Objective: Our goal was assessment of the preoperative staging of rectal carcinoma with MR with double surface coil, MR with endorectal coil, and intrarectal ultrasound (IUS) as correlated with histopathologic findings.

Materials and Methods: Fifteen patients with rectal carcinoma had preoperative evaluation using intrarectal ultrasound (all 15 patients), MR with double surface coil alone (6 patients), and MR with double surface coil combined with endorectal surface coil (9 patients). The results of the preoperative staging were correlated with the histopathologic findings.

Results: IUS correctly staged the depth of bowel wall invasion in 10 of 15 patients, understaged 4, and overstaged 1. MRI correctly staged 10 of 15 patients. Without the endorectal surface coil, three of six were correct, and with endorectal surface coil seven of nine. MR with the endorectal surface coil is able to show the rectal wall in more detail than the double surface coil.

Conclusion: Endorectal surface coil MRI provides increased detail of the rectal wall, leading to better delineation of its different layers. This may lead to better staging results than with other MR techniques. The results with endorectal MRI probably equal those of IUS for staging small tumors in the rectal wall. MR with the double surface coil gives additional information about tumor spread in more advanced cases.

Index Terms: Ultrasound—Rectum, neoplasms—Colon, neoplasms—Surface coil—Cancer, staging—Magnetic resonance imaging.
double surface coil alone and nine patients had MRI with double surface coil plus additional imaging with an endorectal surface coil.

Fourteen patients had a resection, 10 an abdominopeneral resection, and 4 a low anterior resection. One patient died shortly after radiotherapy was started, and autopsy results are used as comparison.

After normal fixation, the surgical specimen was sliced in a transverse plane with sections every 0.5 cm through the whole tumor. Hematoxylin–eosin staining was used in all cases.

IUS was performed in all cases by one experienced radiologist/sonologist. The MR studies were performed 1 or 2 days before the operation. MR studies were read by an experienced MR radiologist and three gastrointestinal radiologists and by the sonologist. The combined MR studies with double surface and endorectal surface coil (nine patients) were interpreted as one study. The interpreters reached consensus in every case.

Reading the MR and IUS images included the identification of the layers of the rectal wall, image quality, and recognition of a disruption and irregularity especially at the nonluminal site of the rectal wall. The depth of tumor infiltration assessed with IUS and MR was related to the pathologic TNM classification: T1 = tumor invades submucosa, T2 = tumor invades muscularis propria, T3 = tumor penetrates rectal wall into perirectal fat, and T4 = tumor invades adjacent organs or structures. For IUS the interpretation of layers by Boscaini and Montori (7) was used. We do not accept the fifth echogenic layer described by other authors (8) for discrimination between T2 and T3 lesions. All visible lymph nodes were noted as N1 in the perirectal area. Besides the characteristics mentioned, no special data format was used. The image interpretations were correlated with the histopathologic findings.

Imaging Protocols

All patients underwent IUS with a biplane linear and sector array 5 MHz probe (Toshiba Medical Systems Europe, Zoetermeer, the Netherlands) and all studies were performed by one radiologist. The US study was performed in the left lateral decubitus position. One hour before the study, a cleansing enema was given. The US probe was covered with a latex sheath that was filled with water to optimize US transmission to the bowel wall. Optimal images required visualization of the five layers of the rectal wall. This was achieved with the linear array transducer of the biplane probe. In one case the sector transducer was used to visualize the tumor that was located at the rectosigmoidal junction.

