considered necessary. Exclusion criteria for LS were tumors larger than 6 cm, a history of extensive adhesions, severe obesity (body mass index >32 kg/m^2), intestinal obstruction, and refusal to undergo LS. The preoperative workup consisted of a clinical investigation, barium enema, total colonoscopy, chest x-ray, abdominal ultrasonography, and computed tomography.

LS was contraindicated for patients with preoperative diagnoses of T3 and T4 tumors in the middle and lower rectum because, with the current instrumentation, it was difficult to perform laparoscopic procedures without grasping and manipulating the bowel or mesorectum near the tumor; our concern was that this would result in accidental tumor spillage. Furthermore, lateral lymph node dissection combined with total mesorectal excision remains the standard surgical procedure for patients with T3 and T4 lower rectal carcinoma in Japan, and lateral lymph node dissection by laparoscopy is still an unexplored frontier.[14–16] As a result, some patients were found to have T3 cancer only after histopathological examination of the surgical specimens. Preoperative or postoperative radiation therapy was not performed in this series because of the low local recurrence rate in patients with T1–T3 lower rectal carcinoma without preoperative radiation.[14,16]

Patients were divided into 3 groups: sigmoid colon/rectosigmoid carcinoma, upper rectal carcinoma, and middle/lower rectal carcinoma. For the patients with rectal carcinoma, a primary rectal carcinoma was defined according to its distance from the anal verge as determined by colonoscopy. The tumors were grouped into lower rectum (0–7 cm), middle rectum (7.1–12 cm), and upper rectum (12.1–17 cm). We combined patients with middle and lower rectal carcinoma as a group because laparoscopic techniques for rectal transection and DST anastomosis were almost same: anastomosis located below peritoneal reflection.[7] Patients with lesions located within 2 cm of the dentate line who underwent laparoscopic intersphincteric rectal resection and hand-sewn coloanal anastomosis were excluded from the present study. This surgical technique has been described previously.[17] Conversion to open surgery was defined as any incision greater than 7 cm, excluding cases in which the incision was enlarged due to a large specimen size that could not be removed with a 7-cm incision.

Laparoscopic Technique

Laparoscopic resection techniques have previously been described, with minor modifications.[7,17] Initial port placement was performed using the open technique, and pneumoperitoneum was induced using carbon dioxide. Two 5-mm ports were then inserted in the left lower midabdominal and the left lower quadrant regions, and 2 other 12-mm ports were inserted in the mid-lower and the right midabdominal regions under laparoscopic guidance.

The left colon was initially mobilized laterally to medially until the left ureter and superior hypogastric nerve plexus were identified. The mobilization of splenic flexure was performed if necessary. Usually, Japanese patients have a long sigmoid colon, and if the surgeon preserves 1 or 2 arcades of marginal vessels of sigmoid colon by division of sigmoidal arteries between superior rectal artery and marginal vessels, mobilization of splenic flexure becomes unnecessary; thus, splenic mobilization was performed in only about 20% of our patients. Then, a window was made between the mesocolon containing the arch of the inferior mesenteric vessels and the superior hypogastric nerve plexus, starting at the bifurcation, with support from an assistant holding the sigmoid mesocolon ventrally under traction and to the left using a 5-mm bowel grasper through the left lower quadrant port. After the dissection, proceeding to the origin of inferior mesenteric artery, taking care not to injure the superior hypogastric nerve plexus and the roots of the sympathetic nerves, intracorporeal high ligation of the inferior mesenteric artery was performed. After cutting the inferior mesenteric vein and left colic artery, mobilization of the rectum and mesorectum was performed. The avascular plane between the intact mesorectum anteriorly and the superior hypogastric nerve plexus, right and left hypogastric nerves, and Waldeyer fascia posteriorly was entered by sharp dissection and extended down to the level of the levator muscle for middle and lower rectal carcinomas, taking care to protect the pelvic nerves. For proximal sigmoid colon carcinoma, the mesentery at the promontory was excised routinely using ultrasonic shears (laparoscopic coagulating shears [LCS], Ethicon Endo-Surgery Inc, Cincinnati, OH) or an endolinear stapler (Endo GIA Universal, Tyco Healthcare, Auto Suture Co, US Surgical Corp, Norwalk, CT). For rectosigmoidal and upper rectal lesions, mesorectal tissue extending down to 5 cm below the tumor was excised routinely using LCS. Middle and lower rectal tumors were treated by total mesorectal excision. Immediately before rectal transection, laparoscopic rectal clamping was performed just above the anticipated point of rectal transection, using a bowel clamping device (Fig. 1) introduced through the 12-mm mid-lower port. A distinct advantage of this device is that the bowel clamp at the head of the device can be easily bent intraabdominally without reducing the grasping strength. Rectal washout was performed routinely using 1000 mL of a 5% povidone-iodine solution. Rectal transection was then performed by a multiple-firing technique, using Endo GIA Universal staples, introduced through the 12-mm right midabdominal port.[18] If the rectal transection was not completed after the first cartridge, the stapler line for the second cartridge was carefully positioned on the anal side stapler line of the first cartridge. The third and fourth firings were performed in the same way. A 4- to 5-cm incision was then made over the mid-lower 12-mm port site, and the bowel was exteriorized under wound protection and divided with appropriate proximal clearance. After inserting the anvil head of the circular stapler into the end of the proximal colon, the proximal colon was internalized and the incision was closed. Intracorporeal anastomosis under a laparoscopic view was performed by means of the DST, using a circular stapler (ECS 29 or 33 mm, Ethicon Endo-Surgery Inc). After the insertion of the body of the circular stapler into the anus, the puncturing cone was pushed through the midpoint of the linear staple line. In patients in whom 2 or more linear stapler cartridges were used for rectal transection, the puncturing cone was pushed near the crossing point of the first and second stapler lines.

The anastomotic air leakage test was performed if the "doughnuts" were incomplete. Patients with a low anastomosis within 1 cm from the dentate line and incomplete doughnuts

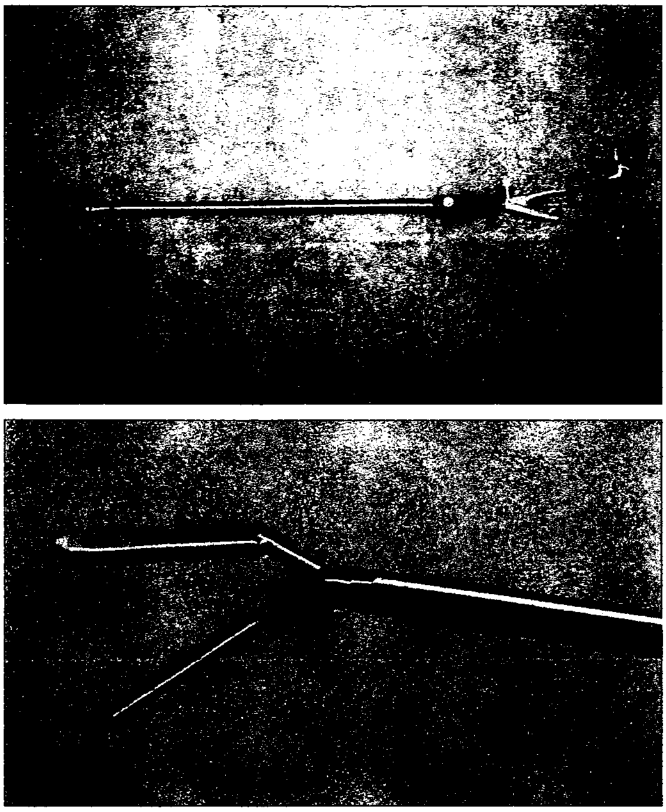

FIGURE 1. Bowel clamping device. A distinct advantage of this device is that the bowel clamp at the head of the device can be easily bent intraabdominally without reducing the grasping strength.

underwent a covering ileostomy. However, the decision to perform a protective ileostomy in this series was based on much looser criteria than those used in OS to avoid major anastomosis complications that could lead to a permanent stoma or a fatal outcome, especially in the early LS cases of lower rectal carcinoma.

Study Parameters

The parameters analyzed included gender, age, body mass index, prior abdominal surgery, operative time, operative blood loss, number of stapler cartridges fired and the length of the first stapler cartridge for rectal transection, conversion rate, days to resume diet, length of postoperative hospital stay, and both intraoperative and postoperative complications within 30 days of surgery. Pathologic staging was performed according to Duke's stage.

Statistical Analysis

Statistical analysis was performed using the χ^2 test, Kruskal-Wallis test with Bonferroni correction, and repeated-measure analysis of variance (ANOVA) with the Scheffe method when appropriate. A P value of <0.05 was considered significant.

RESULTS

The patient demographics are summarized in Table 1. No significant differences were observed in baseline characteristics among the 3 groups. In the middle/lower rectum group, anastomosis was performed <3 cm from the dentate line in 7 patients and >3 cm but below the peritoneal reflection in 3 patients. We performed an anastomotic air leakage test in 2 patients with lower rectal carcinoma and did not find any sign of air leakage; however, both patients underwent a protective ileostomy. Overall, a protective ileostomy was required in 4 patients, and a transverse coloplasty pouch was created in 1 patient.

The number of patients in relation to the number of stapler cartridges used for rectal transection in each group is shown in Table 2. The number of cartridges required during bowel transection was significantly increased in patients with middle/lower rectal carcinomas compared with the other groups. Similarly, significant differences were observed in the length of the first stapler cartridge fired for rectal transection (Table 3). In patients with middle/lower rectal carcinomas, the length of the first stapler cartridge was 45 or 30 mm, and it was 45 or 60 mm for proximal lesions.

Operative and postoperative results are shown in Table 4. Mean operative time and blood loss were significantly greater in the middle/lower rectum group. All the operations were completed laparoscopically. We did not experience any accidental intestinal perforations at or near the tumor site. Liquid and solid food was started at a median of 1 and 3 postoperative days in all groups. The median length of postoperative hospitalization was 8–9 days. No significant differences were observed in the postoperative course among the 3 groups. All patients were discharged home.

