American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Pretreatment Staging of Colorectal Cancer**

Variant 1: **Rectal cancer. Locoregional staging.**

Radiologic Procedure	Rating	Comments	RRL*
MRI pelvis without and with IV contrast	9		O
MRI pelvis without IV contrast	8	Noncontrast MRI is sufficient for T staging, though with and without is routinely used as well.	O
US pelvis transrectal	8	For suspected early T-stage disease instead of MRI.	O
CT abdomen and pelvis with IV contrast	5	May be appropriate if MRI cannot be performed and tumor is locally advanced.	☢☢☢
CT abdomen and pelvis without IV contrast	3	May be appropriate if MRI cannot be performed and tumor is locally advanced.	☢☢☢
CT abdomen and pelvis without and with IV contrast	3	May be appropriate if MRI cannot be performed and tumor is locally advanced.	☢☢☢☢
CT colonography	3	Low dose CTC without IV contrast.	☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: **Colorectal cancer. Staging for distant metastases.**

Radiologic Procedure	Rating	Comments	RRL*
CT chest abdomen pelvis with IV contrast	9		☢☢☢☢
MRI abdomen and pelvis without and with IV contrast	8	MRI or CT can be used. Usually performed along with a chest CT.	O
FDG-PET/CT whole body	6		☢☢☢☢
MRI abdomen and pelvis without IV contrast	5	Rarely used, but may be appropriate in situations when other exams cannot be performed due to contraindications. Usually performed along with chest CT.	O
CT chest abdomen pelvis without IV contrast	4	Only useful in a few very specific situations.	☢☢☢☢
CT chest abdomen pelvis without and with IV contrast	3	Limited added value of non-contrast series at the expense of increased dose.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

PRETREATMENT STAGING OF COLORECTAL CANCER

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Summary of Literature Review

Introduction/Background

Colorectal cancers are the third most common tumors in the United States and the most common gastrointestinal cancer. The American Cancer Society estimates that over 93,090 new cases of colorectal cancer will be diagnosed in 2015 [1]. Most of these patients will undergo surgery for palliation or possible cure. Barring contraindications from associated medical conditions, virtually all patients with colorectal cancer will undergo some form of surgical therapy for attempted cure or palliation. Current treatment strategies are divided into those aimed at local/primary tumor management and those aimed at management of distant metastatic disease. Resection, if possible, of liver metastatic disease and in select oligometastatic sites provides the best overall survival. Although the evaluation and management of distant metastases is generally the same between colon and rectal cancer, the locoregional staging is quite different.

Colon Cancer

The local treatment of colon cancer relies primarily on what section of the colon is involved (right versus left hemicolectomy), with removal of the associated mesentery and regional nodes. The treatment strategy for colon cancer is governed by the location of the mass (generally radical hemicolectomy), with selective adjuvant chemotherapy dictated by lymph node positivity and extramural lymphovascular invasion on pathologic specimen. Locoregional staging (T and N stage) with imaging is not well supported in the literature. Most studies show that imaging is best utilized to identify advanced T stage and distant metastases with locoregional nodal staging being relatively less accurate and of marginal clinical utility [2-5].

Additionally, the role of preoperative imaging to predict T-stage and N-stage is of questionable value, given that neoadjuvant therapy has not been shown to significantly improve survival over surgery alone and the standard surgical approach is radical resection. Preoperative imaging of colon cancer appears to be of most benefit in identifying distant metastases, regardless of its ability to predict T-stage and N-stage. Given the limited role of locoregional staging, the imaging variant discussion for colon cancer will be limited to evaluation of distant metastases only.

Rectal Cancer

Surgical options for rectal carcinoma are more varied than for colon cancer and depend on the relationship of tumor to the sphincter and circumferential resection margins and peritoneal reflection. Several studies have evaluated the efficacy of transanal excision as an alternative to radical resection, with results suggesting this may be appropriate in carefully selected T1-stage patients [6,7]. Close observation and accurate preoperative staging is essential to avoid high recurrence rates in these patients, likely related to involvement of local mesorectal nodes not detected by preoperative imaging [6]. Furthermore, neoadjuvant chemotherapy and radiation added to primary resection in patients with radiologically determined high-risk rectal cancer has been shown to decrease local recurrence and improve survival [8-11]. Thus, preoperative imaging for local staging of rectal cancer is important for determining the need for neoadjuvant therapy and surgical strategy [6,8,12,13].

