Recognition of the Anterior Peritoneal Reflection at Rectal MRI

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OBJECTIVE. The purpose of this article is to assess radiologists' ability to identify the anterior peritoneal reflection on MRI.

CONCLUSION. The peritoneal reflection was identified on MRI by two radiologists in the majority of patients with rectal cancer.

Keywords: MRI, peritoneal reflection, peritoneum, rectal cancer

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The anterior peritoneal reflection separates the intra- and extraperitoneal portions of the rectum and is a well-defined anatomic landmark at laparotomy [1]. Primary colorectal carcinoma in this vicinity can pose vexing anatomic and treatment questions to the surgeon and radiation oncologist, because the exact anatomic transition from the rectum to the sigmoid colon and from the intra- to extraperitoneal rectum may not be readily apparent preoperatively and because colon and rectal cancer are treated differently. Reliable preoperative visualization of the anterior peritoneal reflection could assist the clinical team in individualizing therapy.

Previous reports of high-resolution MRI of the rectum illustrated isolated cases of the anterior peritoneal reflection, with no commentary on the reliability or frequency of its visualization [2, 3]. Studies using laparotomy [4, 5], intraoperative endorectal ultrasound [6], intraoperative proctoscopy [7] and anatomic treatises [1] have described its location and relationship to the rectum and surrounding structures, but, to our knowledge, there have been no comprehensive reports of imaging or other noninvasive methods to achieve this goal.

Given the limited descriptions of the pelvic anterior peritoneal reflection using imaging studies and the increasingly widespread, and in some regions routine, use of MRI for staging rectal cancer, we thought that such a study was indicated. Although many issues regarding the appropriateness of radiotherapy or local transanal excision are still unsettled, depending on the location of a tumor above or below the anterior peritoneal reflection, accurate noninvasive pretreatment identification of this landmark would be an important contribution informing this debate. The purpose of this study was to determine the feasibility and reproducibility of identification of the anterior peritoneal reflection at high-spatial-resolution pelvic phased-array MRI in patients with rectal cancer.

Materials and Methods

Patients

After obtaining a waiver for patient consent, adults with biopsy-proven primary rectal adenocarcinoma of any T and N stage (determined by either endorectal ultrasound or digital rectal examination) undergoing preoperative high-spatial-resolution pelvic phased-array MRI with special attention to the rectum (hereafter termed "rectal MRI") were included. The accrual was consecutive at the European site (because all such patients routinely undergo preoperative MRI) between 2006 and 2010. The accrual at the North American site was a random sample of patients because not all patients routinely underwent preoperative MRI. The MRI referral pattern among the surgeons in North America changed over the years, along with emerging results of trials (e.g., the MERCURY trial [8]), but generally included patients with bulky, fixed, or tethered tumors or those not adequately assessed at endorectal ultrasound (all patients at the North American site do require endorectal ultrasound). However, other patients with a perceived clinical need for these studies were also included. Randomization was accomplished using a computer-generated assignment of random numbers to all patients with rectal MRI performed at the North American site between 1994 and 2010.

MRI Technique

Only sagittal and axial T2-weighted images were made available to each radiologist for the purposes

