fast spin-echo (FSE); [TR/TE = 4000–5000/102–120 ms, 16 echo train lengths (ETL), field of view (FOV) 240 mm, matrix size 512 × 256, slice thickness 5 mm, no interslice gap] was obtained. Axial T2-weighted FSE sequences 3000–5860/119–126 ms, ETL 16 and axial T1-weighted sequences using TR/TE = 360–700/8–12 ms were also obtained. These two sequences were performed in two ways depending on the rectoscopy findings and the level and extension of the rectal tumour on the first sagittal T2-weighted FSE images.

If the perirectal extension was not obvious and the top of the tumour was judged reachable by the endorectal coil (12 patients), patients were removed from the scanner. After digital examination, an endorectal coil (Medrad Colon) was inserted into the rectum. A sagittal localiser scan was repeated to ensure optimal placement of the coil. Thereafter, axial T2-weighted FSE images from the promontorium to the pelvic floor using 16 ETL, FOV 120 mm, matrix size 256 × 128, 4-mm slice thickness, no interslice gap with combined use of the endorectal and the pelvic phased-array coil were obtained. This sequence was followed by an axial T1-weighted SE sequence with the same slice orientation, image matrix and FOV parameters as the T2-weighted sequence.

In the remaining 37 patients, the examination was completed using the pelvic phased-array coil alone. Axial T2-weighted FSE and T1-weighted SE images were obtained from the promontorium to the pelvic floor using an FOV of 160 mm, slice thickness of 5 mm with no interslice gap, and matrix size 256 × 192 for T2-weighted and 256 × 160 for T1-weighted images. In patients with tumours in the upper part of the rectum, a T2-weighted coronal or oblique coronal T2-weighted FSE sequence perpendicular to the tumour with imaging parameters identical to the first sagittal sequence was added to the protocol. The total examination time was 45 min (Table 1).

Endoscopic ultrasonography was performed within 0–25 days (median 6 days) from the MR examination. Examinations were performed using an Olympus UM-20 fibre endoscope equipped with a 7.5- and 12-MHz 360 real-time rotating mechanical transducer, to obtain axial images of the bowel wall. After visual inspection of the tumour, which in most cases could be passed, the rectum was emptied of air by suction and distended with degassed water. A balloon with degassed water at the tip of the instrument ensured that the distance between the transducer and the bowel wall was not too short. The total examination time was 15–20 min.

Each specialist in gastrointestinal radiology prospectively and independently interpreted the MR and EUS examinations blinded to results from the other examination. The depth of tumour penetration and presence of local lymph node metastases was reported according to the TNM system both for MR and EUS (Table 2). After the examinations, but before surgery, 38 patients received external irradiation to the pelvis with 5 Gy for five consecutive days. One patient received 40 Gy in 2-Gy fractions and 1 patient 50 Gy in 1.8-Gy fractions. The remaining 9 patients received no preoperative irradiation.

Surgery was performed within 3 weeks from the examination (median MR 17 days, median EUS 20 days) in all except the 2 patients who received prolonged radiotherapy and in whom surgery was performed 4 months after the examinations. Forty-one patients had a low anterior resection of the rectum attempting total mesorectal excision. In one of these patients, the procedure was combined with a hystero-salpingo-oophorectomy. In another of these patients, the uterus, vagina, urinary bladder as well as a tumour-involved part of the small bowel was surgically removed. Five patients had an abdomino-perineal resection, one of them combined with a resection of the posterior vaginal wall. One patient had a total procto-colectomy. In the remaining 2 patients, the rectal tumour was removed by transanal local excision.