The postoperative complications are listed in Table 5. There were no perioperative mortality and no anastomotic leakage. Reoperation of a laparoscopic division of an adhesive band for a postoperative small bowel obstruction was necessary in 1 patient with sigmoid colon carcinoma. No significant differences were observed in complication rates among the 3 groups.

TABLE 1. Patient's Characteristics*

	Sigmoid Colon/ Rectosigmoid	Upper Rectum	Middle/Lower Rectum
No. of patients	36	21	10
Sex ratio (male:female)	22:14	10:11	8:2
Age (y)	59 (30–79)	59 (37–73)	60 (47–76)
Body mass index (kg/m^2)	23.5 (18.9–29.0)	24.1 (17.5–32.4)	23.8 (19.5–26.4)
Prior abdominal surgery (%)	6 (17)	5 (24)	5 (50)
Duke's stage			
A	27	16	7
B	1	0	0
C	7	3	3
D	1	2	0

*Values are means (range), $P > 0.05$.

TABLE 2. Number of Patients in Relation to the Number of Stapler Cartridges Fired for Rectal Transection*

No. of Stapler Cartridges Fired	Sigmoid Colon/Rectosigmoid†	Upper Rectum†	Middle/Lower Rectum
1	25	8	0
2	9	12	2
3	2	1	6
4	0	0	2

*$P < 0.01$ between groups, Kruskal-Wallis test.
†$P < 0.01$ versus middle, lower rectum/Boneferroni test.

DISCUSSION

In the present study, short-term outcomes were compared among different tumor sites in patients who underwent laparoscopic intracorporeal rectal transection with double-stapling technique anastomosis. The closer the tumor site was to the anus, the more the number of stapler cartridges needed for rectal transection increased and the use of a longer Endo GIA Universal stapler cartridge was significantly restricted, suggesting that rectal transection for Lap-LAR in patients with middle/lower rectal carcinomas may be a difficult and stressful procedure. In the present study, however, the complication rate did not increase despite lower anastomotic sites. With thorough and careful intracorporeal rectal transection and DST anastomosis, the safety of Lap-LAR may be established.

Minimum invasiveness is often noted as one of the merits of LS in comparison with OS for colorectal cancer.[19–23] But even recently, some studies have reported that minimal or no short-term benefits were found with LS compared with standard OS.[24–26] Reviewing these reports raises a question about the conversion rate. Even granting that LS has a lower surgical invasiveness than OS, there is a possibility that the treatment outcomes of LS will be contaminated by the treatment outcomes of OS, when the conversion cases are included in the LS group, based on the intention-to-treat principle. In the study by Weeks et al,[26] who reported a conversion rate of 25%, LS showed only minimal short-term quality-of-life benefits compared with OS in an intention-to-treat analysis, probably due to the high conversion rate. Moreover, they pointed out that patients assigned to laparoscopy-assisted colectomy who required intraoperative conversion to open colectomy had slightly poorer quality-of-life outcomes than patients who successfully underwent minimally invasive resection, and that the length of postoperative hospital stay in the LS group requiring conversion was longer than that in patients assigned to OS (7.4 vs. 6.4 days), although statistical analysis was not performed regarding these points. If the conversion patients did not show a worse outcome than those undergoing OS, patients who might benefit from LS should be considered as candidates for LS. Further studies are necessary to evaluate postoperative and oncological outcomes of patients assigned to laparoscopy-assisted colectomy who then require intraoperative conversion.

The results of the current study suggested that laparoscopic approaches to middle/lower rectal carcinoma do not compromise early postoperative recovery, such as days to oral feeding and length of hospitalization. Previous studies reported an anastomotic leakage rate of 5.7% to 21% in patients undergoing Lap-LAR.[6–12] Some authors have recommended a covering ileostomy as a routine step in Lap-LAR.[6,10,27] At present, patients with a preoperative diagnosis of T1–T2, middle/lower rectal carcinoma are required to decide whether they prefer to undergo OS or LS, after being given full information at our institution.

TABLE 3. Length of the First Stapler Cartridge Fired for Rectal Transection*

Length of the First Stapler Cartridge (mm)	Sigmoid Colon/Rectosigmoid†	Upper Rectum†	Middle/Lower Rectum
60	34	16	0
45	2	5	7
30	0	0	3

*$P < 0.01$ between groups, Kruskal-Wallis test.
†$P < 0.01$ versus middle/lower rectum, Boneferroni test.

TABLE 4. Operative and Postoperative Results

	Sigmoid Colon/Rectosigmoid	Upper Rectum	Middle/Lower Rectum
Operative time,* min (range)	221 (135–348)†	244 (190–328)‡	315 (190–392)
Blood loss,* mL (range)	29 (6–161)†	24 (10–198)†	124 (17–265)
Conversion	0	0	0
Liquid intake, d (range)	1 (1–4)	1 (1–3)	1 (1)
Solid food, d (range)	3 (2–5)	3 (3–4)	3 (2–4)
Hospital stay, d (range)	8 (7–12)	8 (7–11)	9 (7–17)

*$P < 0.01$ between groups, repeated-measure analysis of variance.
†$P < 0.01$ versus middle/lower rectum, Scheffe test.
‡$P < 0.05$ middle/lower rectum, Scheffe test.

TABLE 5. Morbidity and Mortality*

	Sigmoid Colon/ Rectosigmoid	Upper-Rectum	Middle/Lower Rectum
Mortality	0	0	0
Morbidity			
Wound sepsis	2	1	0
Bowel obstruction	1	0	1
Urinary tract infection	1	0	0
Abscess	0	0	1
Neurogenic bladder	0	1	0
Anastomotic leakage	0	0	0
Total	4	2	2

*$P > 0.05$.

In this study, the authors evaluated the safety of laparoscopic rectal transection using an endolinear stapler, which is one of the most technically difficult procedures in Lap-LAR. To date, we have not observed serious complications, such as anastomotic leakage. However, this surgical procedure remains technically difficult. We consider that this method should not be attempted if it is not performed by a laparoscopic surgical team with sufficient experience in LS. Regarding a surgical procedure that can be placed between OS and Lap-LAR, Vithiananthan et al[28] reported a hybrid method. In their procedure, they mobilized the left-sided colon and completed high ligation of the inferior mesenteric vessels with the use of the pneumoperitoneum, and then, from the inferior midline incision measuring 8 cm or longer, they performed rectal mobilization, mesorectal division, rectal transection, and anastomosis by DST using the OS tools. They noted that the mean incision length was 11.1 cm, which is longer than in Lap-LAR but shorter than in OS and that the patients treated with this method showed a significantly faster postoperative recovery than those treated with OS. Hand-assisted laparoscopic surgery may also be another treatment option.[29] However, compared with the standard Lap-LAR technique evaluated in this study, both of these methods may need a larger incision. With the surgeon's proficiency in the surgical procedure and the improvement in and development of instruments, the safety of standard Lap-LAR will probably be established; however, it is important to remember that this surgical technique cannot be employed at an early stage of the learning curve of laparoscopic surgery.

In conclusion, the findings of the present study demonstrate that laparoscopic intracorporeal rectal transection with DST anastomosis can be performed safely without increased morbidity or mortality. Even at present, there are few prospective, randomized trials investigating the short-term and oncological outcomes in patients with middle/lower rectal carcinoma, perhaps mainly because Lap-LAR has not been widely performed compared with LS for colon/upper rectal carcinoma due to the technical difficulties. The radical resection of middle/lower rectal cancers is a procedure that requires advanced technical skills in OS, to say nothing of Lap-LAR; however, we believe that use of Lap-LAR for middle/lower rectal carcinoma will expand with improvements in technology and surgeons' experience in the near future.

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外科治療

側方郭清

――予防的側方郭清と治療的側方郭清――

Lateral pelvic lymph node dissection : Prophylactic dissection and therapeutic dissection

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key words：側方郭清，直腸癌，閉鎖リンパ節，自律神経

はじめに

本邦では中・下部進行直腸癌に対して，側方郭清を行うことが標準術式と考えられてはいるものの，その適応，手術手技，郭清範囲に関しては，未だ完全なコンセンサスは得られていない。また，明らかな側方転移を認めない症例においての，自律神経を原則温存した側方郭清（予防的側方郭清）と，側方転移が疑われる，あるいは明らかな症例においての，自律神経を原則全切除し，必要であれば内腸骨血管も合併切除する側方郭清（治療的側方郭清）とでは，その手技，意義が当然異なる。本稿では，それぞれの手技，意義について考察してみたい。

側方郭清の適応

腫瘍占居部位に関しては，側方転移率の検討から占居部位が Ra 以下，また Ra であっても腫瘍の下縁が腹膜飜転部以下にあるものを側方郭清の適応としている施設が多い。深達度に関しては，MP 以深とする施設もあれば A_1 以深とする施設もあるが，われわれは腫瘍の下縁が腹膜飜転部以下にあり，臨床病期がⅡまたはⅢであるものを適応としている。大腸癌研究会の「直腸癌に対する側方郭清の適応基準に関するプロジェクト研究」では，腫瘍下縁が腹膜飜転部より肛門側にある A_1 以深の直腸癌を適応とすることを推奨している[1]。ただし，これらの適応は，あくまでも予防的な側方郭清の適応であって，明らかな側方転移が認められるのであればこの限りではない。まれではあるが，Rs の腫瘍や SM 癌でも明らかな側方転移を示す症例もあり，このような症例は治癒切除が可能と判断されれば，治療的側方郭清の適応である。