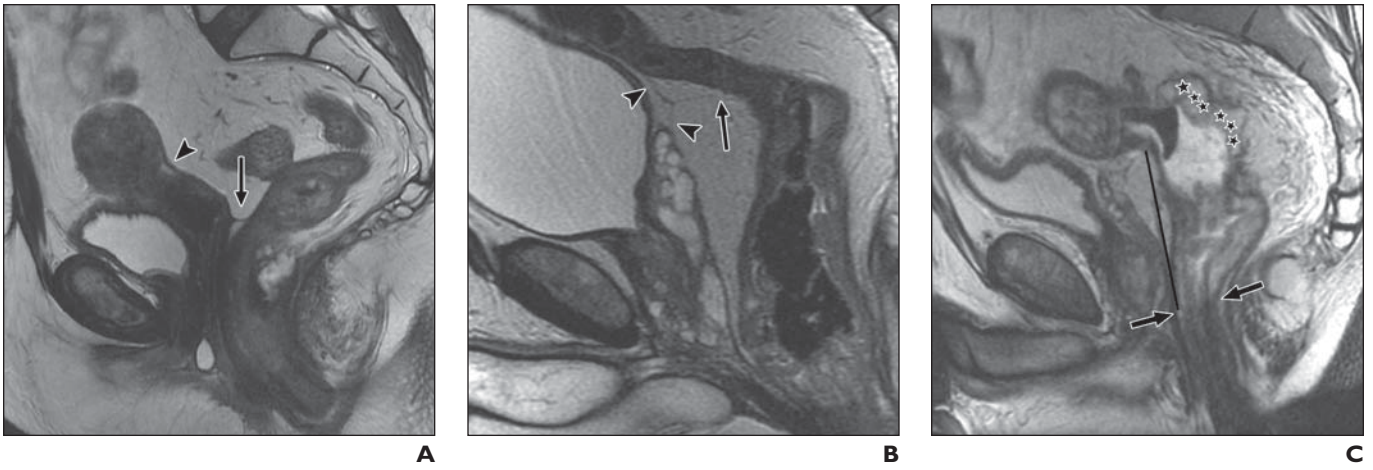

Fig. 1—Sagittal T2-weighted rectal MRI showing anterior peritoneal reflection in different patients.
A, 53-year-old woman. Anterior peritoneal reflection (*arrow*) is seen inserting onto rectum. Note also peritoneal lining (*arrowhead*) seen along superior uterine border.
B, 68-year-old man. Anterior peritoneal reflection (*arrow*) is seen inserting onto rectum, with reflection also seen along superior seminal vesicle and bladder margins (*arrowheads*).
C, Anorectal junction (ARJ) in 61-year-old man is delineated by arrowheads. Distance from ARJ to anterior peritoneal reflection is delineated by straight line. Tumor is indicated by stars.

of this investigation. In North America, the MRI was performed on a 1.5- or 3-T MRI scanner (Signa, GE Healthcare) using a pelvic phased-array coil with 4–32 channels, depending on the regional site where the patient was scanned. The following parameters were used: 2D fast-recovery fast spin-echo; TR/TE, 4000–6000/102 (4000–6000/120 for 3-T MRI); echo-train length, 24; flip angle, 90°; bandwidth, 32 MHz; FOV, 18–36 cm; 3-mm and 1-mm gap; matrix, 192 × 320 (224 × 320 for 3-T MRI); number of excitations, 3 (4 for 3-T MRI); in three planes (sagittal, axial, and coronal) without fat saturation. In Europe, MRI was performed with a 1.5-T MRI unit (Intera, Philips Healthcare) and a pelvic phased-array coil with the following parameters: 2D T2-weighted fast spin-echo; TR/TE, 3427/150; flip angle, 90°; echo-train length, 25; bandwidth, 152.6 Hz; FOV, 20 cm; 3- to 5-mm slice thickness; 2-mm gap; 175 × 256 matrix; number of signals averaged, 6; in three planes (sagittal, axial, and coronal) without fat saturation. Patients did not receive bowel preparation or spasmolytics.