The formalin-fixed specimens were examined histopathologically in two ways. In unopened specimens

Table 2. TN(M) staging criteria for MR, EUS and histopathology

	T-	T0	T1	T2	T3	T4	N0	N1	N2
MR/EUS	No tumour found		Thickness of submucosal layer with preserved muscularis propria	Irregular or thickened muscularis propria layer	Disruption of muscularis propria layer	Tumour extending into adjacent organs	No local lymph node ≥ 5 mm in diameter	One to three lymph nodes ≥ 5 mm in diameter	More than three lymph nodes ≥ 5 mm in diameter
Histopathology	No tumour found	Tumour limited to mucosa	Tumour invasion of submucosa	Tumour invasion of but not through muscularis propria	Tumour invasion of serosa or perirectal fat	Tumour invasion of adjacent pelvic organs	No local lymph node metastases	One to three local lymph node metastases	More than three local lymph node metastases

($n = 40$), giant sections were processed according to routines previously described [21]. From opened specimens ($n = 9$), two or three blocks were prepared from the tumour, from the resection borders and from all identified lymph nodes.

Results

T-staging

According to histopathology, the rectal tumour had penetrated the rectal wall to the serosa or perirectal fat without macroscopical invasion of neighbouring organs (T3) in 29 of 49 patients (59%). In 3 patients tumour involvement of the uterus was found at surgery and confirmed by histopathology (T4). In one of these patients, invasion of the vagina and the small intestine was found as well. In the remaining 17 specimens there was no tumour penetration through the rectal wall (T0–T2; Table 3).

Magnetic resonance imaging verified tumour infiltration into the uterus in all the 3 patients with proven involvement at surgery and histopathology, whereas none was identified by EUS (Fig. 1).

On MR an overall higher T-stage was found in 9 and lower T-stage in 8 patients compared with histopathology. On EUS a higher T-stage was found in 14 and a lower stage in 6 patients compared with histopathology. The sensitivity and specificity to predict a T3 tumour on MR were 86 and 65%, respectively (accuracy 78%). For EUS the corresponding figures were 89 and 33% (accuracy 65%) due to more false-positive findings on EUS. In 5 of 11 tumours overstaged on EUS as T3, only an irregular outer border of the muscularis propria layer was found. Three tumours by EUS "overstaged" as T3 tumours were located high in the rectum and could not be passed by the endoscope. In 1 patient a tumour 12 cm above anal verge, classified as T3 according to histopathology, could not be found by EUS.

There were 11 tumours classified as T2 according to histopathology, only three of them correctly staged by MR and four by EUS. In five tumours staged as T1 according to histopathology, the MR T-stage correlated in only one case and EUS in no cases.

Of the 12 patients examined on MR with an endorectal coil, 4 had tumours staged as T3 according to histopathology. Two of these correlated with MR. The remaining two were "understaged" by MR as T2. Two of four T2 tumours according to histopathology correlated with endorectal MR. One was "overstaged" as T3, and one "understaged" as T1. Of three histopathologically confirmed T1-tumours in this group, one correlated with MR, and the remaining were "overstaged" as T3 by MR. One patient who had a tubulovillous adenoma was "overstaged" by MR as a T4 tumour with tumour extension into the uterus (Fig. 2).

Table 3. Tumour infiltration according to MR, EUS and histopathology

		MRI						
		T-	T0	T1	T2	T3	T4	Total
Histopathology	T0						1	1
	T1			1	1	3		5
	T2			4	3	4		11
	T3				4	25		29
	T4						3	3
	Total	0	0	5	8	32	4	49

		EUS						
		T-	T0	T1	T2	T3	T4	Total
Histopathology	T0				1			1
	T1				1	4		5
	T2				4	7		11
	T3	1			2	25	1	29
	T4					3		3
	Total	1	0	0	8	39	1	49

Local lymph node metastases

Forty-seven of 49 patients could be evaluated for local lymph nodes as two patients only had a local excision. In 12 of the patients, local lymph node metastases were found at histopathology. Enlarged lymph nodes were found in 17 patients on MR and 16 patients on EUS, but no metastases were found at histopathologically. The presence or absence of lymph node metastases correlated with MR in 26 of 47 patients (55%) and with EUS in 28 of 47 patients (60%; Table 4). The N-stage correlated in 22 (47%) of the patients with MR and 26 (55%) patients with EUS.