側方転移の診断

側方転移の有無により，予防的側方郭清か治療的側方郭清かに分かれるため，側方転移の術前・術中診断は重要である。側方転移の診断には，thin slice CT と MRI が有用であるが，側方郭清症例において thin slice CT で 6 mm 以上のリンパ節を転移陽性として検討したところ，感度50％，特異度95％，陽性的中率70％，陰性的中率85％，正診率85％であった。これはリンパ節サイズによる画像診断の限界を示しており，文献的にも同様の結果が示されている[2)3)]。ただし，MRI でリンパ節の辺縁不整像や信号強度の不均一をリンパ節転移の所見とすると，感度85％，特異度97％とかなりよい結果が報告されてはいる[2)]。しかしながら，まだ追試が必要な段階であり，現時点では，画像だけでなく術中の所見も加味し，必要に応じて側方リンパ節の迅速診断も行い，予防的側方郭清か治療的側方郭清かを決定することが望まれる。

予防的側方郭清（自律神経温存側方郭清）

側方転移が明らかでない症例に対して，原則的に自律神経温存側方郭清を行う。その際の側方郭清の範囲であるが，大腸癌取扱い規約により，262，272，273，282番リンパ節を郭清する。その他の280，293番リンパ節は，必ずしも郭清する必要はない。

詳細は他稿に委ねるが，側方郭清の前にまず TME (total mesorectal excision)[4)] または ME (mesorectal

図1 温存された自律神経
矢が左右の下腹神経。矢頭が下腹神経叢

excision）を行い，直腸切除後に側方郭清に入る。ME とは，全直腸間膜を切除するのではなく，腫瘍下縁から 4 cm までの直腸間膜を切除するものをいう[5]。tumor-specific mesorectal excision ともよばれる[6]。これは，これまでの研究で腫瘍下縁から 4 cm 以上癌が進展することがほとんどないことによる[4)7)-9)]。

直腸を剝離，切除する段階で腰内臓神経，下腹神経叢，左右の下腹神経，骨盤神経叢は確認できているので，まず，下腹神経叢，左右の下腹神経にテーピングして，自律神経の走行がわかるようにしておく（図1）。ついで，尿管をテーピングして側方郭清を開始する。

まず腹部大動脈の分岐部より総腸骨動静脈の腹側面と尾側面を露出，確認しながら郭清する（273番郭清）。この郭清は，血管の直上の層に入れば，ほとんど出血しないので，クーパー，メッチェン剪刀でも，電気メスでもよい。総腸骨動静脈から内・外腸骨動静脈への分岐部まできたら，内腸骨動静脈に移り，その内側，腹側，外側の郭清を上膀胱動脈が分岐するところまで行う（272番郭清）。ここで上膀胱動脈をテーピングしておく。ここまでくると，腹膜がじゃまとなってくるので，腹膜を外腸骨血管に沿って尾側に切開すると，視野が展開される。外腸骨動静脈をそれぞれテーピングし，外側に展開し，内外腸骨血管の分岐部から外側の郭清を行うと内閉鎖筋が確認でき，それに沿って下方に郭清を進めると，閉鎖神経が確認できる。この周囲で電気メスを使用すると，大腿内転筋群の収縮が起こるので，電気メスで郭清を行う際には，閉鎖神経に 27G 針で直接局麻剤を注入すると郭清が容易となる。

閉鎖神経が大腰筋の下方から出現するところを側方郭清の上限として，内閉鎖筋に沿って，閉鎖腔外側の郭清を行う。ここは，腹腔側からアプローチすると腹膜を外腸骨血管に沿って切り上げていく必要があり，視野展開が難しくなることもあるので，膀胱側腔を開放して腹膜外からアプローチするのも一つの方法であり，そのようにしている施設も多い。内閉鎖筋に沿って外側から尾側に郭清を進めていくと，閉鎖神経の末梢側が確認され，その周囲に閉鎖動静脈が確認できる。これらの血管は，郭清のじゃまには必ずしもならないが，じゃまになるようであれば結紮切離してもよい。ここまできたら，膀胱下腹筋膜（内腸骨動脈，上膀胱動脈から膀胱外側に連なる筋膜）に沿って郭清を進めると，最終的に閉鎖神経周囲にこれまで郭清してきた脂肪織が集まるので，神経を確認しながら脂肪織を切離すると，側方の脂肪織が一塊として切離できる（282番郭清）。最後に，骨盤神経叢を損傷しないように内腸骨血管内側の郭清を進め，中直腸動脈があれば結紮切離する。このまま下方に進むと，下膀胱動脈が確認できるので，その周囲を郭清し，郭清が困難であれば結紮切離する。下膀胱動脈より末梢で Alcock 管となるので，ここで内腸骨血管内側，尾側の郭清は終了となる（262番郭清）。

摘出された側方脂肪織を図2に示す。この組織を触診して転移が疑われるようであれば，迅速病理に提出して転移の有無の確認をし，もし転移があるのであれば次に述べる治療的側方郭清に切り替える。郭清終了時の状態を図3，4に示す。

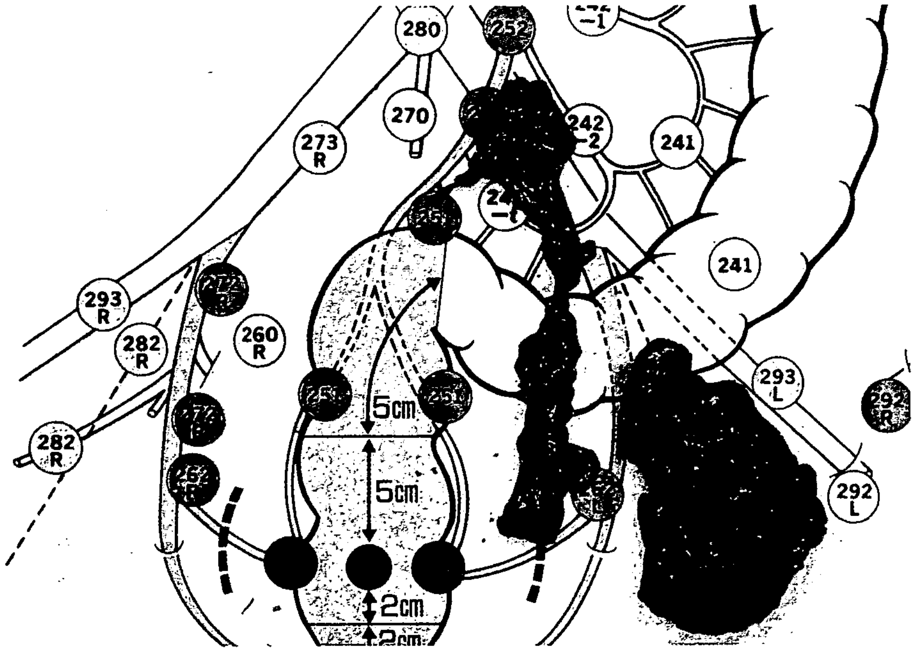

図２　郭清された側方脂肪織
リンパ節番号に該当する場所に郭清した脂肪織を配置している。きっちりと郭清すれば，だいたいこの程度の組織が摘出されるはずである

閉鎖腔はその外側縁，尾側縁は内閉鎖筋，内側縁は膀胱下腹筋膜，背側は坐骨神経，梨状筋で囲まれたコンパートメントで，この真ん中を貫くように閉鎖神経が存在すると認識して手術を行うと理解しやすい。閉鎖脂肪織は本来一塊の脂肪織であるので，その真ん中を貫く閉鎖神経周囲の郭清を先に行うと脂肪織がくずれ，周囲組織との境界がわかりにくくなるので，閉鎖神経を確認してテーピングした後は，閉鎖神経周囲の郭清を最後にするのが脂肪織を一塊として切除するコツである。

自律神経周囲の郭清をどこまで行うかは問題であるが，予防的郭清においては，機能の温存を重視して自律神経周囲の剝離は最低限にとどめている。図３でも自律神経叢周囲組織が比較的残存しているのがわかるかと思う。このような自律神経温存により，排尿機能はほぼ完全に温存できている[10]。

治療的側方郭清（自律神経非温存側方郭清）

側方転移が疑われる，もしくは明らかな場合には，自律神経の温存はすべきでなく，下腹神経叢から下腹神経，骨盤神経叢まで切除し，場合により内腸骨血管も切除して，郭清の徹底を図る。

自律神経温存術と異なり，262，272，273，282番リンパ節のみならず，280，293番リンパ節も郭清する。また予防的側方郭清と異なり，直腸を切離する際に，すでに下腹神経叢，左右の下腹神経を切除しながら骨盤神経叢のレベルまで剝離を進める。この層で剝離を行うと，骨盤神経叢をいわゆる側方靱帯として認識される。したがって，もし神経温存しているつもりで側方靱帯と思われる組織を認識した場合には，自律神経を切除する層で入っていることを示している。骨盤神経をどこまで切除するかで，当然，骨盤神経叢の温存程度が異なる。治療的郭清では原則温存しないので，骨盤神経叢に仙骨神経から背側から入ってくる骨盤内臓神経 S2，S3，S4（もっともはっきり認識できるのは S3）を確認して，仙骨神経からの起始部ですべて切除する。部分温存する場合は，S3の部分切除か，S3を全切除して，そのレベルで骨盤神経叢を切離，横断すると，神経叢の内側の層に容易に入るため，そこから剝離を進めれば，残りの骨盤神経叢は容易に温存できる。骨盤神経叢を全切除する場合には，側方靱帯の外側，すなわち内腸骨血管の内側から切除することとなるので，272番，262番の郭清を行いながら行うほうがよい。このようにして自律神経を切除しつつ直腸の剝離が終了したら，直腸を切離した後，残りの郭清を行う。

まず腹部大動静脈分岐部から尾側に郭清を進めて，280番の郭清を行う。血管直上で剝離すれば，郭清は容易である。仙骨前面部では正中仙骨動静脈があるので，これを損傷しないように注意する。必要であればこの周囲も郭清（270番郭清）するが，実際にはほと