Radiologist Interpretation Strategy and Anatomic Measurements

Two radiologists experienced with rectal MRI (15 and 10 years) independently reviewed all images from both sites on PACS monitors at their respective institutions. Sagittal and axial images alone were allowed for identification of the anterior peritoneal reflection. All distance measurements were made only on sagittal images. Other than the knowledge of the presence of a "rectal" cancer on the basis of prior clinical assessment, radiologists were blinded to the location of the mass. Identification of the anterior peritoneal reflection was rated on a 5-point confidence scale (0 = definitely not visible, 1 = probably not visible, 2 = possibly visible, 3 = probably visible, and 4 = definitely visible). The quality of the MRI was also rated subjectively as either "good," "average," or "poor." In the midsagittal plane, the peritoneum is identified as a thin hypointense line noted along the superior bladder (men) or uterus (women) and extending inferiorly and posteriorly to the cul-de-sac in women and approximately to the tip of the seminal vesicles in men, after which the posterior extension attached to the rectal wall anteriorly. The anterior peritoneal reflection specifically was recorded as the insertion site onto the colon (Figs. 1A and 1B). The anorectal junction (ARJ) was identified as a transition from low T2 signal (the superior border of the sphincter and puborectalis complex) to intermediate T2 signal (rectal wall and mucosa), as well as, variably, the point of posterior angulation of the rectum with respect to the anal canal (Fig. 1C). For all cases rated with a confidence score of 2–4 by at least one radiologist, distances were measured as a single line between the anterior peritoneal reflection and ARJ (Fig. 1C). Finally, rectal adenocarcinoma tumor masses were identified for their distance from the ARJ to the lower pole of the rectal tumor mass (Fig. 2A), their total

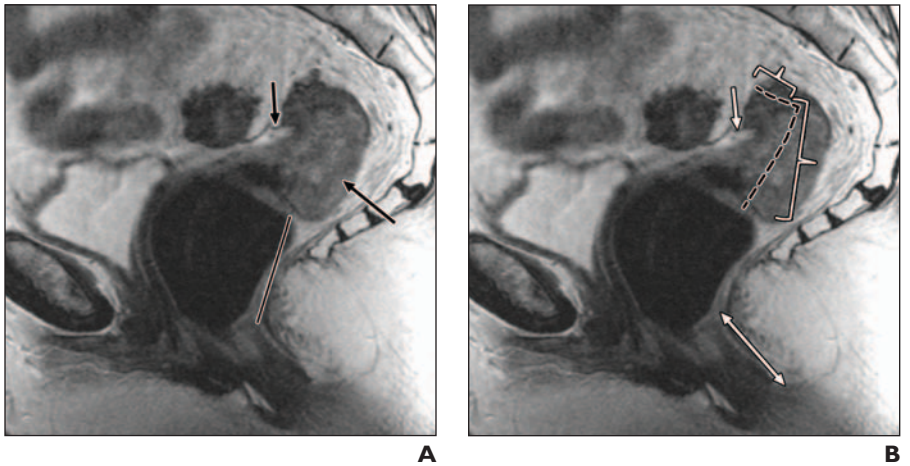

Fig. 2—74-year-old woman with hypointense to intermediately intense mass in rectum, partly above and below anterior peritoneal reflection.
A, Sagittal T2-weighted rectal MRI shows tumor (*long arrow*) and its distance (*line*) from anorectal junction. Note anterior peritoneal reflection (*short arrow*).
B, Tumor length would be measured approximately along curvature of lumen (*dashed line*). Portion of tumor above (*small bracket*) and below (*large bracket*) anterior peritoneal reflection is seen, given line drawn perpendicular to sacrum. Note anterior peritoneal reflection (*short arrow*) and anal canal (*double-headed arrow*).

length (Fig. 2B), and the relationship of the tumor to the anterior peritoneal reflection (i.e., the percentage of the tumor above and below the anterior peritoneal reflection, as shown in Fig. 2B). These measurements represented the luminal length of colon an endoscope would need to travel to reach these landmarks and may have necessitated two or more interconnecting angulated lines, sometimes on two or more adjacent sagittal slices for an approximate summated total length. A single set of anal canal lengths was also measured in each patient to facilitate comparison with published endoscopic values, which are typically measured from the clinically visible anal verge. Age and sex differences in length were also analyzed.