All 15 patients underwent an MR examination of the rectum. MRI with a Helmholtz double surface coil was performed in 6 of the 15 patients on a 1.5 T MR system (Philips Medical Systems Europe, Best, the Netherlands). Straps were placed over the lower abdomen and pelvis to help reduce respiratory artifacts. Motion artifacts due to peristalsis were reduced by giving all patients 0.5 ml glucagon i.v. and 1.5 ml glucagon i.m immediately before the examination. The T1-weighted SE images were obtained in the axial and sagittal plane using a TE of 35 ms and a TR of 350 ms. Matrix size was 256 x 256 and the FOV was 350 mm. In some patients, images were obtained in the coronal plane. Proton-density and T2-weighted transverse images were obtained with a SE multislice technique (SE TR 2,000/TE 100) and one data acquisition. Section thickness used in both sequences ranged from 6 to 10 mm with no interslice gap. The study was performed after a routine cleansing of the rectum with a water enema. Patients were placed in a supine position; in some cases, the rectum was additionally filled with air by insufflation via a barium enema tip.

Nine of the 15 patients had MRI with the double surface coil and with an additional examination that employed an endorectal surface coil. These studies were performed on a 1.5 T unit (Magnetom SP; Siemens Medical Systems Europe, Erlangen, Germany). Patient preparation was the same as in the first group. The study started with the double surface Helmholz coil and a 3D MP-RAGE image of the whole pelvis. This sequence provided an overview of the whole pelvis to detect not only perirectal lymph nodes but also more distant lymph nodes. This technique has been described before (9). Then the double surface coil was replaced for the endorectal colon surface coil (Medrad, Pittsburgh, PA, U.S.A.), which by its shape differs from the endorectal prostate coil in that it is more rounded and does not have the preshaped concavity for the prostate (10). All patients were imaged in the supine position. A sagittal localizing image was obtained to select axial locations. Axial and sagittal T1 (TR 420/TE 22) images with 4 or 5 mm section thickness, a 1 mm gap, 26 cm FOV, a 192 x 256 matrix, and two acquisitions resulted in an imaging time of 2.44 min. For T2-weighted images in the axial and sagittal plane, a FLASH 2D sequence (TR 510/TE 12, 15° flip angle, three acquisitions, FOV 200, matrix 256 x 256, acquisition time 6.30 min) and a turbo spin echo (TSE) sequence were used (TR 2,940/TE 160, three acquisitions, matrix 260 x 512, FOV 260, acquisition time 6.00 min).

RESULTS

At pathologic examination five patients had tumor confined to the rectal wall and nine had perirectal spread or involvement of adjacent organs. In

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TABLE 1. Staging rectal carcinoma: results of three applied techniques

<table>
<thead>
<tr>
<th></th>
<th>No. of patients</th>
<th>Correct stage</th>
<th>Image qualitya</th>
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<tr>
<td></td>
<td></td>
<td>1  2  3 4</td>
<td></td>
</tr>
<tr>
<td>IUS</td>
<td>15</td>
<td>10</td>
<td>12 1 — 2</td>
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<tr>
<td>MR with double</td>
<td>6</td>
<td>3</td>
<td>— 6 — —</td>
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<tr>
<td>surface coil</td>
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<tr>
<td>MR with double</td>
<td>9</td>
<td>7</td>
<td>5 3 — 1</td>
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<tr>
<td>surface and</td>
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<tr>
<td>endorectal coil</td>
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* For explanation, see text.

one patient no resection was undertaken because the tumor proved to be nonresectable due to severe fibrosis and/or large tumor extent. This patient died shortly after radiotherapy was started and autopsy results are used as reference.

The results are summarized in Table 1. In the comparative group, IUS versus MR without endorectal surface coil, IUS performed better than MR in two cases, MR was better than US in one case, and they were equal in three cases. In the comparative group, IUS versus endorectal MR, IUS performed better in three cases (Fig. 1), MR was better in two cases, and in four cases they were equal. On MRI with the endorectal coil, the rectal wall was displayed in five layers on the T2-weighted images (Figs. 1 and 2). These five layers consisted of an inner layer of high signal intensity, a layer of low signal intensity, a middle layer of high signal intensity, a second layer of low signal intensity, and an outer layer of high signal intensity. The tumor was displayed as an isointense mass compared to the rectal wall on T1- and was hyperintense on T2-weighted images especially compared with the hypointense outer layer of the rectal wall (Figs. 1 and 2).