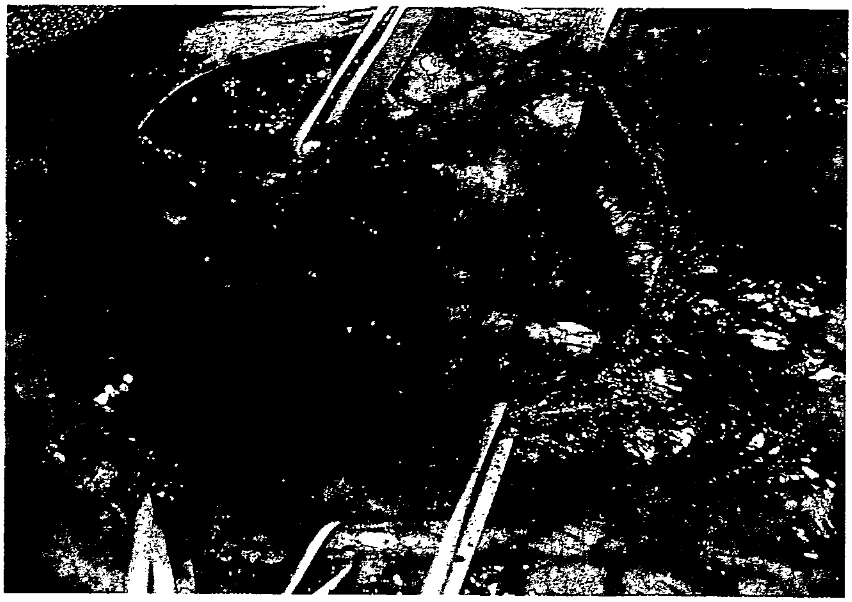

図３　予防的側方郭清
内腸骨血管周囲から閉鎖腔にかけての郭清状況。真ん中に温存された自律神経（下腹神経叢と下腹神経）がみえる

図４　予防的側方郭清
閉鎖腔の郭清状況。左上に黄色テープで牽引されている閉鎖神経がみえる

んど脂肪織はない。引き続き総腸骨血管の郭清を行うと，内外腸骨動脈，静脈の分岐をきれいに確認できる。ついで外腸骨血管の郭清に移り，血管をテーピングしながら，鼠径部近くまで郭清する（293番郭清）。ここから後は，神経温存の項で行った方法と同様である。必要であれば内腸骨血管を合併切除をしながら側方郭清を行うと，骨盤側壁は空虚な空間として残るのみで，完全な郭清が可能となる（図５，６）。内腸骨血管の切除は，上膀胱動脈を温存する場合とそうでない場合があり，血管がAlcock管に入るところまでを切除している。ただし，内腸骨血管壁側枝の上殿，下殿動静脈を温存して，臓側枝の上膀胱，下膀胱，中直腸，子宮動静脈を切除しても十分な郭清が可能である。図５，６はいずれもそのような切除をしている。治療的郭清を両側に行うと排尿機能は根絶してしまうので，対側の骨盤神経叢は，側方転移が認められなければ完全あ

図5　治療的側方郭清
真ん中に温存された閉鎖神経があり，周囲に郭清された外腸骨血管と内腸骨動脈の一部がみえる。その向こうに郭清により空虚となった骨盤側壁がみえる

図6　治療的側方郭清
内腸骨血管の臓側枝をすべて切離した郭清状況。白くみえるのが閉鎖神経。骨盤側壁は空虚な空間のみとなっている。この症例は左の自律神経を温存している

るいは部分温存して排尿機能の温存に努める。図5，6の症例も対側の骨盤神経叢は全温存した結果，術後一時期自己導尿を要したが，すぐに回復している。

側方郭清の意義

側方転移例の5年生存率は当院の成績を含め，各施設からの報告では30～40％である[11)～14)]。これは肝転移切除や肺転移切除例の5年生存率の30～40％とほぼ同等であることから，総リンパ節転移個数や側方転移個数にもよるが，治療的側方郭清の意義は十分あると考えられる。2000年に作成されたGuidelines 2000 for Colon and Rectal Cancer Surgery[5)]においても，側方郭清に関しては明らかなリンパ節転移のないものには郭清を推奨する根拠は乏しいが，臨床的に側方リンパ節転移が疑われる場合には，切除可能と判断するなら

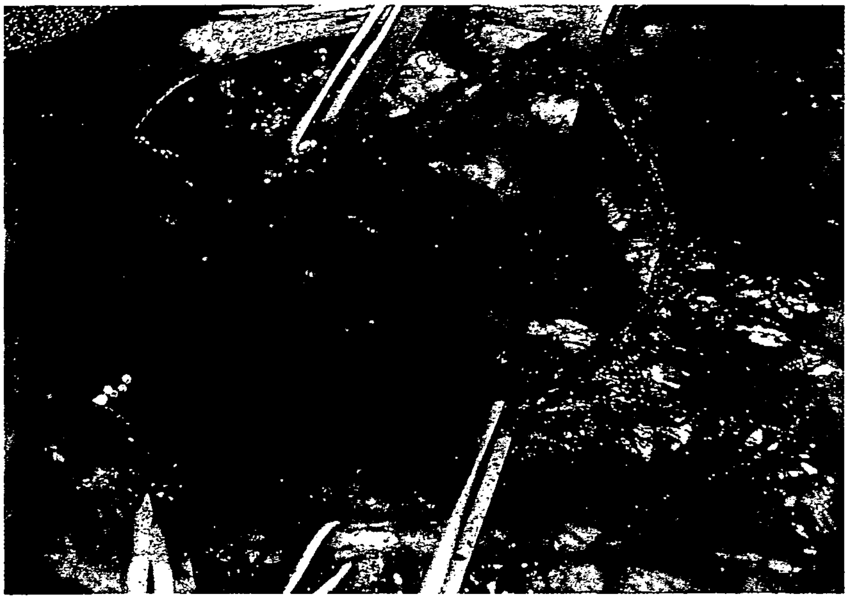

図３　予防的側方郭清
内腸骨血管周囲から閉鎖腔にかけての郭清状況。真ん中に温存された自律神経（下腹神経叢と下腹神経）がみえる

図４　予防的側方郭清
閉鎖腔の郭清状況。左上に黄色テープで牽引されている閉鎖神経がみえる

んど脂肪織はない。引き続き総腸骨血管の郭清を行うと，内外腸骨動脈，静脈の分岐をきれいに確認できる。ついで外腸骨血管の郭清に移り，血管をテーピングしながら，鼠径部近くまで郭清する（293番郭清）。ここから後は，神経温存の項で行った方法と同様である。必要であれば内腸骨血管を合併切除をしながら側方郭清を行うと，骨盤側壁は空虚な空間として残るのみで，完全な郭清が可能となる（図５，６）。内腸骨血管の切除は，上膀胱動脈を温存する場合とそうでない場合があり，血管がAlcock管に入るところまでを切除している。ただし，内腸骨血管壁側枝の上殿，下殿動静脈を温存して，臓側枝の上膀胱，下膀胱，中直腸，子宮動静脈を切除しても十分な郭清が可能である。図５，６はいずれもそのような切除をしている。治療的郭清を両側に行うと排尿機能は根絶してしまうので，対側の骨盤神経叢は，側方転移が認められなければ完全あ

表1　側方郭清の局所再発率

	対象期間	対象症例	症例数	stage	局所再発率
国立がんセンター中央病院[11]	1980〜1994	腹膜飜転部または以下	448	Ⅰ88，Ⅱ142 Ⅲ218	9.4%（全例） 3.4%（stageⅡ） 2.8%（stageⅡ） 16.1%（stageⅢ）
都立駒込病院[12]	1975〜1996	腹膜飜転部以下	157	Ⅲ157	7.4%
癌研究会附属病院[13]	1975〜1995	記載なし	764	Ⅰ，Ⅱ425 Ⅲ339	7.8%（全例） 1.9%（stageⅠ，Ⅱ） 15.3%（stageⅢ）
弘前大学[14]	1988〜2000	中・下部直腸	212	記載なし	6.3%

表2　TMEの局所再発率

	対象期間	対象症例	症例数	stage	局所再発率
The North Hampshire Hospital, UK[15]	1978〜1998	AV15cmまで	519	Ⅰ102 Ⅱ167 Ⅲ142 Ⅳ108	6%（全例） 3%（治癒切除例）
Memorial Sloan-Kettering Cancer Center and Beth Israel Medical Center, USA[16]	1979〜1998	AV12cmまで	544	Ⅰ162 Ⅱ114 Ⅲ170	5.2%（全例） 2.4%（stageⅠ） 2.5%（stageⅡ） 10.5%（stageⅢ）
Cleveland Clinic Foundation, USA[17]	1980〜1990	AV15cmまで（下部AV8cmまで）	666	Ⅰ223 Ⅱ201 Ⅲ221 Ⅳ21	2.8%（上部） 8.6%（下部）
Mayo Clinic, USA[6]	1982〜1989	AV15cmまで	514	Ⅰ272 Ⅱ111 Ⅲ63 Ⅳ68	7%（全例） 4%（stageⅠ） 9%（stageⅡ） 10%（stageⅢ）

ば郭清を試みるべきであるという評価となっている。

Guidelines 2000 for Colon and Rectal Cancer Surgeryでは推奨されていない予防的側方郭清であるが，本邦の代表施設の治療成績を表1に示す[11)~14)]。ただし，これは治療的側方郭清例も含む結果であることに注意しなくてはならない。いずれも中・下部進行直腸癌で数%の局所再発率で，TME導入以前の欧米の局所再発率が20〜30%であることからすれば，明らかな局所制御効果が認められる。一方，イギリスとアメリカの代表施設のTMEの局所再発率を表2に示す[6)15)~17)]。上部直腸癌も含まれ，明らかな側方転移例は除外されているため，直接比較することは困難ではあるが，Cleveland Clinicの下部直腸癌の成績は，側方郭清の成績と遜色ないものであることと，術前・術中所見では側方転移が不明で側方郭清してはじめてわかるような側方転移例は，TME例のなかに当然含まれていることから考えると，TMEは局所制御に関しては側方郭清と遜色のない結果を示しており，文献的には予防的側方郭清の意義は不明である。実際，臨床病期Ⅱ，Ⅲの下部直腸癌で側方郭清を行った症例と行わなかった症例の検討でも，リンパ節転移が少ない症例において側方郭清の有用性が示唆されたのみであった[18)]。このため，予防的側方郭清が意義あるものかどうかを明らかにする目的で，JCOG（Japan clinical oncology group）大腸がん外科研究グループ（47施設）で，腹膜飜転部以下の臨床病期Ⅱ，Ⅲの進行直腸癌を対象として，MEを行った後，予防的側方郭清を行う群と行わない群に分け，その無再発生存期間を比較する臨床試験が，2003年6月から登録を開始され，現在まで120例が登録がされている。参加施設，研究の概要につい

ては，JCOG ホームページ（http://www.jcog.jp/）で公開されているので参照してほしい。結果がでるのは10年先の話ではあるが，これまで長い間論争されてきた予防的側方郭清の意義について，一つの結論を示す重要な試験であり，この成果を期待していただきたい。

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Original Report

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Thin-Section MRI with a Phased-Array Coil for Preoperative Evaluation of Pelvic Anatomy and Tumor Extent in Patients with Rectal Cancer

OBJECTIVE. The aim of our study was to assess the accuracy of thin-section MRI performed with a phased-array coil as a technique for the preoperative evaluation of pelvic anatomy and tumor extent in patients with rectal cancer.