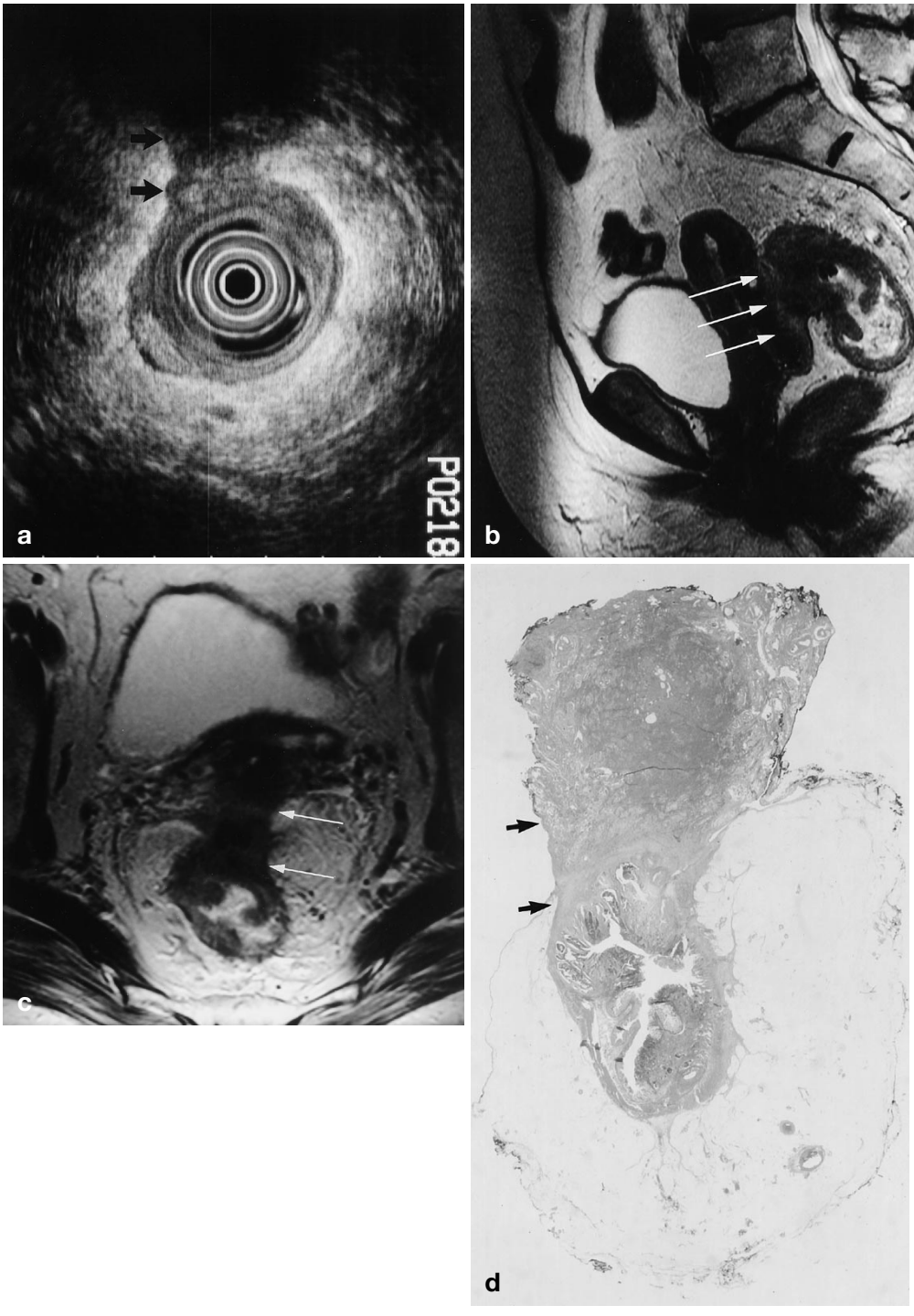

Fig. 1 a–d. A 72-year-old female patient with clinically resectable rectal cancer 11 cm above anal verge. **a** Axial endoscopic ultrasonography (EUS) image shows an anteriorly located rectal tumour with perirectal extension (stage T3; *arrows*) extending to the limits of the field of view which in this patients led to underestimation of the tumour extension into neighbouring organs. **b** Sagittal and **c** axial T2-weighted fast spin-echo (FSE) MR image clearly shows that the rectal tumour extends beyond the border of the mesorectum and infiltrates the uterus (stage T4; *arrows*). **d** Histopathological giant section verifies extension of the tumour to the uterus (stage T4; *arrows*)

