Original article

Extent and completeness of mesorectal excision evaluated by postoperative magnetic resonance imaging

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Background: **The major advance in rectal cancer management over the past 20 years has been the standardization of mesorectal excision. The aim of this study was to determine the prevalence and localization of inadvertent residual mesorectum detected on magnetic resonance imaging (MRI) after rectal cancer surgery.**

Methods: **Postoperative T2-weighted MRI of the pelvis was performed on patients following mesorectal excision. A multidisciplinary team radiologist evaluated the images with regard to residual mesorectum and distal margin. Only mesorectum above the level of the anastomosis perpendicular to the bowel was regarded as inadvertent residual mesorectum after partial mesorectal excision. Histopathological records, standardized photographs and clinical records were assessed. The pathology and MRI findings were evaluated independently in a blinded fashion.**

Results: **MRI-detected residual mesorectum was identified in 54 (39·7 per cent) of 136 patients. There was agreement with the pathology findings in 88 patients (64·7 per cent). Residual mesorectum was more frequent in patients treated with partial mesorectal excision (63 per cent) than those who had total mesorectal excision (36 per cent) or abdominoperineal resection (13 per cent) ($P < 0·001$). Pathology and MRI findings both showed that the distal resection margin after partial mesorectal excision was less than 5 cm in more than three-quarters of patients, and less than 3 cm in more than one-third.**

Conclusion: **Inadvertent residual mesorectum was commonly found on postoperative MRI, especially after partial mesorectal excision.**

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Introduction

Rectal cancer management has been refined significantly during the past 20 years. The main advance has been the specialization and standardization of mesorectal excision. Pathological involvement of the circumferential resection margin (CRM) and/or an incomplete mesorectum are predictors of local recurrence[1,2]. In a Swedish series, half of the patients with local recurrence had visible residual mesorectal tissue in the pelvis on postoperative magnetic resonance imaging (MRI) and computed tomography (CT), suggesting that suboptimal surgery had been performed[3,4]. In this group, a surprisingly high rate of local recurrence was observed in patients treated with partial mesorectal excision. The aim of the present study was to determine the prevalence and localization of residual mesorectal tissue by postoperative MRI of the pelvis. Histopathological quality assessment of the rectal cancer specimen was assessed in relation to the postoperative MRI findings of residual mesorectum.

Methods

The study was approved as a quality assurance project by the local ethics committee, with no need for oral or written consent according to Danish law.

The Department of Surgery at Aarhus University Hospital has a primary catchment population of 400 000 inhabitants, and annually approximately 120 rectal cancers are treated surgically. It serves as a secondary referral centre for low rectal cancers in the region (population 1·25 million) and as a tertiary referral centre for very

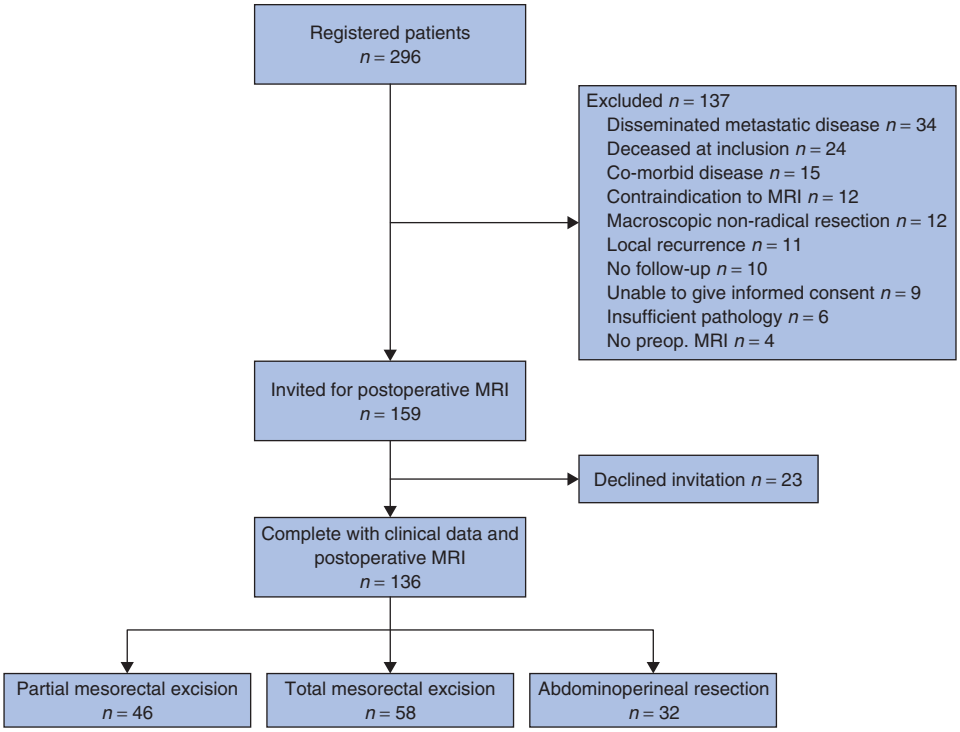


Fig. 1 Flow chart for the study. MRI, magnetic resonance imaging

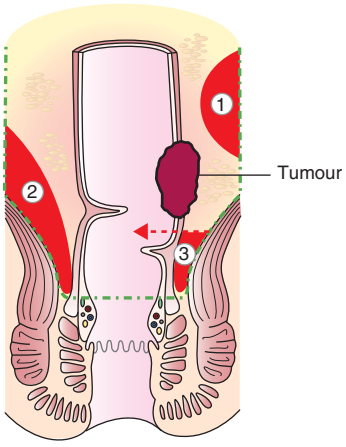


Fig. 2 Residual mesorectum according to localization following total mesorectal excision. Green dashed line indicates complete mesorectal excision. Red area (1) shows cranially located mesorectum independent of the distal level of resection. Red area (2) shows perianastomotic residual mesorectum in direct relation to the anastomosis. Red area (3) shows residual mesorectal tissue below the distal level of resection (red dashed line)