CONCLUSION. Thin-section MRI with a phased-array coil is accurate and reliable for preoperative evaluation of pelvic anatomy and depth of transmural tumor invasion. Thus, it may be helpful in the selection of the appropriate treatment for patients with rectal cancer.

The principal problems associated with rectal cancer treatment are tumor recurrence and impairment of anorectal and genitourinary functions after surgery. For a patient with rectal cancer to achieve a better prognosis and quality of life, the extent of surgery should accurately reflect the disease status. The internal and external anal sphincters, which are essential for anorectal function, are adjacent to the rectum. The pelvic autonomic nervous system—consisting of the hypogastric plexus, hypogastric nerves, and pelvic plexuses—is essential for genitourinary functions and is adjacent to the mesorectal fascia surrounding the mesorectum [1]. The mesorectum is defined as the lymphovascular, fatty, and neural tissue that is circumferentially adherent to the rectum [2]. Therefore, excessive resection easily leads to unnecessary damage of anorectal and genitourinary functions, whereas insufficient resection inevitably leads to tumor recurrence. Indeed, reported incidences of permanent stoma, erectile dysfunction, urinary dysfunction, and local recurrence generally are 34% [3], 45% [4], 58% [5], and 22–27% [6, 7], respectively. However, the incidences of these outcomes in a series of patients who received ideal treatment from experts were reported to be only 6% [8], 13% [9], 5% [9], and 5–7% [9, 10], respectively.

Treatment options should be selected according to the extent of the tumor. In general, T1 tumors invading the superficial submucosa can be effectively treated by local excision, which is minimally invasive and promises excellent maintenance of anorectal and genitourinary functions [11]. T1 tumors invading the deep submucosa, T2 tumors invading the muscularis propria, or T3 tumors invading the perirectal fat slightly but remaining within the mesorectal fascia can be treated by mesorectal excision, which maintains good genitourinary functions and fair anorectal function if the anal sphincter can be preserved [8–11]. Patients with T3 tumors invading the mesorectal fascia or T4 tumors invading the neighboring organs require more radical surgery, and preservation of genitourinary functions is more difficult.

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Randomized controlled studies have shown that adjuvant preoperative radiation therapy is effective for reducing local recurrence and prolonging survival in patients with rectal cancers, especially those with T3 tumors or node-positive cancer [6, 7]. Thus preoperative radiation therapy is becoming standard treatment for advanced rectal cancer. However, surgery alone can achieve local control in almost all T1 or T2 tumors and in many cases in T3 tumors as well. In addition, radiation therapy is complicated by toxicity [12], so the adjuvant therapy adopted also should reflect the accurate disease status.

The extent of tumor spread is generally evaluated using digital examination, endorectal sonography, CT, and MRI. The accuracy rates of endorectal sonography in the evaluation of the depth of transmural tumor invasion have been reported to be 82–88% [13, 14], and the technique has been described as superior to others for preoperative staging [15–17]. However, endorectal sonography is not applicable for stenosing tumors; further improvements are necessary for optimum tailoring of treatment for the individual patient.

Recent advances in medical imaging have shown that thin-section MRI performed with a phased-array coil is accurate and useful for preoperative evaluation of the extent of rectal cancer [18, 19]. Thus, we used a new phased-array coil that originally was developed to permit the early diagnosis of pancreatic cancer. Our previous study [unpublished] showed that this coil is superior to the conventional body coil, as indicated by the signal intensity distributions. The purpose of this study was to evaluate accuracy of thin-section MRI performed with this coil for the preoperative evaluation of pelvic anatomy and tumor extent in patients with rectal cancer.

TABLE 1 TNM Classification of Transmural Tumor Invasion Depth

T Stage	Definition
Tis	Carcinoma in situ
T1	Tumor invading submucosa
T2	Tumor invading muscularis propria
T3	Tumor invading through muscularis propria into subserosa or into nonperitonealized pericolic or perirectal tissues
T4	Tumor directly invading other organs or structures and/or perforating visceral peritoneum

TABLE 2 Criteria for MRI Staging of Rectal Cancer

T Stage	MRI Criteria
T1	Tumor signal intensity confined to submucosal layer—signal intensity low compared with high signal intensity of the adjacent submucosa
T2	Tumor signal intensity extends into muscle layer, with loss of interface between submucosa and circular muscle layer
T3	Tumor signal intensity extends through muscle layer into perirectal fat, with obliteration of interface between muscle and perirectal fat
T4	Tumor signal intensity extends into adjacent structure or viscus

Subjects and Methods

Between June 2001 and April 2002, 34 consecutive patients with primary rectal cancer proven by biopsy were examined with thin-section MRI using a phased-array coil for the preoperative evaluation of tumor extent. The patients were 25 men and nine women with a median age of 57 years (age range, 34–82 years). Of the 34 tumors in the patients, two were in the upper rectum, or 10–15 cm from the anal verge; seven were in the middle rectum, or 5–10 cm from the anal verge; and 25 were in the lower rectum, or less than 5 cm from the anal verge. None of the patients received preoperative radiation therapy. Informed consent was obtained from all patients.

MRI was performed preoperatively and interpreted by one gastrointestinal radiologist and one colorectal surgeon who were blinded to the findings of the digital rectal examination, endorectal sonography, and CT. The resected specimens were histopathologically examined by pathologists who were blinded to the findings of the preoperative evaluation of tumor extent. The depth of transmural tumor invasion was assessed according to the TNM classifications [20] (Table 1) for both MRI and histopathologic examinations, and results were compared prospectively.

MRI Methods

The patients received a 150-mL glycerin enema before examination and were placed in a supine, head-first position. No air insufflation was used, but an intramuscular antispasmodic was administered. We used a 1.5-T whole-body system (VISART/EX Scanner, Toshiba Medical Systems) and placed a wraparound quadrature phased-array coil (Pancreatic QD paired array coil, Toshiba Medical Systems) at the patient's pelvis. Initially, sagittal T2-weighted fast spin-echo images (TR/TE, 4,000/120; echo-train length, 23; slice thickness, 6 mm; gap, 1.2 mm; signal averages; 4; matrix, 166 × 256; field of view, 15 × 15 cm) of the pelvis were obtained. These images were used to plan T2-weighted thin-section axial imaging. Axial T2-weighted thin-section fast spin-echo images (9,500/120; echo-train length, 23; slice thickness, 3 mm; gap, 0 mm; signal averages; 4; matrix, 166 × 256; field of view, 15 × 15 cm) of the pelvis were then obtained.

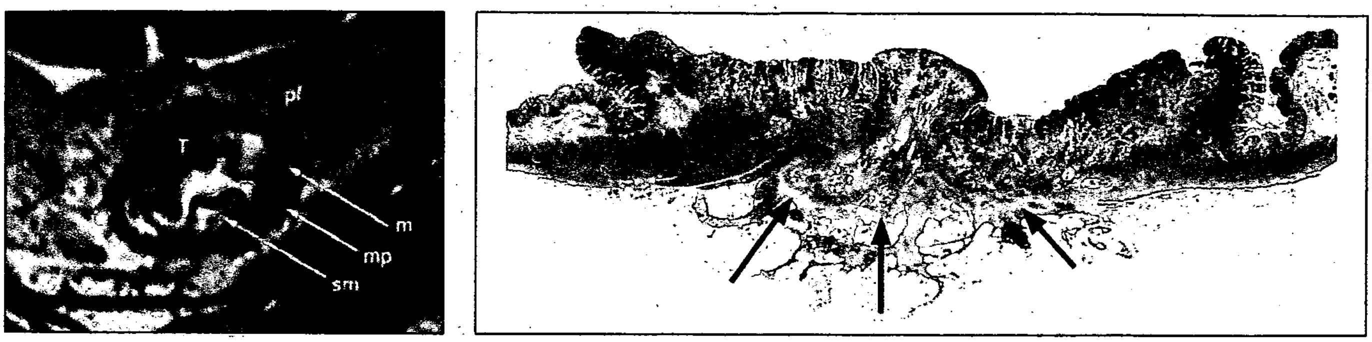
MR Image Interpretation

One experienced gastrointestinal radiologist and one experienced colorectal surgeon who had no knowledge of the clinical and histopathologic data interpreted each MR image in consensus on the workstation monitor. Distance was measured with electronic calipers. The reviewers assessed the visualization of the rectal mucosa, submucosa, muscularis propria (inner circular and outer longitudinal muscle layers), and mesorectal fascia; depth of the transmural invasion by the tumor; mesorectal involvement by the tumor; visualization of the branches of the named arteries such as the superior rectal and the internal iliac arteries; visualization of the mesorectal and extramesorectal lymph nodes; numbers of detected lymph nodes; and smallest short-axis diameters of the lymph nodes.