In 4 patients perirectal intravascular metastases were found at histopathology. None of them were reported by MR or EUS (Fig. 3). In 1 patient multiple free mucus-producing metastases were found in the perirectal fat according to histopathology but no lymphatic tissues. In this patient perirectal lymph node metastases were considered at MR.

In 6 patients the circumferential (lateral) margin of the mesorectum was involved in the surgical specimen. In two of these patients, the perirectal fascia was prospectively judged involved by tumour according to preoperative MR. In the remaining 4 patients, in a retrospective review of MR, a large dorsal perirectal tumour component not separable from the retrosacral fascia was found in 2 patients (Fig. 3), and in 2 patients the tumours were located anteriorly in the upper rectum not separable from the peritoneal border.

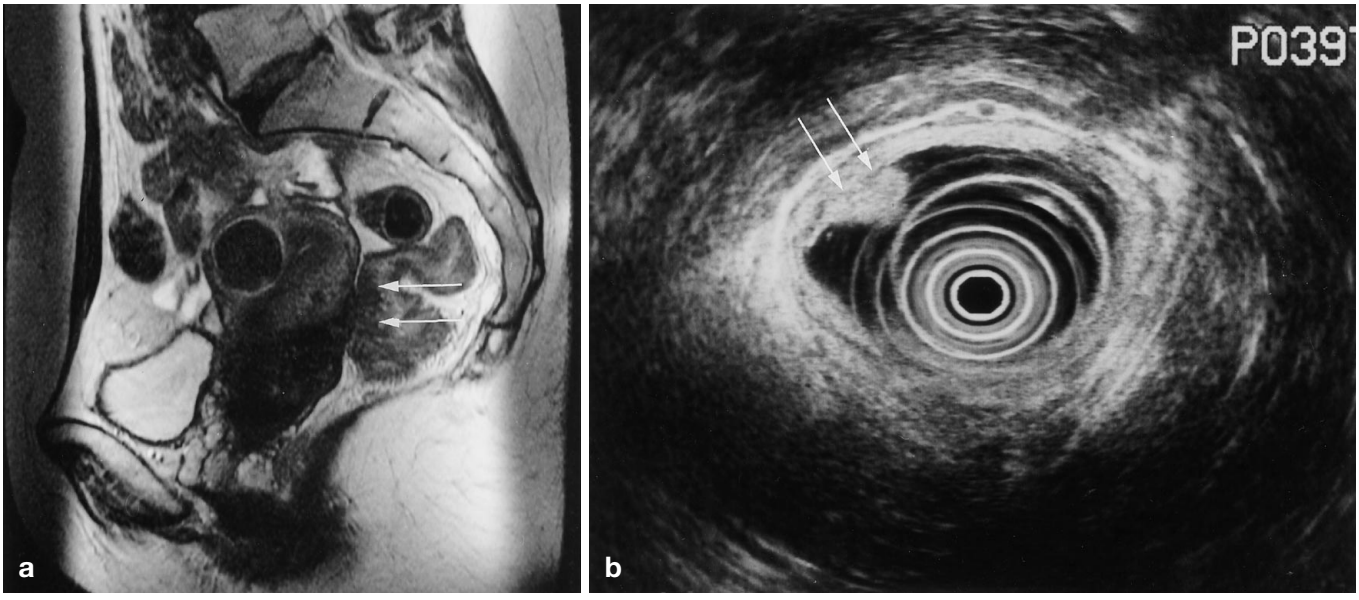

Fig. 2 a, b. A 59-year-old female patient with clinically resectable rectal tumour. **a** Sagittal T2-weighted FSE MR image shows a tumour anteriorly in the rectum *(arrows)* not separable from the uterus which diffusely thickened posteriorly due to adenomyosis. There is also a leiomyoma in the fundus. Due to these abnormalities in the uterus that were not separable from the rectal tumour, the rectal tumour was interpreted as stage T4. **b** Axial TRUS image showing the tumour anteriorly *(arrows)* judged as infiltrating to, but not through, the propria muscle of the rectum (Stage T2). The tumour was removed by local excision and was found to be a tubulovillous adenoma Stage T0