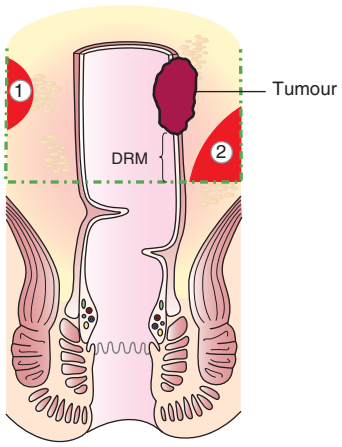


Fig. 3 Inadvertent residual mesorectum according to localization following partial mesorectal excision. Green dashed line indicates optimal dissection and perpendicular transection. Red area (1) shows cranially located mesorectum independent of the distal level of resection. Red area (2) shows perianastomotic residual mesorectum directly above the level of the anastomosis. The distal resection margin (DRM) is marked from the distal border of the primary tumour to the level of resection

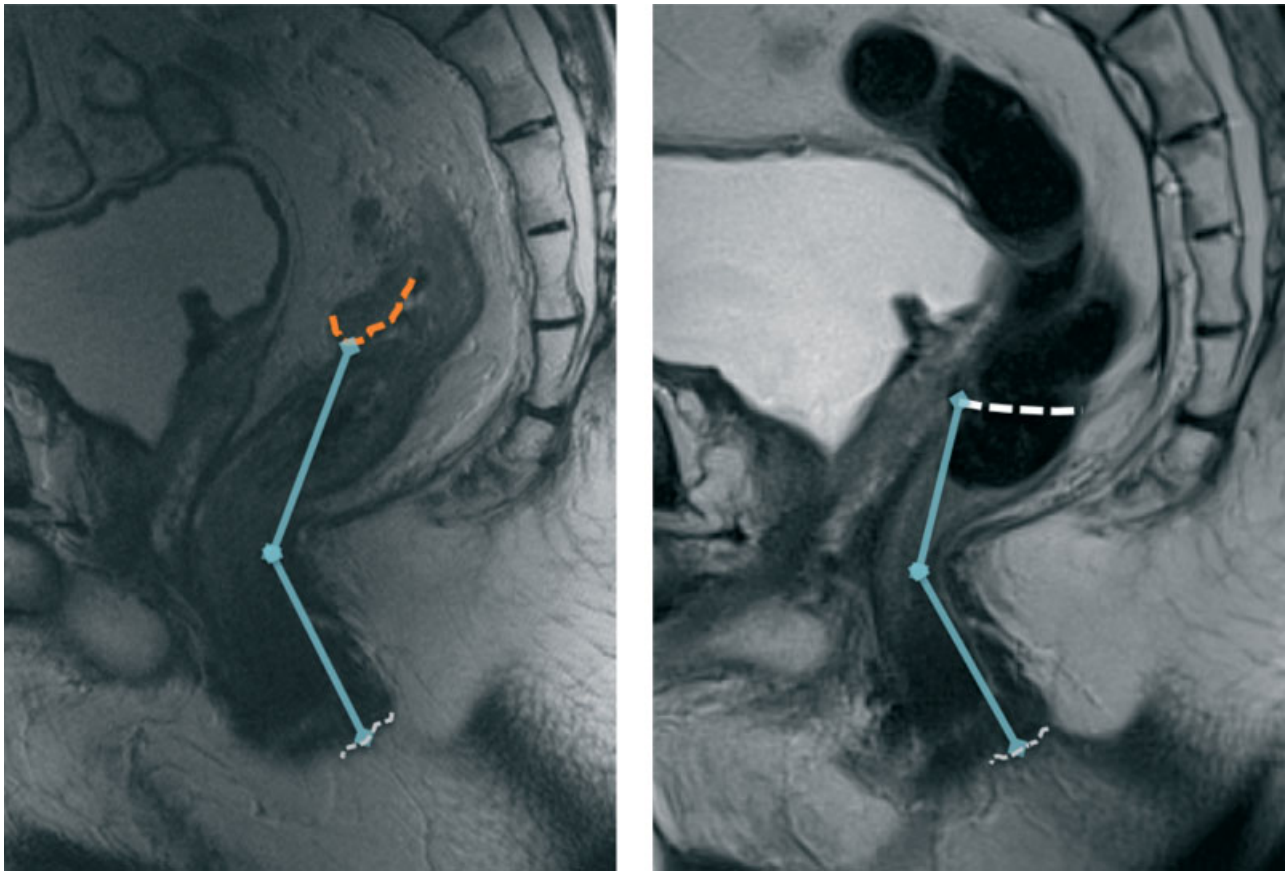


Fig. 4 Distal resection margin after partial mesorectal excision. **a** Preoperative sagittal T2-weighted magnetic resonance imaging (MRI) shows tumour located 9·8 cm from the anal verge. The orange line marks the distal border of the tumour. Rigid proctoscopy located the tumour 11 cm from the anal verge. **b** Postoperative MRI. Anastomosis located 8·5 cm from the anal verge. The white line marks the level of the anastomosis. For both images the grey line marks the level of the anal verge, and blue lines indicate the distance to the lower border of the primary tumour (**a**) and the level of the anastomosis (**b**)

advanced rectal cancers and locally recurrent rectal cancers in Denmark (population 5·5 million).