Biostatistical Methods

Descriptive statistics were used to provide baseline data on the patients with regard to age, sex, and length to anterior peritoneal reflection. For comparison of differences in measurements between patients, the independent samples Student *t* test was used. For comparison between radiologists in the same patients, the paired samples Student *t* test was used. The analysis of variance test was used to examine differences between age categories. To determine interobserver agreement for the ability to confidently visualize the anterior peritoneal reflection, weighted quadratic kappa statistics were used. For agreement between measurements from the two radiologists, the intraclass correlation coefficient (ICC) was used. For the kappa and ICC statistics, the following scale was used: poor, 0–0.2; fair, 0.21–0.4; moderate, 0.41–0.6; good, 0.61–0.8; and excellent, 0.81–1.0. Statistical analyses were performed with SPSS (version 16.0, SPSS) and Stata (version 11.0, StataCorp) software.

Results

Patient Characteristics

There were 180 patients (73 from the North American site and 107 from the European site), including 54 women (30%) and 126 men, with a mean (± SD) age of 66.6 ± 10.7 years. The quality of the MRI scans was good in 138, fair in 34, and poor in eight cases.

Visibility of Anterior Peritoneal Reflection

The anterior peritoneal reflection was deemed as probably or definitely visible in 81.6% (radiologist 1) to 88.5% (radiologist 2) of cases. Both radiologists indicated that the anterior peritoneal reflection was "probably" or "definitely" visible in 134 of 180 cases (74.4%). The weighted quadratic kappa value for confidence level in visibility of the anterior peritoneal reflection was 0.362 (range, 0.237–0.487), indicating fair agreement. One radiologist deemed all anterior peritoneal reflections to be possibly, probably, or definitely visible. The other radiologist deemed nine anterior peritoneal reflections to be not visible or probably not visible (prior surgery [$n = 3$], average image quality [$n = 3$], motion artifact [$n = 2$], and metachronous sigmoid tumor [$n = 1$]).

Distance to the Anterior Peritoneal Reflection

For the distance from the ARJ to the anterior peritoneal reflection, the mean, median, and range were 68.9, 69.0, and 41–128 mm, respectively, for radiologist 1 and 67.0, 67.0, and 35–130 mm, respectively, for radiologist 2. The ICC was 0.835 (range, 0.78–0.88), indicating excellent agreement. The average length of the anal canal was 4.1 cm for men and 3.6 cm for women.

Tumor Length

For tumor length, the mean, median, and range were 54.0, 52.0, and 14–126 mm, respectively, for radiologist 1 and 52.1, 50.0, and 12–115 mm, respectively, for radiologist 2. The ICC was 0.838 (range, 0.788–0.876), indicating excellent agreement.

Tumor Relationship to Anterior Peritoneal Reflection and ARJ

The mean percentage of tumor below the anterior peritoneal reflection was 77.7% ± 32.3% for radiologist 1 and 76.4% ± 33.6% for radiologist 2. The mean distance from the ARJ to the lower pole of the tumor was 38.4 ± 32.8 mm for radiologist 1 and 38.2 ± 31.6 mm for radiologist 2. The ICC between radiologists was 0.879 (range, 0.841–0.909), which is consistent with excellent agreement (Fig. 3).

In eight cases, the readers disagreed regarding whether the tumor was 10% below the anterior peritoneal reflection ($\kappa = 0.74$). The reasons were as follows: subjectivity of the estimation of 10% because the tumor straddled the anterior peritoneal reflection to one degree or another (e.g., one reader thought one tumor was 15% below the anterior peritoneal reflection [$n = 3$]), reason unknown (possibly reader fatigue or human error [$n = 2$]), and one case each of reduced image quality, scirrhous tumor with uniform wall thickening, and difficulty in distinguishing tumor margins.