In an attempt to classify the images on a quality scale, all the MR and US studies were reviewed. A subjective performance scale was applied for both modalities: 1 = excellent image. The rectal wall layers are visible in at least more than half of the circumference of the bowel wall. 2 = good image. Slight artifacts but they do not interfere with staging. The rectal wall layers are not seen or just slightly (Fig. 3). 3 = poor image. Severe artifacts interfere with tumor staging. Signal noise prevents visibility of rectal wall layers. 4 = incomplete and insufficient images. Due to artifacts or bad position of the probe or coil, only part of the tumor is visualized and can be evaluated. This classification resulted in 11 excellent IUS studies that were correct in 10 and 5 excellent MR images, all with the endorectal surface coil, which were all correct (Table 1).

DISCUSSION

The prognosis of rectal carcinoma is poor. Despite advances in surgical technique, it has not changed in the last decades (11). Patients who have a rectal carcinoma with a low potential to develop pelvic recurrence would benefit from local therapy (12,13), whereas patients with unfavorable tumors in a more advanced stage could benefit from preoperative radiotherapy (2,4). Improved accuracy in preoperative staging would allow preoperative radiotherapy to be administered only to those patients with deeply invading lesions and permitting sphincter-saving surgery in other cases with superficial small carcinomas. Radiologic modalities that have been used in staging of rectal carcinoma include CT, MRI, and IUS.

Staging Local Disease

The accuracy of staging the local extent of carcinoma by CT is reported to be between 60 and 70% (14,15). Shank et al. (16) concluded that CT scan-
STAGING RECTAL CA WITH MRI AND IUS

2a,b

2c,d

2e

FIG. 2. a: MR with double surface coil, SE T2-weighted image. High signal intensity mass in the low signal intensity of lower rectum and anal canal (arrows). b: MRI with endorectal surface coil, SE T2-weighted image. Right-sided mass (m) in the rectum invading the muscular low intensity layer of the rectal wall (arrowheads). No invasion of the perirectal fat. c: IUS, longitudinal (sagittal) view. Partially ulcerating (u) tumor (t) in the right lateral side of the rectal wall. Muscularis (arrow) is invaded; no delineation possible with the internal anal sphincter (is). External sphincter (es) is not infiltrated. d: Specimen stained with hematoxylin–eosin depicts a superficially growing adenocarcinoma (straight arrow) extending in the muscular layer (small arrows). The transition between rectal mucosa and anal canal is seen by the curved arrow. The internal sphincter is not invaded by the tumor. e: Same specimen, transverse section like the MR sections. The carcinoma is extending into the muscular layer (arrows).

Ning of primary rectal carcinoma should not be relied upon for staging or for the selection of patients for treatment options.

Until recently there have been few articles published about the use of MRI to stage rectal carcinoma (6,10,11,17-23). These studies can be divided into those that use a body coil (17-22), a Helmholtz double surface coil (11), or the endorectal surface coil (6,10). In Table 2 results of staging are listed. The reported accuracy ranges from 59 to 100% for staging perirectal invasion. With optimal body coil MR technique, MR images would be equal to CT in staging local disease (17,19) and by applying (double) surface coils slightly better (11).

Preliminary work done by Imai et al. (24) showed that with a dedicated endorectal surface coil, the histologic layers could be visualized in vitro. This has been confirmed in vivo studies by the group of Chan and Schnall and co-workers (6,10), resulting in images of the rectal wall that were comparable with those seen on IUS and with comparable staging results (accuracy 81%). IUS staging is based on the recognition of the five layers of the rectal wall composed by interfaces and real histologic layers. The fourth low echogenic layer represents the muscular layer, and staging of local extent is based mainly on the identification of this layer and infiltration of tumors through it. The reported accuracy...
FIG. 3. a: IUS of a rectal carcinoma, sagittal view. Centrally the tumor is invading the perirectal fat (arrow). b: 3D MP-RAGE with double surface coil. The tumor is invading the perirectal fat at the same site as seen on IUS (arrow). Different layers cannot be differentiated. c: Endorectal MRI. Severe motion artifacts (arrowheads) on a SE T1-weighted image show identical image as in (a) and (b) of the tumor infiltration (arrow). Because of pain, patient could not sustain a TSE T2-weighted image.