Patients

Patients with rectal adenocarcinoma (15 cm or less from the anal verge) who underwent partial mesorectal excision, total mesorectal excision or abdominoperineal resection from August 2007 to December 2010 were included in the study. The type of operation was determined from the surgical reports. Consecutive patients were invited for postoperative MRI of the pelvis. Patients with disseminated disease, previous diagnosis of local recurrence or macroscopic non-radical resection (R2), or who had died at identification, were not eligible. Additional exclusion criteria are shown in *Fig. 1*. All patients in the study underwent MRI at least 6 months from the date of operation to avoid confusion with postoperative changes.

Surgery

Partial mesorectal excision is advocated for the majority of tumours in the upper rectum (10·1–15 cm), with the rationale that this procedure has better functional outcomes while being as oncologically safe as total mesorectal excision[5–9]. The mesorectum is transected perpendicularly to the bowel a minimum of 5 cm below the tumour, ideally leaving hairpin 'sharp' edges with no coning of the mesorectum.

Total mesorectal excision involves dissection of the plane between the mesorectum and the parietal tissues, with complete removal of the mesorectum for

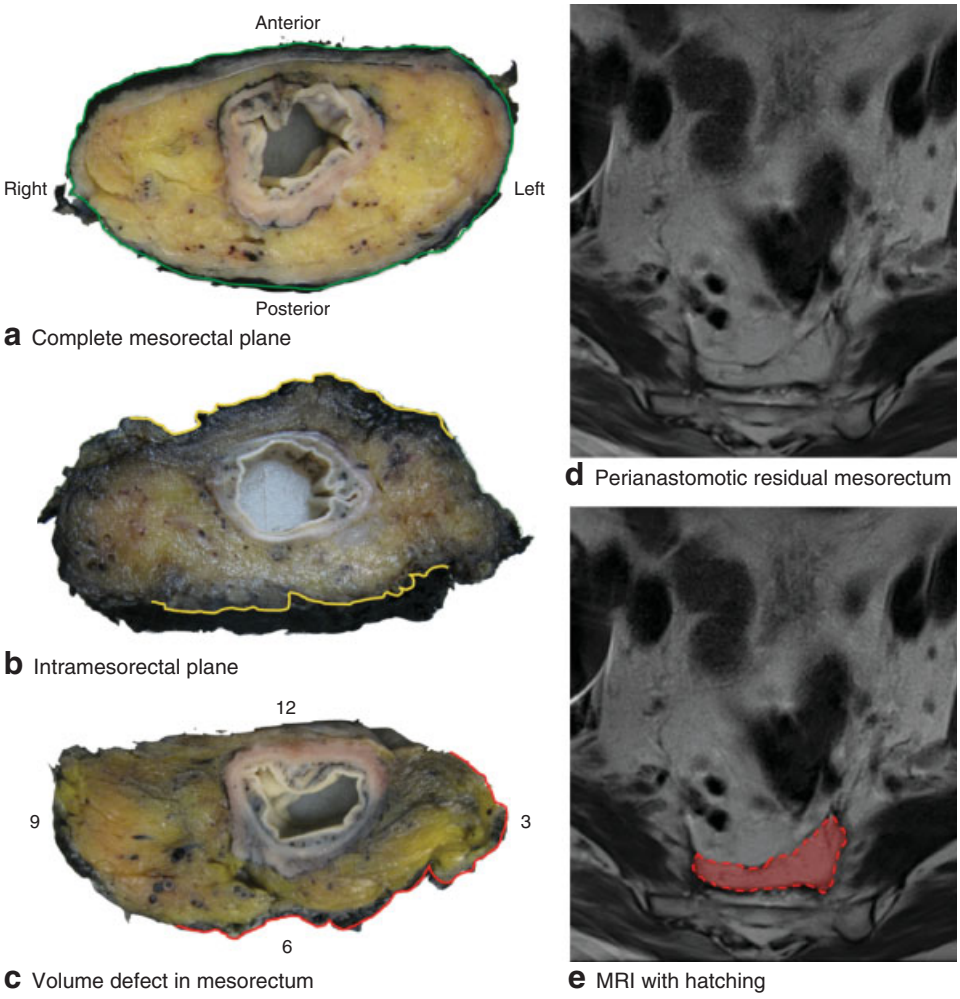


Fig. 5 Evaluation of mesorectal volume defects at pathology and correlation with magnetic resonance imaging (MRI) findings. The correlation between the localization of cranial and perianastomotic residual mesorectum and volume defects in the mesorectum at pathology was estimated by comparison of the areas as hours on a clock face. Findings with overlap in areas were regarded as in concordance. By definition, distal residual mesorectum following total mesorectal excision could not be recognized on pathological examination. **a** Complete mesorectal plane and no volume defect in the mesorectum. **b** Intramesorectal plane of surgery with no substantial volume defect in the mesorectum (yellow line). **c** Volume defect in mesorectum (2 to 7 o'clock; red line). **d,e** Axial T2-weighted images showing MRI-detected perianastomotic residual mesorectum after partial mesorectal excision in the area from 3 to 7 o'clock (hatched with red in **e**); same patient as in **c**

tumours of the mid-rectum (5·1–10 cm). Most low rectal tumours (lower than 5 cm) require an abdominoperineal resection.