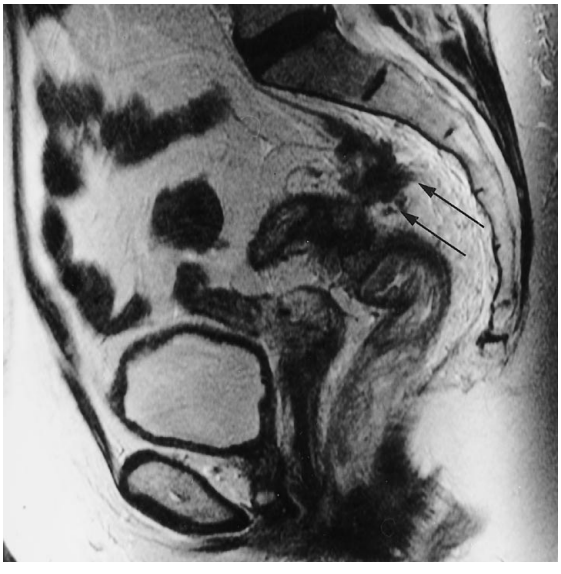

Fig. 3. A 65-year-old female patient with clinically resectable rectal cancer 7 cm above anal verge. Sagittal T2-weighted FSE MR image shows a large perirectal tumour extending through the level of the superior haemorrhoidal vessels close to the rectosacral fascia *(arrows)*, although still stage T3. After total mesorectal excision, a stage-T3 tumour with involvement of the lateral resection margin as well as intravascular metastases were found

Table 4. Presence of lymph node metastases according to MR, EUS and histopathology

		MRI N0	N1–N2	Total
Histopathology	N0	18	17	35
	N1–N2	4	8	12
	Total	22	25	47
		EUS N0	N1–N2	Total
Histopathology	N0	19	16	35
	N1–N2	3	9	12
	Total	22	25	47

Discussion

Several previous studies have demonstrated that TRUS is more accurate than CT in assessing preoperative local staging of rectal cancer [7, 18]. In a recent large multicenter study comparing CT and MR, better prediction of transmural tumour penetration was found by CT than by MR (accuracy 74 vs 58 %) [22]; however, it was suggested that recent developments in MR could affect these results.

In previous studies similar results were found when comparing body-coil MR and TRUS in 30 patients [17], endorectal MR and TRUS in 10 patients [15], in 21 patients [28] and combined use of double surface coil and endorectal MR and TRUS in 15 patients [29]. In one of these studies [17], MR was found to be slightly better than TRUS in determining tumour invasion into adjacent organs.

In the present study, despite availability of recent technology such as phased-array and endorectal surface coils, MR as well as EUS were found to be of limited value in predicting lymph node involvement. This result