of IUS ranges from 64 to 94% (8,25–30), and IUS is currently regarded the best imaging modality for staging local disease (5). A major drawback of IUS is overstaging due to inflammatory changes around the tumor that cannot be differentiated from malignancy (8). With endorectal MR, however, this problem has not been solved either (6). The fact that in endorectal surface coil MRI the five layers are not constantly seen (6), which is confirmed in our study, also limits its potential.

For planning surgical procedures in advanced cases, MRI is superior to IUS in displaying the real extent of the mass in the pelvis (31,32). Due to the limited view of IUS and endorectal coil MRI, these methods are not really needed in these cases (6). In the present study, MR performed better than IUS in

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Year</th>
<th>MR coil</th>
<th>n</th>
<th>Accuracy of T staging (%)</th>
<th>Accuracy of N staging (%)</th>
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<td>Butch et al.</td>
<td>1986</td>
<td>Body</td>
<td>11</td>
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<td>Küper et al.</td>
<td>1985</td>
<td>Body</td>
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<td>27</td>
<td>59</td>
<td>39</td>
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<td>de Lange et al.</td>
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<td>29</td>
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<td>78</td>
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<td>Ou (20)</td>
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<td>Body</td>
<td>35</td>
<td>74</td>
<td>74</td>
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<tr>
<td>Okizuka et al.</td>
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<td>Body</td>
<td>25</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Okizuka et al.</td>
<td>1993</td>
<td>Body</td>
<td>33</td>
<td>79</td>
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<td>With intrarectal balloon</td>
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<tr>
<td>Chan et al.</td>
<td>1991</td>
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<td>100</td>
<td>57</td>
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<tr>
<td>Guinet et al.</td>
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<td>Body</td>
<td>19</td>
<td>sens 75</td>
<td>sens 40</td>
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<td>Schnärl et al.</td>
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<td>36</td>
<td>81</td>
<td>78</td>
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four cases. In all these cases, a large tumor was studied in which the capability of MR to show more of the surrounding tissues than IUS was responsible for the better staging results.

**Lymph Node Metastases**

Endorectal surface coil MRI and IUS are both suitable for depicting perirectal lymph nodes as small as 2–3 mm in diameter. The perirectal nodes found in three patients were inflammatory and ranged in size from 3 to 5 mm. The metastatic lymph nodes in the mesosigmoid and iliac area in three cases, however, are not depicted with both methods.

Differentiation of inflammatory nodes from metastatic nodes is difficult in both endorectal surface coil MRI (6) and IUS studies (33). The application of size criteria to assess the status of perirectal adenopathy would improve specificity but reduce sensitivity (6,34). Because it is important that no patient with N1 disease be untreated, we believe it is best to maintain a high sensitivity.

In contrast to endorectal surface coil MRI, IUS is well tolerated by the patients and artifacts are easily recognized. Movement and motility during a real-time IUS study are not disturbing but indicative of fixation and ingrowth to adjacent organs. The transducer can easily be placed in the optimal position on the tumor. The endorectal surface coil tends to migrate and sometimes repositioning is needed, thus prolonging study time.

The patients in our study complained of pain and discomfort during the MR study with the endorectal coil. This resulted in three studies with more or less serious artifacts due to motion of the patient (Fig. 3).

**SUMMARY**

Endorectal surface coil MR gives improved images of the rectal wall showing five different histologic layers on T2-weighted images. It has the potential to give the same information as IUS. However, the endorectal MRI technique is uncomfortable for the patient and does not add any more information than provided by a more comfortable, shorter IUS study. MR with the double surface Helmholtz coil gives additional information about tumor spread in more advanced cases. Detection of regional lymph node metastasis is still unreliable with both techniques.

**REFERENCES**