Magnetic resonance imaging

MRI was performed using a Magnetom Avanto 1·5-Tesla MRI scanner (Siemens AG, Erlangen, Germany). Sagittal, axial and coronal T2-weighted turbo spin echo images were obtained in addition to a sagittal short T1 inversion recovery (STIR) image of the bony pelvis and a sagittal T2 three-dimensional sequence of the smaller pelvis. The radiologist was blinded to the pathological assessment and all clinical data, with the exception of preoperative MRI findings and type of surgery. The same multidisciplinary team radiologist evaluated all radiological examinations.

Magnetic resonance imaging-detected residual mesorectum

On postoperative MRI, mesorectal fatty tissue with a discernible tissue interface of fibrosis, which separates

Table 1 Demographic and clinical data

	No. of patients ($n = 296$)
Age (years)*	67 (32–93)
Sex ratio (M : F)	176 : 120
Distance of primary tumour from anal verge (cm)†	
10·1–15	107 (36·1)
5·1–10	100 (33·8)
0–5	89 (30·1)
Adjuvant therapy	
None	172 (58·1)
Long-course preop. radiochemotherapy	114 (38·5)
Short-course preop. radiotherapy	10 (3·4)
Operation	
Partial mesorectal excision	85 (28·7)
Total mesorectal excision	101 (34·1)
Abdominoperineal resection	110 (37·2)
CRM‡	
Negative	240 (81·1)
Positive	50 (16·9)
Missing	6 (2·0)
Tumour stage§	
pT0	20 (6·8)
pT1	17 (5·7)
pT2	57 (19·3)
pT3	151 (51·0)
pT4	48 (16·2)
Missing	3 (1·0)
Plane of surgery	
Muscularis propria	90 (30·4)
Intramesorectal	97 (32·8)
Mesorectal	99 (33·4)
Missing	10 (3·4)

Values in parentheses are percentages unless indicated otherwise; *values are median (range). †Measured by rigid proctoscopy; ‡positive if 1 mm or less; §based on pathological evaluation of excised specimen (the pathological tumour category for the 124 patients who had preoperative adjuvant therapy (ypT) was: T0, 16; T1, 5; T2, 21; T3, 62; T4, 20). CRM, circumferential resection margin.

the mesorectum from the mesocolon, was considered a sign of residual mesorectal tissue. Tissue fibrosis was differentiated from the mesorectal fascia as fibrosis typically has a lower signal on T2-weighted images, often seems more continuous, and may appear thicker than the mesorectal fascia.

Residual mesorectum was defined as any residual mesorectal tissue detectable after total mesorectal excision or abdominoperineal resection. Only mesorectum above the level of the anastomosis perpendicular to the bowel was regarded as inadvertent residual mesorectum following partial mesorectal excision. The localization of residual mesorectum was categorized in relation to height in the pelvis and position to the level of resection in a standardized manner dependent on the type of surgery performed (*Figs 2* and *3*).

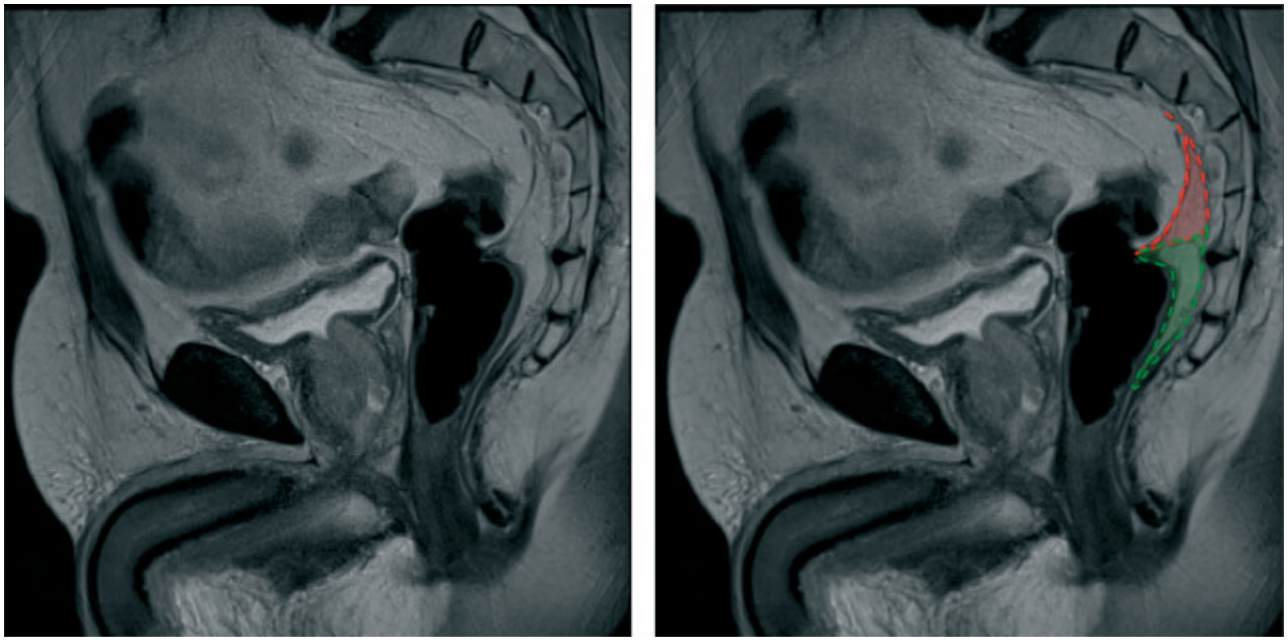
Table 2 Magnetic resonance imaging-detected residual mesorectum