Age and Sex

The mean distance from the ARJ to the anterior peritoneal reflection for men was 67.6 mm for radiologist 1 and 66.5 mm for radiologist 2 ($p = 0.079$, paired samples Student *t* test). The mean distance from the ARJ to the anterior peritoneal reflection in women was 71.8 mm for radiologist 1 and 68.3 mm for radiologist 2 ($p = 0.002$, paired samples Student *t* test). There was no statistically significant difference in ARJ to anterior peritoneal reflection distances between men for both radiologists, but between radiologists, lengths for women were statistically significant (absolute difference, 3 mm). When comparing men's and women's lengths per radiologist, there was no difference in length for radiologist 2, but there was a statistically different length between men and women for radiologist 1 ($p = 0.043$). When patients were categorized as younger than 55 years, 55–70 years old, or older than 70 years, using analysis of variance, there was no statistically significant difference in anterior peritoneal reflection–to-ARJ measurements at different age categories.

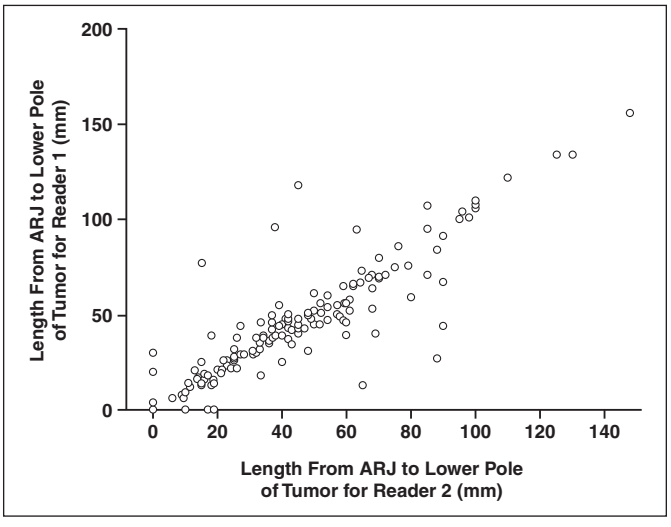

Fig. 3—Scatterplot of reader agreement of length from anorectal junction (ARJ) to lower pole of tumor.

Discussion

We have shown that two experienced gastrointestinal radiologists found it feasible to identify the anterior peritoneal reflection in the majority of rectal MRI scans. Furthermore, the distances from the ARJ to the anterior peritoneal reflection (6.9 cm for radiologist 1 and 6.7 cm for radiologist 2) were nearly identical and revealed excellent interreader agreement, further supporting the ease of identification of the anterior peritoneal reflection. Radiologists also showed excellent agreement on rectal cancer tumor lengths and, specifically, their relationship to the anterior peritoneal reflection, an issue of primary concern we wished to address in this investigation.

These results indicate that, in addition to previous more-invasive means to identify the peritoneal reflection (i.e., surgery or endoscopy), imaging alone with MRI can also reliably accomplish this task. On most MRI scans, in the midsagittal plane, the anterior peritoneal reflection consisted of a thin T2-hypointense line 1 mm or less in thickness. Although agreement in reader confidence levels was fair, overall, most cases were confidently seen by the individual readers. In men, the tip of the seminal vesicles was a consistent landmark for the location of the most inferior portion of the peritoneal membrane, to reflect off of and proceed posteriorly and superiorly to then invest onto the anterior rectal wall, whereas in women, the uterocervical angle was a common location to see this reflection. In cases where the anterior peritoneal reflection was not seen, the reasons included postoperative status, poor image quality, motion artifact, a paucity of pelvic fat planes, motion artifact, retroversion of the uterus, or large exophytic rectosigmoid tumors. One pitfall to avoid is visualization off-midline, where the peritoneal reflection is higher as it proceeds laterally and superiorly (Fig. 4). The anterior peritoneal reflection was especially well seen in cases where a trace amount of fluid was present in the pelvic cul-de-sac. Optimizing the MRI technique with anterior fat-saturation bands and the administration of spasmolytic intestinal agents might overcome the artifacts that can obscure the 1-mm anterior peritoneal reflection.