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Overview of Imaging Modalities

The diagnosis of colorectal cancer is often based upon clinical presentation of blood in stools, obstruction, anemia, or detection at colonoscopy surveillance. Computed tomography (CT), magnetic resonance imaging (MRI), and transrectal ultrasound (TRUS) have all been evaluated in initial staging of colorectal carcinoma. There are some studies supporting the use of CT colonography in local staging of colon cancer as well [14-17]. Furthermore, an important role of imaging in staging patients with colorectal cancer is the detection of distant metastases, which can be accomplished with CT, positron emission tomography (PET)/CT, and MRI. All 3 of these modalities benefit from the use of intravenous (IV) contrast, with new MRI contrast agents allowing hepatobiliary phase imaging to improve accuracy [18,19]. In rectal tumors, due to the need for high-resolution anatomic detail in determining local tumor extension, the local staging of tumor is often considered separately from the evaluation of distant metastatic disease, resulting in the need for a combination of modalities to fully stage the patient (ie, MRI pelvis for local staging and CT chest, abdomen and pelvis for metastases). The optimal combination of imaging studies should take into consideration accuracy and cost-effectiveness.

Ideally CT is performed with IV contrast and can be performed as a single post-contrast portal venous phase of the chest, abdomen, and pelvis. Alternatively, a multi-phase protocol of the liver (generally consisting of arterial, portal venous, and delayed phases) can be paired with post-contrast imaging of the chest and pelvis. Acquiring multiple phases of the liver may improve diagnostic characterization of focal liver lesions. In addition to the phases of contrast, thin slices (ranging from 3–5 mm) and optimized technique (in relation to contrast bolus and imaging parameters) are essential for adequate staging accuracy with CT [20,21].

Liver MRI is ideally performed with and without IV contrast, with multiphase dynamic post-contrast imaging as the standard acquisition. There are 2 main types of MRI IV contrast for liver imaging, traditional extracellular agents (producing similar contrast kinetics to CT contrast) and hepatobiliary agents. Hepatobiliary agents allow for both dynamic contrast images (arterial, portal venous) and hepatobiliary phase images. The hepatobiliary phase images are acquired at a delayed timepoint that corresponds to greatest liver parenchymal enhancement due to uptake of the contrast agent by hepatocytes and where there is excretion of the administered contrast agent into the bile ducts. During the hepatobiliary phase, liver lesions are dark against a bright liver and may be more conspicuous than on traditional dynamic phases. MRI with diffusion-weighted imaging also produces greater diagnostic accuracy, especially when combined with hepatobiliary phase imaging [22-27]. Although the use of IV contrast agents is ideal for staging, in patients who cannot receive an IV contrast agent due to severe allergy or renal failure, MRI without an IV contrast agent may be an option that provides better anatomic detail than CT without contrast.

A brief mention of IV contrast agents and renal function is essential to guide choices in the staging setting. Iodinated contrast agents used for CT are potentially nephrotoxic and should be avoided in patients with compromised renal function. Gadolinium-based IV contrast agents used in MRI are not nephrotoxic and may be a better option for patients with mild renal insufficiency. However, gadolinium agents carry a black box warning against use in severe renal dysfunction due to the risk of nephrogenic systemic fibrosis. More detailed discussion of contrast agents can be found in the ACR *Manual on Contrast Media* [28].

Variant 1: Rectal cancer. Locoregional staging.

In this clinical scenario, a patient has a known diagnosis of rectal carcinoma and presents for staging of the primary tumor and locoregional nodes. Initial staging of rectal cancer should provide information regarding transmural extension (T-stage), locoregional nodal involvement, and involvement of adjacent organs or important anatomic structures (such as the sphincter complex and resection margin). These factors guide surgical planning and determine the need for neoadjuvant treatment. Surgical excision with satisfactory margins is necessary to provide a significant disease-free interval.