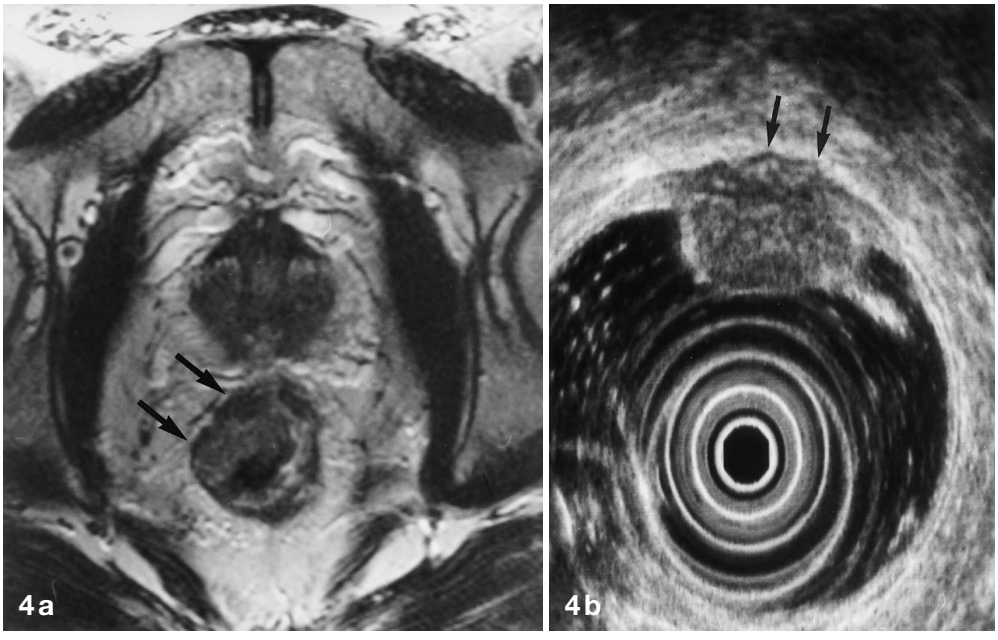

Fig. 4 a, b. A 52-year-old male patient with rectal cancer 6 cm above anal verge. **a** Axial T2-weighted FSE MR image shows a tumour anteriorly in the rectum *(arrows)*. The muscularis propria is somewhat irregular, but no tumour within this layer is seen, and the tumour regarded as T1. **b** On endoscopic ultrasonography, tumour is seen to invade the propria muscle (*arrows*; stage T2) which also was proved by histopathology

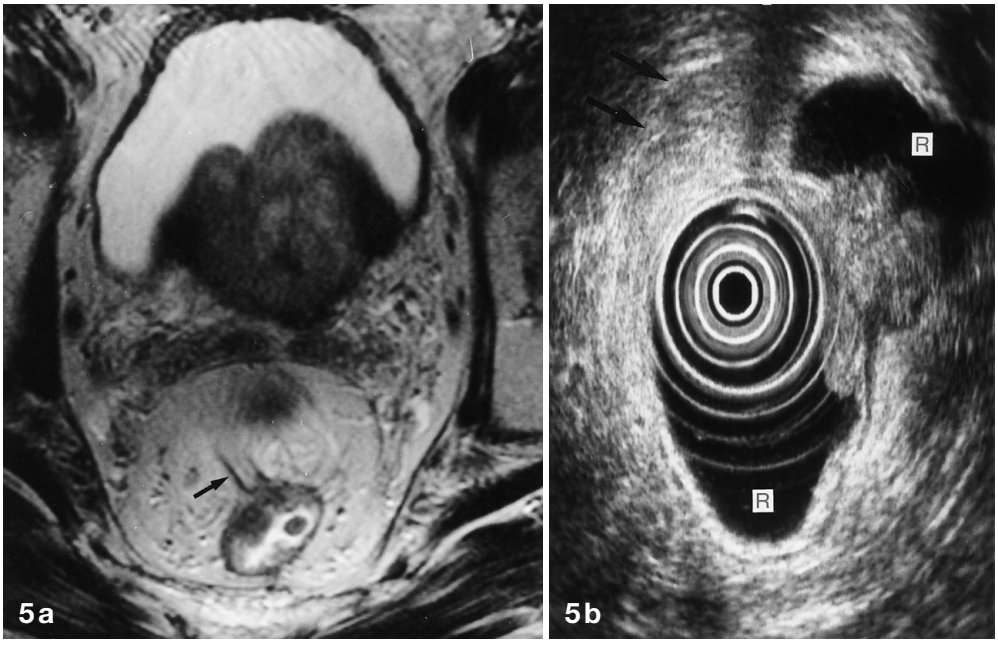

Fig. 5 a, b. A 76-year-old male patient with rectal cancer 11 cm above anal verge. **a** Axial T2-weighted FSE MR image shows tumour-like spiculations *(arrow)* from in the perirectal fat from the anteriorly located rectal tumour. The tumour was judged as stage T3; however, the imaging plane is not perpendicular to the plane of the upper rectum. **b** On endoscopic ultrasonography, the tumour was also judged as invading the perirectal fat (stage T3; *black arrows*). However, the tumour covered a fold in the rectum which made it difficult to obtain images completely perpendicular to the bowel wall across the tumour (the rectal lumen is marked with an *R*). The tumour was shown to invade only the submucosa (stage T1) by histopathology