	No. of patients ($n = 136$)	No residual mesorectum ($n = 82$)	Residual mesorectum ($n = 54$)	P¶
Sex ratio (M : F)	85 : 51	51 : 31	34 : 20	1·000
Distance of primary tumour from anal verge (cm)*				< 0·001
10·1–15	49	19 (39)	30 (61)	
5·1–10	51	34 (67)	17 (33)	
0–5	36	29 (81)	7 (19)	
Adjuvant therapy				0·102
None	92	50 (54)	42 (46)	
Long-course preop. radiochemotherapy	40	29 (72)	11 (28)	
Short-course preop. radiotherapy	4	3 (75)	1 (25)	
Operation				< 0·001
Partial mesorectal excision	46	17 (37)	29 (63)	
Total mesorectal excision	58	37 (64)	21 (36)	
Abdominoperineal resection‡	32	28 (87)	4 (13)	
CRM†				0·763
Negative	124	74 (60)	50 (40)	
Positive	12	8 (67)	4 (33)	
Pathological tumour category§				0·795
pT0	11	6 (55)	5 (45)	
pT1	11	5 (45)	6 (55)	
pT2	32	21 (66)	11 (34)	
pT3	65	39 (60)	26 (40)	
pT4	17	11 (65)	6 (35)	
Plane of surgery				0·328
Muscularis propria	33	18 (55)	15 (45)	
Intramesorectal	48	33 (69)	15 (31)	
Mesorectal	55	31 (56)	24 (44)	

Values in parentheses are percentages. *Measured by rigid proctoscopy; †positive if 1 mm or less; ‡20 extralevatory, eight intersphincteric, four standard operation; §based on pathological evaluation of excised specimen (the pathological tumour category for the 44 patients who had preoperative adjuvant therapy (ypT) was: T0, 6; T1, 3; T2, 11; T3, 20; T4, 4). CRM, circumferential resection margin. ¶Fisher's exact test.

Distal resection margin after partial mesorectal excision

The distal resection margin on MRI was calculated as the difference between the height of the anastomosis on postoperative MRI and the height of the lower border of the tumour on preoperative MRI. The height was measured from the lower border of the subcutaneous part of the external sphincter reflecting the anal verge (*Fig. 4*). The distance in the mesorectum from the lower border of the tumour to the pelvic floor was estimated. The distal resection margin on fixed specimens was



a Perianastomotic residual mesorectum **b** MRI with hatching

Fig. 6 Inadvertent residual mesorectum after partial mesorectal excision. **a,b** Sagittal T2-weighted images showing perianastomotic residual mesorectum above the level of the anastomosis (hatched with red in **b**). **b** Green zone shows intended residual mesorectum below the level of resection. MRI, magnetic resonance imaging

measured as the distance between the luminal border of the tumour and the distal resection of the bowel wall and mesorectum.

Pathology

The quality of the excised specimen was determined prospectively by the pathologist, according to the grading system classified by Quirke and colleagues[1,10] (mesorectal, intramesorectal and muscularis propria plane). The data were analysed with regard to the plane of surgery achieved, the CRM (positive CRM was defined as tumour or involved lymph node 1 mm or less from the lateral margin) and tumour characteristics according to the fifth edition of the tumour node metastasis (TNM) classification[11]. Fresh specimens were fixed for at least 24 h with formaldehyde followed by GEWF solution (glacial acetic acid, ethanol, distilled water and formaldehyde) for at least a further 24 h. The specimen was unpinned and unstretched. Non-peritonealized areas of the specimen were painted with ink.

Based on standardized photographic documentation, a trained multidisciplinary pathologist, blinded to the clinical data and MRI findings, evaluated the specimens retrospectively for possible volume defects in the mesorectum according to adequacy of the excision, smoothness of the specimen and infiltration of ink beneath the CRM (*Fig. 5*).

Local recurrence

Any infiltrative, expansive or asymmetrically located pelvic mass that could not be explained by normal anatomy or postoperative changes was referred for evaluation by the multidisciplinary team.

Statistical analysis

χ^2 statistics and Fisher's exact test were used for comparison of proportions. The exact agreement between the pathological and MRI evaluations was calculated[12]. Stata® version 11 (StataCorp LP, College Station, Texas, USA) was used for statistical analysis.

Results

A total of 296 patients were treated surgically with partial mesorectal excision, total mesorectal excision or abdominoperineal resection for primary rectal adenocarcinoma between August 2007 and December 2010 (*Table 1*). A total of 136 patients had postoperative MRI (*Fig. 1*).