The depth of transmural invasion by each tumor was categorized according to the TNM classification [20] (Table 1) and was assessed according to the reported criteria [18] (Table 2). In accordance with the findings of Brown et al. [18], we did not regard the presence of spiculation within the fat alone as sufficient evidence of extramural invasion. Small interruptions of the outer contours of the muscle coat were also not regarded as sufficient for diagnosis of a T3 lesion. To further evaluate agreement in the assessment of invasion depth, reviewers performed second interpretations after an interval of at least 4 months.

Histopathologic Study

All patients underwent radical surgery. The median interval between MRI and surgery was 22 days (range, 1–55 days). Procedures performed were mesorectal excision [8–10] in 30 patients (low anterior resection in 24 and abdominoperineal resection in six), pelvic exenteration in three, and pelvic exenteration with partial sacrectomy in one. Immediately after surgery, resected specimens were opened on the side opposite the tumor and fixed in 10% formalin. After fixation, we obtained serial slices through the whole tumor in Tis–T2 cases or through more than two sections of the deepest part of the tumor in T3 or T4 cases. The slices were embedded in paraffin, sectioned, and examined histologically after H and E staining. The depth of



A B

Fig. 1.—64-year-old woman with pT3 rectal carcinoma.
A, Unenhanced T2-weighted fast spin-echo image shows rectal mucosa (m) as low-intensity, submucosa (sm) as high-intensity, muscularis propria (mp) as low-intensity, and perirectal fat (pf) as high-intensity layers. Signal intensity of tumor (T) is higher than that of proper muscle layer but lower than that of submucosa. Tumor is seen invading through muscularis propria (*arrowheads*).
B, Photograph of histologic specimen reveals tumor invading through muscularis propria (stage pT3) (*arrows*).

transmural tumor invasion was classified according to the TNM classification (Table 1) [20].

Identification of the Pelvic Plexuses

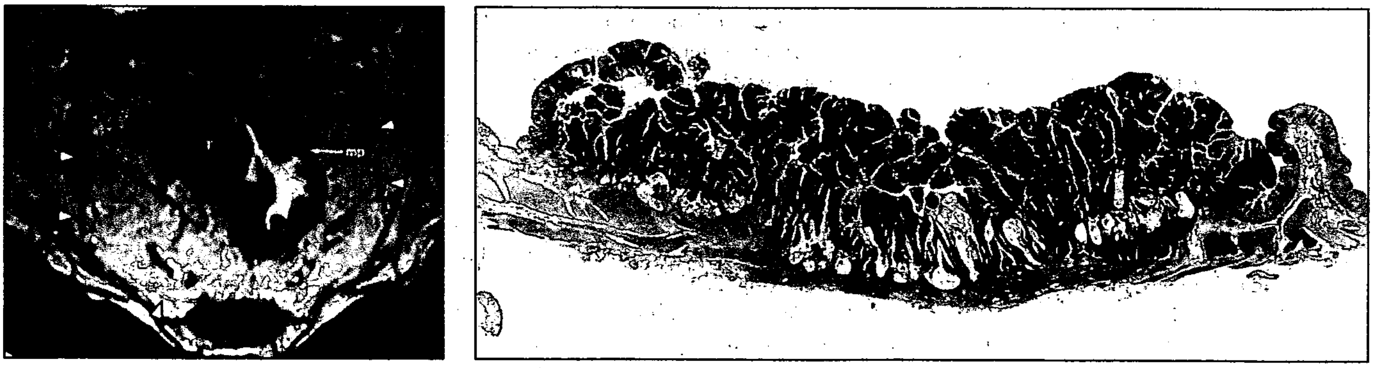
Postoperative MR images were compared with ones obtained preoperatively in two patients so that the exact locations of the pelvic plexuses—which are essential for genitourinary function—could be identified. During surgery, metal hemostatic clips had been applied to the cut ends of the middle rectal arteries and veins on the inner surfaces of the pelvic plexuses. These clips facilitated identification of the pelvic plexuses on postoperative MR images.

Statistical Methods

The agreement regarding MRI-determined and histologically determined tumor stage was assessed with the weighted kappa statistic, as was the agreement between the first and second interpretations.

Results

All patients tolerated the thin-section MRI examination well. The total scanning time was about 20 min. Although motion artifacts complicated findings in five patients (15%), the images were of sufficient quality to allow assessment. The histologic diagnoses were well-differentiated adenocarcinoma in 11 patients, moderately differentiated adenocarcinoma in 16, poorly differentiated



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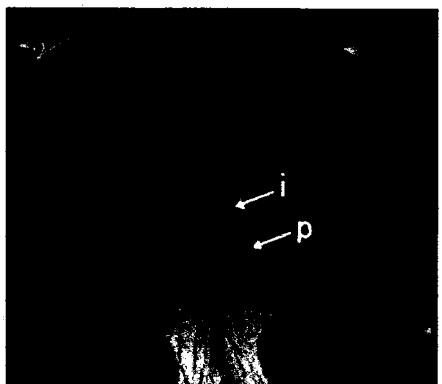


C

Fig. 2.—42-year-old man with pT2 rectal carcinoma.
A, Unenhanced T2-weighted fast spin-echo image shows mesorectal fascia (*arrowheads*) as fine linear hypointense structure enveloping mesorectum. Tumor (T) is revealed as being confined in muscularis propria (mp) and was staged as T2.
B, Photograph of histologic specimen shows tumor confined in muscularis propria (stage pT2).
C, Unenhanced T2-weighted fast spin-echo image shows internal sphincter muscle (i) and puborectalis muscle (p) as low-intensity layers separated by hyperintense intersphincteric plane.

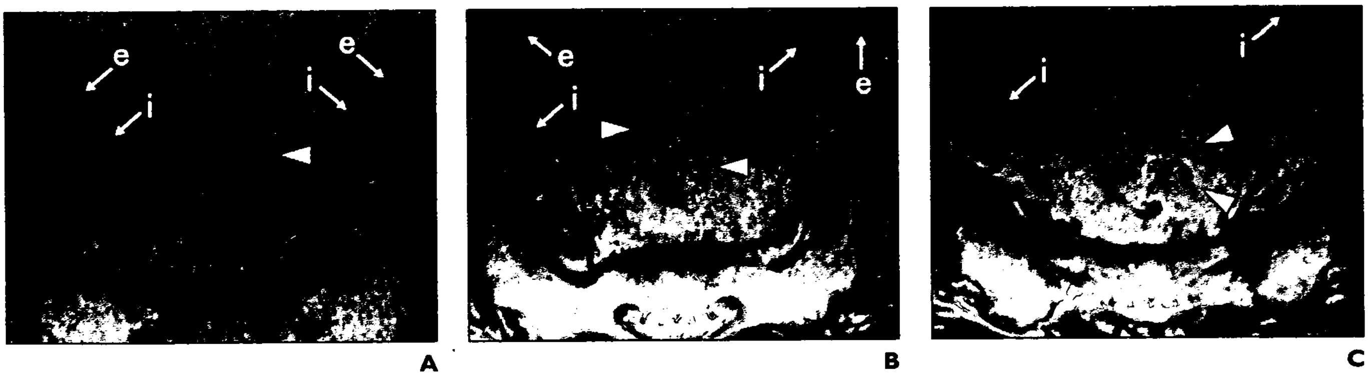


Fig. 3.—65-year-old man with rectal carcinoma.
A–D, Unenhanced T2-weighted fast spin-echo images reveal main trunk (**A**, *arrowhead*) and first (**B**, *arrowheads*), second (**C**, *arrowheads*), and third (**D**, *arrowheads*) branches of superior rectal artery seen as hypointense vascular structures. e = external iliac artery, i = internal iliac artery.
E, Unenhanced T2-weighted fast spin-echo image reveals obturator lymph node (*arrowhead*) and mesorectal lymph node (*black arrow*), displaying lower signal intensity than that of perirectal fat but higher signal intensity than those of arteries and veins. o = obturator artery.

adenocarcinoma in two, mucinous adenocarcinoma in four, and linitis plastica carcinoma in one. The histologic transmural invasion depths were pT1 in four patients, pT2 in nine, pT3 in 15, and pT4 in six. The mesorectal fascia was involved in eight patients. The median tumor diameter was 4.1 cm (range, 1.5–9.0 cm).

Visualization of the Pelvic Anatomy

In all patients, the rectal mucosa was visualized as a low-intensity layer; the submucosa, as a high-intensity layer; the muscularis propria, as a low-intensity layer; and the perirectal fat, as a high-intensity layer (Fig. 1). However, the inner circular muscle and outer longitudinal muscle layers could be distinguished only in three patients (9%). The mesorectal fascia was consistently depicted as a fine linear hypointense structure enveloping the mesorectum in all patients (Fig. 2A). In all patients, the internal and external sphincter muscles were shown as low-intensity layers separated by a hyperintense intersphincteric plane (Fig. 2C).

The first, second, third, and fourth branches of the superior rectal artery were seen as hypointense vascular structures in 34 (100%), 34 (100%), 31 (91%), and 11 patients (32%), respectively (Figs. 3A–3D). The bilateral obturator arteries branching from the internal iliac arteries were shown as hypointense vascular structures in all patients (Fig. 3E).