is in keeping with most studies using cross-sectional modalities. Both methods were also found to be sensitive but not accurate enough in predicting tumour extension outside the rectal wall. Magnetic resonance was better in this respect with seven false-positive patients with T3 tumours compared with 11 false positives using EUS. This "overstaging" can be explained both by the criteria used for determining an irregular outer border of the propria muscle on EUS as T3, but also by a peritumoral tissue reaction indistinguishable from tumour which has been described in several studies [19, 27, 30].

In this study, neither MR nor EUS were accurate in predicting the degree of tumour penetration within the rectal wall (T2). The number of patients with T0–T1 tumours (6 patients) was too small to be assessed statistically (Figs. 4, 5).

Results for MR were not better in the group of 12 patients examined with an endorectal coil together with a pelvic phased-array coil. In this group, eight tumours did not penetrate the bowel wall at histopathology, but five were "overstaged" as doing so according to MR. The use of intravenously administered contrast and fast T1-weighted images during dynamic scanning may improve the evaluation of the depth of tumour penetration within the rectal wall in this group of patients [16].

In the patient with a tubulovillous adenoma "overstaged" by MR as a T4 tumour with tumour extension into the uterus, the endorectal coil did not optimally reach the top of the tumour and there were abnormalities found in the adjacent part of the uterus retrospectively on MR consistent with adenomyosis rather than rectal tumour invasion (Fig. 2).

It is pointed out that 38 of 49 patients received preoperative irradiation between the clinical preoperative examination and the histopathological examination of the surgical specimen. Obviously, shrinkage of the rectal tumour as well as regression of perirectal lymph nodes induced by radiotherapy [31] may have contributed to the "overstaging" found by MR and by EUS.

All patients included in this study were clinically regarded as primarily resectable indicating that the clinical examination and rectoscopy did not reveal tumour fixation to the adjacent organs in the pelvis. Despite this, invasion of adjacent organs was found at surgery in 3 patients all of whom were detected preoperatively by MR but not by EUS.

The FOV of EUS with a 7.5-MHz transducer reaches up to 5 cm. Tumour and lymph nodes at greater distances cannot be visualized.

Furthermore, in six additional patients, the lateral resection margins in the surgical specimen was found to be involved by the tumour at histopathology. Difficulty in obtaining complete excision of the tumour by total mesorectal excision could have been expected from findings at the preoperative MR examinations.

Several recent studies have not recommended routine preoperative local staging of rectal cancer by any cross-sectional imaging method [20, 22, 25, 32]. The main aim in most studies has been to identify tumour infiltration into the perirectal fat and the presence of lymph node metastases. At present, accurate selection of patients for preoperative adjuvant treatment, such as radiotherapy-based prediction of extrarectal disease, cannot be made in all patients. In one study three local tumour recurrences were found in 19 patients in whom no preoperative radiotherapy had been administered based on previous TRUS results [25].

Since the perirectal fascia defines the excision plane when performing rectal cancer surgery, the tumour relation to this fascia, to the mesorectal border and to the neighbouring organs in the pelvis by preoperative imaging are probably more important to assess than the presence of extrarectal tumour invasion. If the lateral resection margin of the surgical specimen is involved by tumour, the patient is at high risk of developing local recurrence [33]. For this reason preoperative MR can be helpful in selecting patients for adjuvant extended preoperative treatment as well as a guideline for the surgeon in pointing out critical areas of close proximity between the tumour and the mesorectal border.

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