Prior reports have depicted the anterior peritoneal reflection on axial images with an appearance of a midline infolding fascial reflection—that is, the so-called V-shaped configuration [3]. We found this appearance to be uncommon and instead focused on the sagittal view for a more complete assessment of the entire tumor and its relationship with the anterior peritoneal reflection. We chose to use the easily recognized ARJ in lieu of the anal verge to obtain more reproducible measurements for the distance to the anterior peritoneal reflection. The anal verge, which is the junction of hair-bearing to non-hair-bearing skin of the anus, is obviously not an imaging landmark, but it is the clinical landmark most often used during digital rectal examination and endoscopy when describing rectal masses as well as distances to the anterior peritoneal reflection in prior reports. However, for the purpose of comparing our anterior peritoneal reflection distances with those quoted in the literature, we separately measured the anal canal length. Adding these values resulted in mean distances from the anal verge to the anterior peritoneal reflection of 10.9 cm for both men and women. These lengths are longer than the 7.5 cm for men and 5.5 cm for women reported in classic textbooks of anatomy with respect to the anal verge [9], or above the dentate line [10], as well as more recent descriptions [1] using intraoperative direct observation or proctoscopy [5, 7]. Little to no difference was found in anterior peritoneal reflection lengths between the sexes (for one radiologist only, the mean difference was 3 mm) and for different age categories. Although tumors were, at times, difficult to identify in the noncleansed rectum and were best seen because of differences in signal intensity and wall thickness, there was excellent agreement on tumor lengths and tumor relationships with the anterior peritoneal reflection and the ARJ. A further comparison on accuracy of these values compared with endorectal ultrasound measurements is under way. Although important treatment decisions will also rely on the proximity of the tumor to the ARJ, this is easily assessed at endorectal ultrasound and digital rectal examination and was not the focus of this investigation.

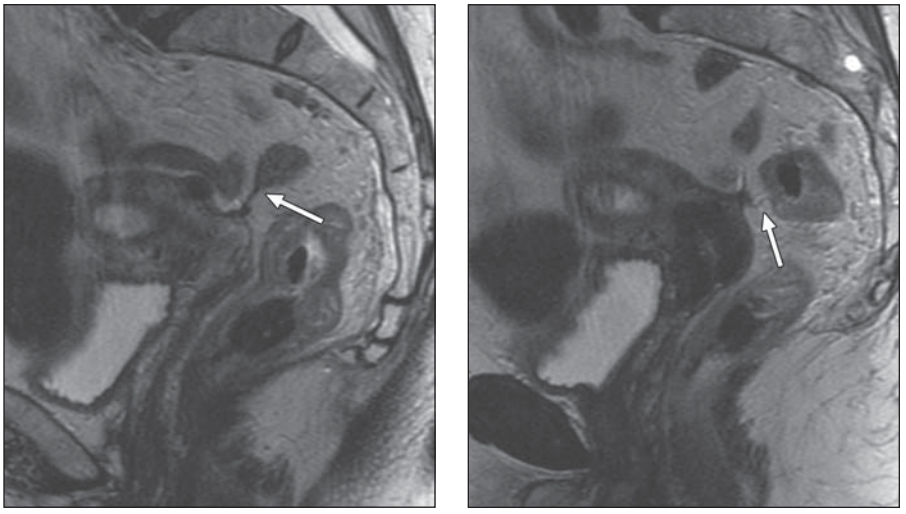

Fig. 4—41-year-old woman with known rectal cancer.
A, Sagittal T2-weighted rectal MRI shows parasagittal (off-midline) visualization of peritoneal reflection (*arrow*) more laterally and superiorly. Note nonmidline appearance of pubic bone and other structures.
B, Midline sagittal visualization of true anterior peritoneal reflection (*arrow*), which is 1.6 cm left of that shown in panel **A**.