The lymph nodes were identified as having lower signal intensity than the perirectal fat but as having higher signal intensity than the arteries and veins (Fig. 3E). In patients with mucinous carcinoma, metastatic lymph nodes were shown as hyperintense nodules alone or as hyperintense nodules within hypointense nodules. The shapes of the lymph nodes were

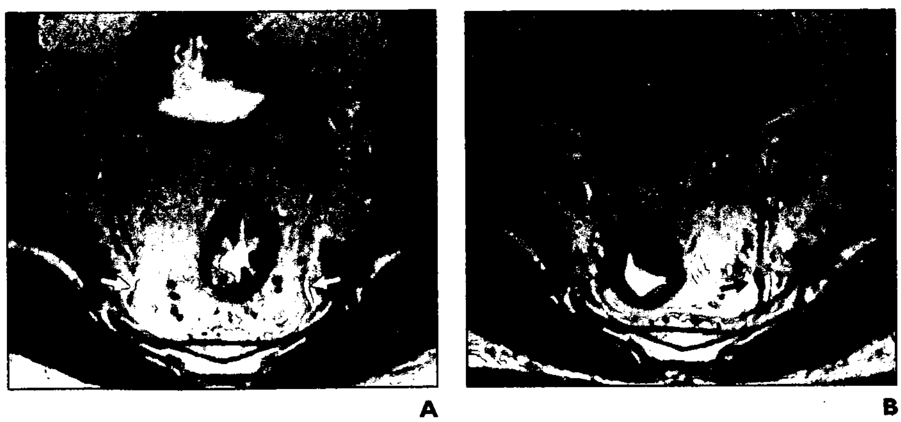


Fig. 4.—42-year-old man with rectal carcinoma.
A and **B**, Comparison of pre- and postoperative MR images show pelvic plexuses are located just outside mesorectal fascia. MR image obtained before surgery (**A**) shows pelvic plexuses (*white arrows*). Postoperative MR image (**B**) shows one of metal hemostatic clips that were applied to inner surfaces of pelvic plexuses during surgery to mark their exact locations (*black arrow*).

spherical or spheroidal, so that they could be distinguished easily from vascular structures. The mesorectal lymph nodes were apparent in all patients (Fig. 3E); the median number detected was five (range of nodes detected, 1–12). The median short-axis diameter of the smallest detected lymph nodes was 2.7 mm (range, 1.3–8.3 mm). The iliac or obturator lymph nodes were detected in only nine patients (33%) (Fig. 3E); the median number detected was 0 (range of nodes detected, 0–4). The median short-axis diameter of the smallest detected lymph nodes was 0 mm (range, 0–8.2 mm).

Comparisons of preoperative and postoperative MR images showed the pelvic plexuses to be located just outside the mesorectal fascia (Figs. 4A and 4B). However, even with metal hemostatic clips applied during surgery, the plexuses themselves could not be visualized on thin-section MRI.

Assessment of the Depth of Transmural Tumor Invasion

All rectal cancers were detected on thin-section MRI and, in most patients, showed higher signal intensity than the proper muscle layer but lower signal intensity than the submucosa (Fig. 1A). However, linitis plastica carcinoma showed signal intensity as low as that of the proper muscle layer, and mucinous carcinoma showed a signal intensity that was higher than that of the submucosa in parts of the mucous lakes.

At the first interpretation, MRI staging agreed with the histologic staging in 28 (82%) of 34 patients (weighted κ = 0.82; 95% confidence interval [CI], 0.69–0.95). Detailed results of the MRI staging are shown in Table 3. Sensitivity, specificity, overall accuracy rate, positive predictive value, and negative predictive value for detection of proper muscle invasion (T2) were 97% (29/30), 100% (4/4), 97% (33/34), 100% (29/29), and 80% (4/5), respectively (Fig. 2). Those values for detection of perirectal fat invasion (T3) were 95% (20/21), 77% (10/13), 88% (30/34), 87% (20/23), and 91% (10/11), respectively (Fig. 1). For detection of adjacent organ invasion (T4), the respective values were 100% (6/6), 96% (27/28), 97% (33/34), 86% (6/7), and 100% (27/27). The values for detection of the mesorectal fascia involvement were 100% (8/8), 100% (26/26), 100% (34/34), 100% (8/8), and 100% (26/26), respectively (κ = 1.0) (Fig. 5).

At the second interpretation, MRI staging agreed with the histologic staging in 29 (85%) of 34 patients (weighted κ = 0.85; 95% CI, 0.74–0.97). Sensitivity, specificity, overall accuracy rate, positive predictive value, and negative predictive value for detection of proper muscle invasion (T2), adjacent organ invasion (T4), and mesorectal fascia involvement were the same as those for the first interpretation. Those values for detection of perirectal fat invasion (T3) were 95% (20/21), 85% (11/13), 91% (31/34), 91% (20/22), and 92% (11/12), respectively. The agreement of the first and second interpretations on the depth of transmural invasion depth was good (κ = 0.87; 95% CI, 0.73–1.0).

Of the six cases in which staging errors were encountered at the first interpretation, four were overstaged, and two were understaged (Table 3). Histologic review of the specimens revealed that in three of the overstaged cases, the tumor invaded close to the deeper uninvolved layer and reactive changes were present in the connective tissue around the tumor, including inflammatory cell aggregation, desmoplastic change, and hypervascularity (Fig. 6). In addition, the deepest part of the tumor was not sectioned vertically on MRI but was sectioned obliquely, so that interpretation was difficult (Fig. 7). Histologic review of the two understaged cases revealed that they had only microscopic invasion beyond the estimated involved layers and that reactive changes of the connective tissue around the tumor were either only very slight or absent.

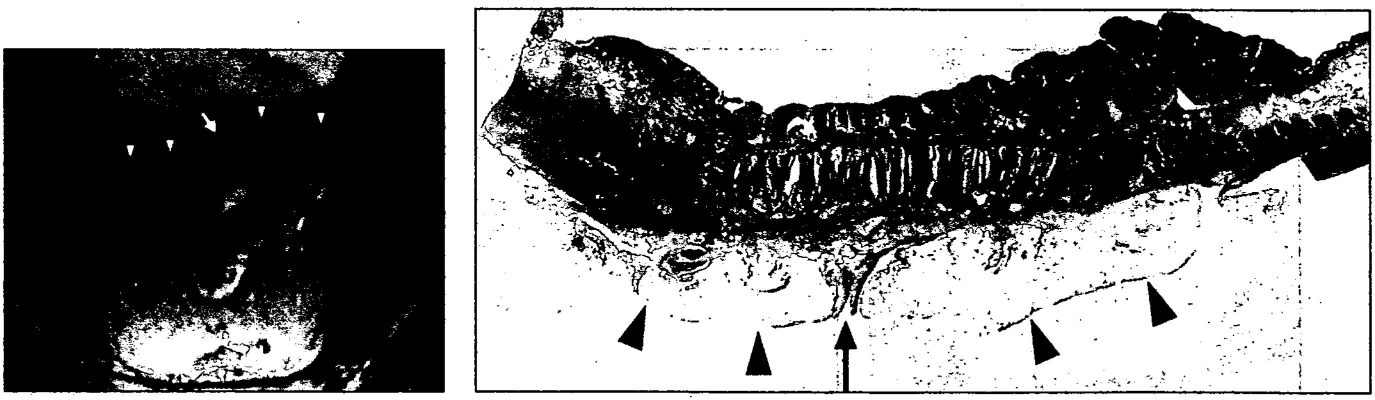
TABLE 3 Depth of Transmural Tumor Invasion in Rectal Cancer: Comparison of MRI and Histopathologic Findings

Histology		MRI			
pT	*n*	T1	T2	T3	T4
pT1	4	4			
pT2	9	1	5	3	
pT3	15		1	13	1
pT4	6				6

Note.—*n* = number of patients, T = MRI classification, pT = pathologic classification.

Discussion

As these results show, thin-section MRI performed with a quadrature phased-array coil has sufficient accuracy to depict fine details of the rectal wall (mucosa, submucosa, and muscularis propria), the anal sphincter, the mesorectum (perirectal fat; superior rectal artery and vein and their branches; lymph



A B

Fig. 5.—44-year-old man with pT3 rectal carcinoma involving mesorectal fascia.
A, Unenhanced T2-weighted fast spin-echo image shows tumor (*arrow*) involving mesorectal fascia (*arrowheads*).
B, Photograph of histologic specimen reveals tumor (*arrow*) involving mesorectal fascia (*arrowheads*).

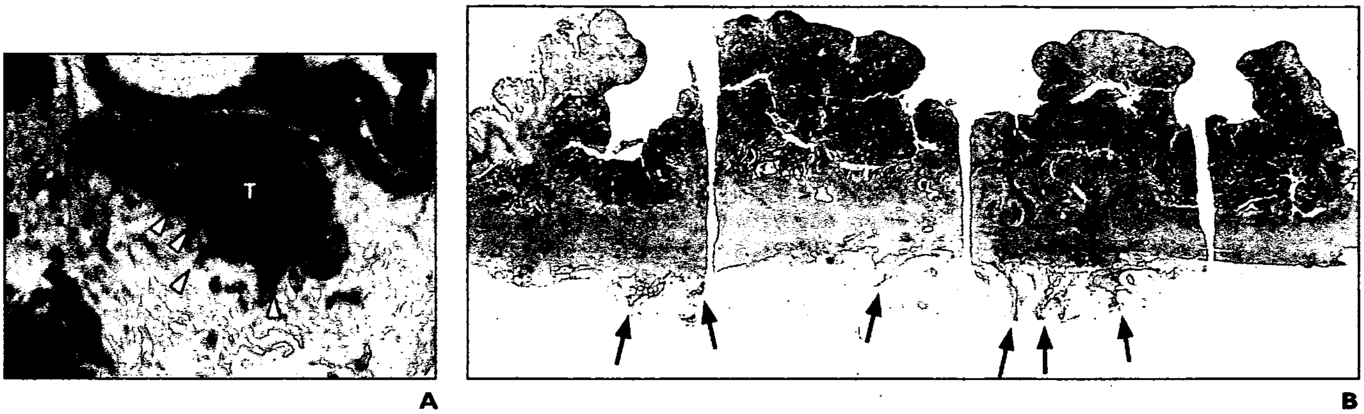


Fig. 6.—80-year-old man with pT2 rectal carcinoma.
A, Tumor (T) was overstaged as T3 because spiculation (*arrowheads*) was interpreted as cancer invasion on unenhanced T2-weighted fast spin-echo image.
B, Photograph of histologic specimen reveals tumor confined in muscularis propria (stage pT2). However, reactive changes in connective tissue around tumor, including desmoplastic change and hypervascularity (*arrows*), can affect MRI findings and mimic tumor invasion.

node; and mesorectal fascia), and the extramesorectal structures (internal iliac artery and vein and their branches; and lymph node) clearly in every patient. Fourth branches of the inferior mesenteric artery and lymph nodes measuring 2 mm could be visualized in most patients. In addition, although the pelvic plexuses per se could not be visualized on our thin-section MRI, we identified their exact locations just outside the mesorectal fascia via metal hemostatic clips placed on their inner surfaces during surgery and comparisons of preoperative and postoperative MR images.