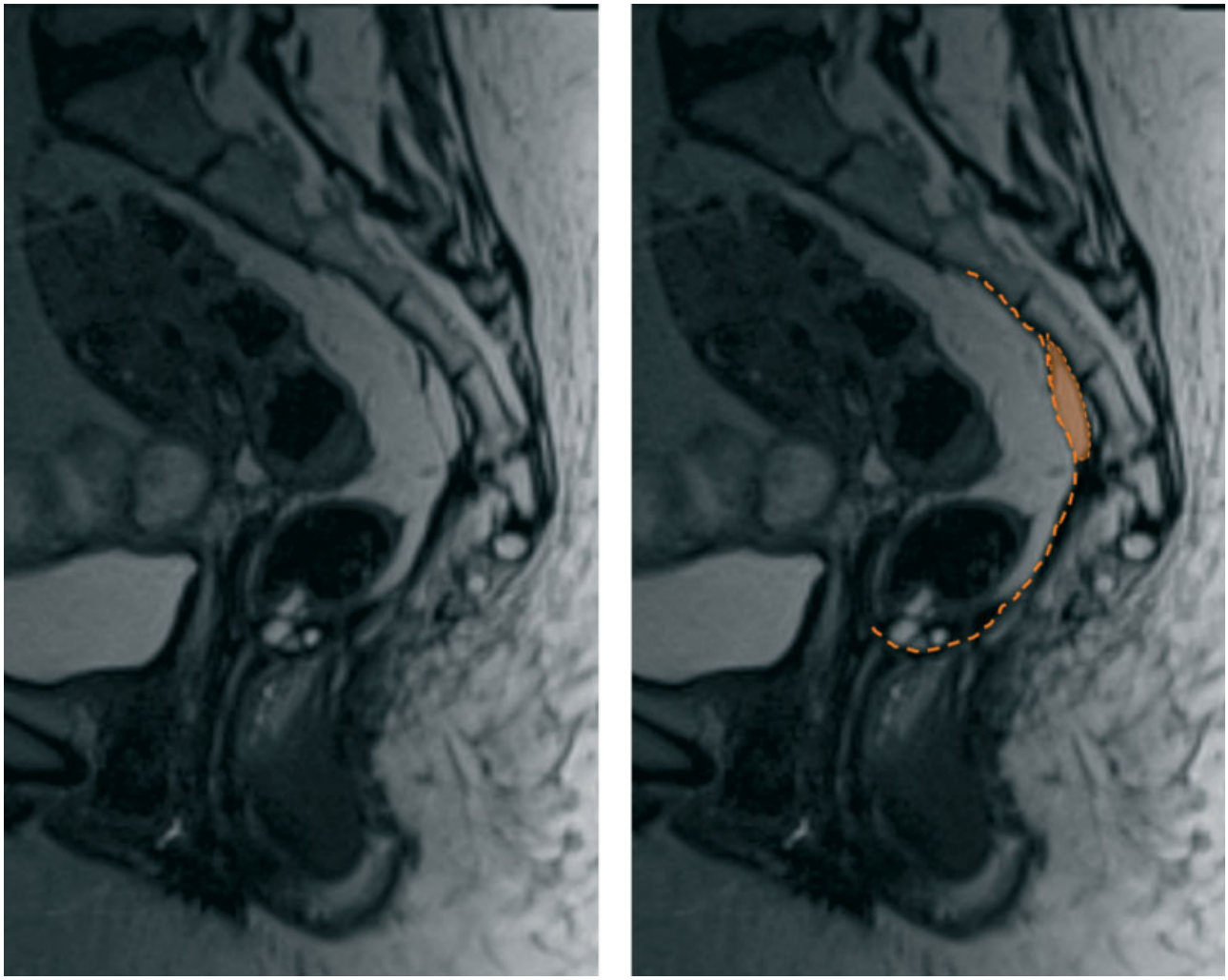


Fig. 7 Residual mesorectum after total mesorectal excision. **a,b** Sagittal T2-weighted images show cranial residual mesorectum (hatched with orange in **b**). Inclusion cysts are seen in relation to the anastomosis. MRI, magnetic resonance imaging

Residual mesorectum

Inadvertent residual mesorectum was identified in 54 (39·7 per cent) of the 136 patients. The plane of surgery achieved, tumour stage, radicality of the resection, adjuvant treatment and sex did not correlate with evidence of inadvertent residual mesorectum (*Table 2*).

Inadvertent residual mesorectum was apparent in 29 (63 per cent) of 46 patients who had partial mesorectal excision; all of these were categorized as perianastomotic mesorectum (*Fig. 6*). Following total mesorectal excision, 21 (36 per cent) of the 58 patients demonstrated residual mesorectum in 30 different locations: eight cranial (*Fig. 7*), ten perianastomotic and 12 distal (*Fig. 8*). Cranial residual mesorectum was identified in four (13 per cent) of the 32 patients who had an abdominoperineal resection.

Distal resection margin after partial mesorectal excision

The distal resection margin was estimated by MRI and measured by prospective histopathological assessment (*Fig. 9*). As measured by MRI, 80 per cent of partial mesorectal excisions (35 of 44) had less than 5 cm of distal margin and 52 per cent (23 of 44) had less than 3 cm. The pathological assessments reported a distal resection margin of less than 5 cm in 89 per cent (41 of 46)