The clinical impact and benefit of noninvasively identifying the anterior peritoneal reflection and its relationship with a rectal tumor before treatment are the potential differences in pathways of tumor spread (e.g., transperitoneal and lateral lymph nodes) and, thus, potentially different optimal treatment strategies.

As conventionally described, the upper third of the rectum is invested with peritoneum anteriorly and laterally, the middle third is partially invested anteriorly, and the lower third is completely extraperitoneal [5]. Posteriorly, there is no peritoneal investment. The serosa on the anterior surface of the upper rectum is closely applied to the outer longitudinal muscularis propria, with little intervening fibrofatty connective tissue; therefore, tumors that lie anterolaterally at or above the peritoneal reflection ("intraperitoneal rectum") and grow deeply into the wall of the bowel are theoretically at risk for spread of cells into the peritoneal cavity. In a study of 209 patients with tumors located

near the anterior peritoneal reflection, local peritoneal involvement was found in 26%. Survival was worse in this group [11].

The location of a tumor above or below the anterior peritoneal reflection also has important treatment implications. Transanal excision of an early-stage rectal cancer that is anteriorly located at or above the anterior peritoneal reflection could cause perforation into the peritoneum [6]. In the case of a more-advanced tumor treated with radiation, effective radiotherapy would be difficult and potentially morbid, because the tumor may be on a mobile mesentery and be surrounded by loops of small intestine, exposing the patient to potentially increased morbidity from radiation enteritis [12]. Some controversy also exists regarding the efficacy of radiation in high tumors. For example, the Dutch TME trial showed no beneficial effect of radiotherapy for tumors above 10 cm [13].

Risk might also be encountered if a high rectosigmoid tumor was not recognized to have a component below the anterior peritoneal reflection and was treated strictly as a colon cancer. This risk, which is thought to be greater with more caudal tumors because of lateral drainage to the internal iliac nodes via the inferior or middle rectal lymphatics [1] within the "lateral ligament," is thought to be a primary cause of the high rate of recurrent tumors in the pelvis ("local failure"). It is this risk that radiation treatment addresses. In a recent pathologic study, lateral spread in the pelvis occurred in 21% and 42% of tumors at and below the peritoneal reflection, respectively. These studies confirm the importance of localizing the peritoneal reflection from the standpoint of patterns of tumor spread. Controversies abound regarding radiation treatment with total mesorectal excision versus routine lateral lymphadenectomy, but these issues are beyond the scope of this investigation.

Our study is limited in several ways. Because this was a retrospective study, we were unable to obtain intraoperative confirmation of our measurements, and a prospective study is planned to overcome this weakness. In addition, assessments were made by two experienced academic radiologists, with 25 combined years of experience in reading rectal MRI, and our 82–89% success rate in visualizing the anterior peritoneal reflection on well-performed MRI scans may be an overestimate of what is possible in the general community. Finally, because MRI was not performed on every patient with rectal cancer at the North American site, but rather was reserved for more advanced disease, there may have been a selection bias with oversampling of gross disease.

In summary, our data revealed that two experienced observers saw the anterior peritoneal reflection in more than three fourths of rectal MRI examinations. There was excellent agreement between observers on the distance from the ARJ to the anterior peritoneal reflection. In addition, tumor lengths and relationships to the anterior peritoneal reflection were equally well appreciated and consistent between these two observers. The ability to visualize the anterior peritoneal reflection noninvasively with MRI confers an even greater utility to preoperative MRI for staging of rectal cancer and carries direct implications for patterns of tumor spread, treatment individualization, and, by extension, recurrence patterns and prognosis. Further prospective studies with surgical validation are required. More importantly, MRI studies that correlate the tumor location relative to the anterior peritoneal reflection with the type of treatment chosen and survival outcomes could shed further light on what remains an ill-defined and at times controversial clinicopathologic topic.

Acknowledgment

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