Previous studies using similar instruments also provided precise images of the rectal and pelvic anatomy [18, 19]. Brown et al. [18] reported that their technique had an in-plane resolution of 0.6 × 0.6 mm and allowed differentiation of the inner circular and outer longitudinal muscle layers. We could distinguish the layers in only 9% of the patients, but such differentiation is not clinically important because treatment for the tumor invading the inner muscle is the same as that for the tumor invading the outer muscle.

All intraluminal cancers measuring more than 1.5 cm were detected. Most tumors showed a signal intensity that was higher than that of the proper muscle layer but lower than that of the submucosa, as has been reported previously [18, 19]. In addition, we found that linitis plastica carcinoma had a signal intensity that was as low as that of the proper muscle layer and that mucinous carcinoma had a signal intensity higher than that of the submucosa in parts of the mucous lakes. These findings are useful for predicting histologic diagnosis and may contribute to treatment selection because they are risk factors for a poor prognosis [21–23]. However, whether the histology of the tumor affects staging accuracy could not be determined because of the limited number of patients studied.

In our prospective study, we performed unenhanced thin-section MRI (slice thickness, 3 mm) on a 1.5-T scanner with a quadrature phased-array coil. The depth of transmural tumor invasion and mesorectal fascia involvement were predicted correctly in 82% and 100% of the patients, respectively. In their retrospective evaluation, Beets-Tan et al. [19] used contrast-enhanced thin-section MRI (slice thickness, 3 mm) on a 1.5-T scanner with a quadrature phased-array spine coil and

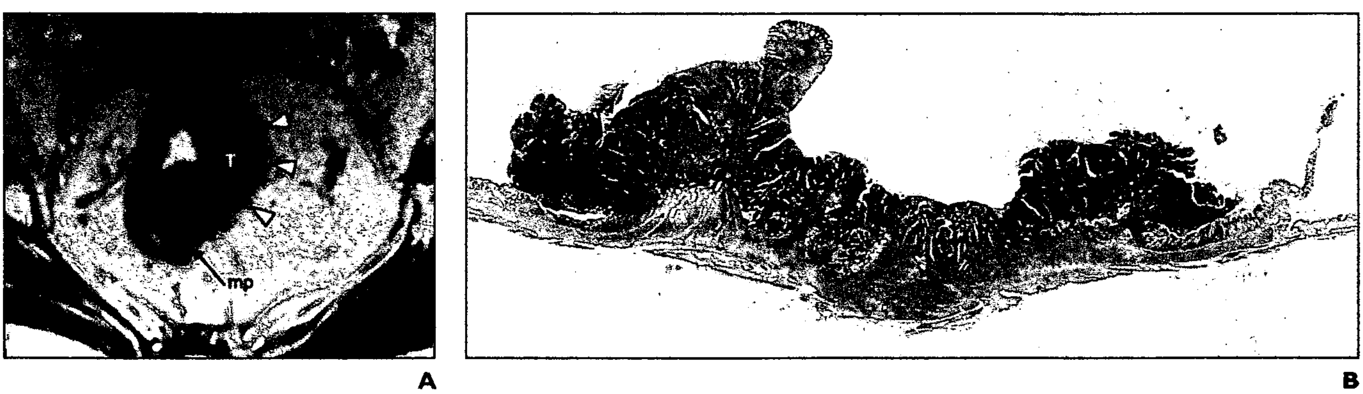


Fig. 7.—56-year-old woman with pT2 rectal carcinoma.
A, Tumor (T) was overstaged as T3 because site of deepest invasion (*arrowheads*) was sectioned obliquely on MRI and mimicked cancer invasion beyond muscularis propria (mp).
B, Photograph of histologic specimen reveals tumor confined in muscularis propria (stage pT2).

reported that the depth of transmural tumor invasion and mesorectal fascia involvement were predicted correctly in 83% and 100% of their patients, respectively. Brown et al. [18] used unenhanced thin-section MRI (slice thickness, 3 mm) on a 1.5-T scanner and a four-element flexible wraparound surface coil and conducted a retrospective study that found correct invasion depth assessment was attained in 100% of their cases. Thus, thin-section MRI performed on a 1.5-T scanner with a phased-array coil in general can be considered to provide moderate to good accuracy in the prediction of invasion depth and good accuracy in the prediction of mesorectal fascia involvement. These data are comparable to accuracy rates of 82–88% [13, 14] obtained with endorectal sonography for the prediction of invasion depth. However, endorectal sonography is not applicable for stenotic or obstructive tumors and cannot visualize the mesorectal fascia and obturator space because of the limitations of sonographic attenuation [14]. In addition, good-quality sonograms can be guaranteed only if the images are acquired by a skilled operator [14]. Therefore, thin-section MRI can be concluded to be clinically more useful than endorectal sonography.

As to reproducibility, we did not evaluate interobserver agreement, but concordance between the first and second interpretations was good for both invasion depth ($\kappa = 0.87$) and mesorectal fascia involvement ($\kappa = 1.0$). Brown et al. [18] evaluated only interobserver agreement and reported good agreement between experienced reviewers for invasion depth ($\kappa = 1.0$). Beets-Tan et al. [19] assessed both intraobserver and interobserver agreement. For assessment of invasion depth, intraobserver agreement was good ($\kappa = 0.8$) for a radiologist experienced in pelvic MRI but was only moderate ($\kappa = 0.49$) for an inexperienced radiologist; interobserver agreement was moderate ($\kappa = 0.53$). In contrast, intraobserver and interobserver agreements for the prediction of involvement of circumferential resection margin [24–26] (the same as mesorectal fascia involvement in patients who undergo mesorectal excision [8–10]) were good, because intraclass correlation coefficients for the experienced reviewer, inexperienced reviewer, and both reviewers were 0.99, 0.91, and 0.93, respectively. Therefore, examinations for invasion depth should be interpreted by a reviewer experienced in pelvic MRI; involvement of the circumferential resection margin or mesorectal fascia is more easily interpretable.

Thin-section MRI is sufficiently accurate and reliable to provide clinically useful information. Prediction of involvement of the mesorectal fascia, adjacent organs, or circumferential resection margin is especially important [24–26]. Involvement of these structures requires surgery more radical than mesorectal excision [8–10], preoperative adjuvant therapy, or both to reduce local recurrence and overall recurrence [27]. Prediction of an absence of such involvement allows performance of mesorectal excision alone [8–10], reducing the incidence and severity of anal and genitourinary dysfunctions [9] and preventing toxicity from unnecessary adjuvant radiation therapy [28, 29], chemotherapy, or both. Accurate prediction of invasion depth of T1 tumors ensures proper assignment of candidates for local excision to enhance patient survival and quality of life [11].

Although thin-section MRI is very accurate, it is not perfect. In our series, two thirds of staging errors in invasion depth resulted from overstaging and were most common with pT2 tumors, as has been reported for endorectal sonography [13, 14]. Reactive changes in the connective tissue around the tumor, including inflammatory cell aggregation, desmoplastic change, and hypervascularity, mimic tumor invasion on MR images. Such reactive changes have also been previously noted as a main cause of overstaging on sonography [14, 30] and MRI [18, 19]. Contrast enhancement may be helpful for differentiating these reactive changes from true tumor invasion. However, Beets-Tan et al. [19], who used gadolinium as a contrast medium, reported that MRI could not be used to distinguish reliably between fibrosis with and fibrosis without tumor cells. The best results were reported by Brown et al. [18], who could differentiate between desmoplastic spiculation and true invasion. Therefore, the best technique may be the one described in their report or may involve more precise image acquisition and administration of effective contrast material. In addition, the direction of MRI sectioning is important. Obliquely sectioned images make contours of tumors obscure and interpretation difficult, as seen in our study. This difficulty may be overcome by more precise image acquisition and 3D data accumulation.

One third of the staging errors in our study involved underestimation that was mostly attributable to microscopic invasion that is fundamentally undetectable on MRI or difficulties in attaining a complete examination with the 2D rather than 3D approach, so that we obtained not continuous images but rather interrupted images. To reduce overstaging and understaging, investigators need to address the possibility of using an image matrix smaller than 166 × 256, a slice width thinner than 3 mm, techniques for achieving a higher signal-to-noise ratio, 3D data accumulation, effective contrast material, and a shorter scanning time. MRI with an endorectal coil may have higher signal-to-noise ratio near the coil and produces better visualization of the rectal wall structure [31, 32]; however, its limited field of view makes assessment of the mesorectal fascia and surrounding structures difficult, and insertion of the coil is difficult in patients with annular stenotic lesions. Therefore, approaches using thin-section MRI with a phased-array coil still seem better.

Although our study concerned a relatively small number of patients, we conclude that thin-section MRI with a phased-array coil is accurate and reliable for the preoperative evaluation of the pelvic anatomy and the depth of transmural tumor invasion Thus, it may be helpful in the selection of the appropriate treatment for patients with rectal cancer. However, the accuracy of this technique is not perfect, so further investigation to improve accuracy is warranted. In addition, for validation, a multiinstitutional prospective study is necessary.

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