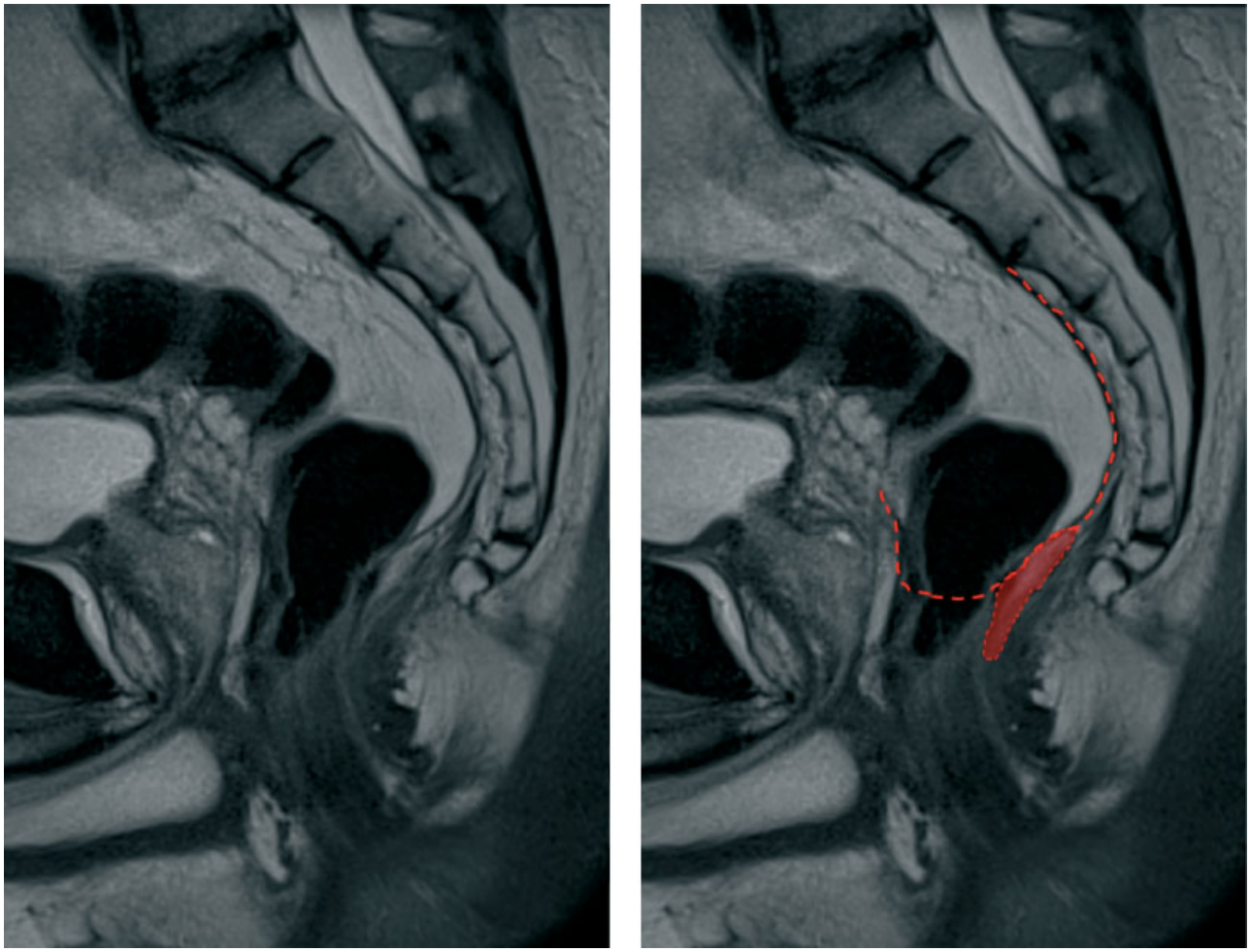


Fig. 8 Residual mesorectum after total mesorectal excision. **a,b** Sagittal T2-weighted images show distal and perianastomotic residual mesorectum below the level of resection (hatched with red in **b**). MRI, magnetic resonance imaging

and less than 3 cm in 37 per cent (17 of 46) of partial mesorectal excisions. The difference between margin lengths measured by MRI and pathological assessment ranged from a minimum of −23 mm to a maximum of +44 mm (mean −0·25 mm) ($P = 0{\cdot}908$) and good correlation ($\kappa = 0{\cdot}62$). In two patients, the distal resection margin was not estimated by MRI because the primary tumour was not visible on preoperative MRI and the level of anastomosis on the postoperative MRI could not be located adequately.

Tumour height and partial mesorectal excision

As measured by MRI, 12 (26 per cent) of 46 patients had partial mesorectal excision for tumours located in the mid-rectum (5·1–10 cm from the anal verge). The distance in the mesorectum on MRI between the distal edge of the tumour and the pelvic floor was less than 5 cm in 28 patients (61 per cent).

Pathology and magnetic resonance imaging

Discernible volume defects in the mesorectum, when re-evaluated by the pathologist on standardized photographic documentation, were present in 74 (54·4 per cent) of 136 specimens. Twenty-three (42 per cent) of 55 specimens with observable volume defects in the mesorectum were initially graded by the prospective pathological evaluation to have achieved a mesorectal plane of surgery.

Volume defects in the mesorectum estimated by retrospective evaluation were visible in 24 (52 per cent) of 46 patients after partial mesorectal excision and in 31

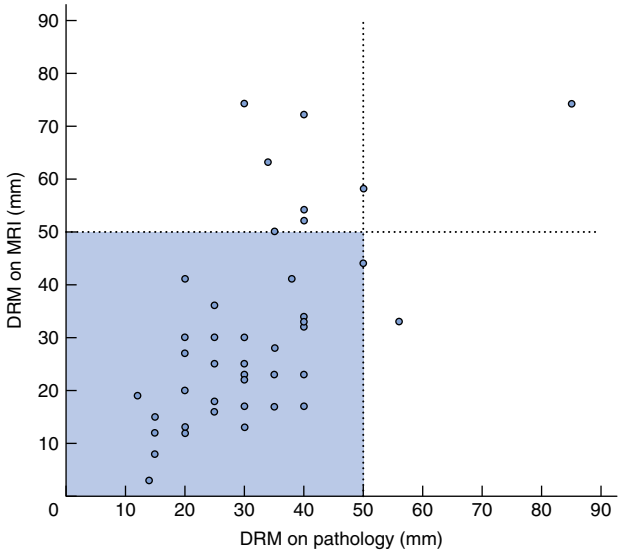


Fig. 9 Distal resection margin (DRM) following partial mesorectal excision, as estimated by magnetic resonance imaging (MRI) and measured by the pathologist on the fixed specimen. Shaded area indicates distal margin of less than 5 cm on both MRI and pathological assessment

(53 per cent) of 58 after total mesorectal excision, whereas the proportion for abdominoperineal resection was 59 per cent (19 of 32). Exact agreement between the findings of residual mesorectum on MRI and mesorectal volume defects in the specimens was found in 88 (64·7 per cent) of the 136 patients ($\kappa = 0{\cdot}32$).

In patients with both MRI-detected residual mesorectum and mesorectal volume defect on pathological examination, overlap between the areas was present in 69 per cent (25 of 36). In patients with perianastomotic residual mesorectum after partial mesorectal excision, 74 per cent (14 of 19) had a mesorectal volume defect in the two posterior quadrants at pathology (3 to 9 o'clock areas).

Local recurrence

Postoperative MRI was performed a median of 17 (range 6–29) months after surgery. In seven patients a previously undiagnosed local recurrence was suspected on MRI. Of these, two were discounted after further examination. Two of the patients with verified local recurrence were treated primarily with total mesorectal excision, but no residual mesorectum was noted on MRI. Perianastomotic residual mesorectum was identified in two of the three patients who developed local recurrence after partial mesorectal excision. All three had an insufficient distal resection margin.

Discussion

This study has demonstrated that the extent and completeness of mesorectal excision can be assessed by postoperative MRI. Patients with macroscopic non-radical resection and those with local recurrence of disease were excluded, and this may have excluded the patients who were more likely to have residual mesorectum. Thus, the data reported here may underestimate the prevalence of inadvertent residual mesorectum in the total population, as CRM-positive resections were found in 16·9 per cent of the 296 patients, and a mesorectal plane of surgery was achieved in only 33·4 per cent of these.

Postoperative MRI and CT findings were analysed by Syk and co-workers[4] in 99 patients with local recurrence after primary resection for rectal cancer. Visible residual mesorectal fat was found in 51 per cent of the total population and in 74 per cent of patients with primary tumours located in the upper two-thirds of the rectum.

Perianastomotic residual mesorectum was the most prevalent type in the present study and may indicate coning of the mesorectum. Coning refers to dissection performed inwards from the mesorectal plane during distal resection and is a consequence of the difficulty of performing a perpendicular transection in the bowel and mesorectum.

By definition, total mesorectal excision involves complete removal of the mesorectum, yet there was distal residual mesorectum in 21 per cent (12 of 58 patients) as a result of incomplete distal resection. As expected, there were few occurrences of residual mesorectum following abdominoperineal resection.

The results reported here demonstrate a discrepancy in the assessments made by pathological examination and MRI. From the retrospective evaluation of the standardized photographic documentation, volume defects were described in 42 per cent of the specimens initially judged to have been performed in the mesorectal plane of surgery. Overestimation of volume defects due to anatomical variations may be a problem for pathologists, as the morphology of the mesorectum differs between patients[13]. Moreover, the value of pathological grading of residual mesorectal tissue has limitations, as the pathologist can grade the specimen only according to the tissue removed at surgery. Clearly, the accuracy of pathology as the standard in quality assessment of rectal cancer is dependent on standardization of the method and requisite guidelines for pathological examination, together with thoroughness in the sampling process and in the number of tissue blocks analysed.

The finding of residual mesorectum on postoperative MRI was not related to the plane of surgery achieved,

which may in part be explained by the difference in the parameters graded. An intramesorectal or muscularis propria plane can be determined due to even relatively small defects or cuts, but may not highlight larger volume defects in the mesorectum and may not be detectable on MRI. Direct correlation between MRI and pathological assessments may be unmatched, as these methods grade according to the residual mesorectum and the specimen removed at surgery respectively. A correlation between the area of volume defect in the mesorectum and MRI-detected residual mesorectum would strengthen the validity of the assessment by MRI. However, it can be difficult to compare these areas with accuracy, as the specimen often rotates during fixation and slicing, resulting in differences of 2–3 'hours' in terms of orientation. The aim of this study from the outset was to assess the completeness of the mesorectal excision performed by MRI. However, the findings indicate that there is a need for quality assessment of pathology evaluations as well.

Discontinuous mesorectal deposits from the primary tumour arise in 12–24 per cent of specimens, for which 5 cm in a fixed specimen is the furthest extent reported to date[14–18]. In the present study, several partial mesorectal excisions had a distal margin of less than 5 cm, indicating a discrepancy between the guidelines and the actual surgery performed. Thus, guidelines based on fixed specimens may not be appropriate to determine adequate operative margins. Japanese guidelines recommend a 3-cm margin for upper rectal cancer, but Komori *et al.*[17] have described a distal spread of 36·3 mm after fixation. Many studies do not specify how the margin length was determined; some pathologists measure a fixed unpinned stretched specimen, some measure the specimen after fixation and pinning, and others measure the fresh specimen only.

Currently, type of surgery is determined by the tumour height in the rectum. The present authors observed that the exact height of the lower border of the primary tumour differs between measurements made by rigid proctoscopy and MRI to such a degree that it may have clinical implications. In 26 per cent of patients treated with partial mesorectal excision the primary tumour was located in the mid-rectum according to MRI, for which total mesorectal excision would be required. MRI can be used to supplement the preoperative workup further, as it offers information on the topography and tumour relations in the pelvis, such as the height of the peritoneal reflection and the distance from the primary tumour to the pelvic floor[19].

Based on the present evidence, the recommendation to perform partial mesorectal excision for more advanced and high-risk tumours of the upper rectum may be questioned. The most common location for local recurrence after primary rectal cancer of the upper two-thirds of the rectum is at the anastomosis[4,20], which could be due to residual mesorectum. Moreover, omission of radiotherapy for tumours of the upper rectum may be a risk for local recurrence.

Acknowledgements

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Disclosure: The authors declare no conflict of interest.

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