Transrectal Ultrasound

TRUS has been considered the gold standard for T-stage evaluation of rectal carcinoma with rich historical evidence to support its use. TRUS enables one to distinguish layers of the rectal wall and provides high accuracy in detecting and characterizing tumors within the superficial layers of the rectal wall. Reported accuracies range between 80% and 97% for T-stage determination [29]. The T-stage accuracy for TRUS (84.6%) is far superior to that of CT (70.5%) [30]. Evaluation of extent of tumor infiltration into the mesorectum (differentiating minimal from advanced T3 tumors and minimal T3 from T2 tumors) is of clinical interest in determining the need for neoadjuvant treatment but remains a challenge for TRUS [31,32]. Although TRUS performs better than MRI for

T1 tumors, similar for T2-3, it may be less accurate in characterizing locally advanced tumors (T4) with a tendency to understage [33]. The use of TRUS in assigning patients to transanal endoscopic microsurgery (TEM) versus traditional surgery remains controversial. Despite some authors reporting good accuracy for some T stages, a retrospective evaluation of the use of TRUS in patients selected to undergo TEM for presumed early-stage disease showed disappointing results with inaccurate staging seen in 44.8% of the 165 patients who underwent TRUS preoperatively (32.7% were understaged and 12.1% were overstaged) [34].

A significant limitation of TRUS is the limited field of view that compromises assessment of relationship of the tumor, mesorectal tumor implants, tumor invasion in extramural vessels and malignant nodes to the mesorectal fascia, in addition to limited assessment of high rectal tumors. MRI may better evaluate these findings as it offers a larger field of view.

Lymph node involvement: Detection of lymph node involvement with TRUS is limited to mesorectal nodes in the immediate vicinity of the tumor, which limits sensitivity. The sensitivity ranges from 45%–74% [35,36] and overall accuracy ranges from 62%–83% [37]. Although TRUS can frequently be used to detect regional lymph nodes, it has not been shown to be predictive of the histology of the visualized lymph nodes. Many lymph nodes measuring <5 mm in diameter have associated micrometastases, and some early-stage T1 and T2 tumors are likely to have lymph node micrometastases missed on TRUS. This may be responsible for the high rate of pelvic recurrence within this patient group [38]. Lymph nodes along the superior rectal vessels and outside the mesorectal fascia along the internal iliac and obturator nodal stations also cannot be assessed with TRUS. This can also be clinically important; 1 series showed that 27% of the rectal cancer study cohort (Dukes class C; T2–4 tumors) demonstrated positive lateral lymph node involvement, with a small percentage with lateral lymph node involvement only (4%) [39]. TRUS similarly is limited in evaluating lateral lymph nodes.

Magnetic Resonance Imaging

Like TRUS, MRI can depict the separate layers of the rectal wall with high-resolution, especially when performed at 3 T and with an endorectal coil [40]. Although the use of endorectal coils may provide improved diagnostic accuracy for T-stage as compared to phased-array coils alone, high-resolution imaging using phased-array MRI coils, as is used in multicenter trials (MERCURY), has performed well when done at either 1.5 or 3 T [41,42]. Additionally, when going from 1.5 T to 3 T there may be only small incremental improvements in diagnostic accuracy [43,44]. In a meta-analysis of 21 studies, phased-array coil MRI demonstrated a specificity of 94% (95% confidence interval [CI], 88–97) for determining circumferential resection margin involvement and a specificity of 75% (95% CI, 68–80) for determining T-stage [45]. However, MRI technique and image quality play a critical role in the attainment of these objectives, accuracy is dependent on obtaining high-resolution images (0.5–0.6 cm in-plane voxel size) that are perpendicular to the plane of the tumor.

Agreement between high-resolution MRI and TRUS in determining early (<T3 stage) versus advanced tumors (≥T3 stage) was found to be high (kappa value = 0.93) in a study of 86 consecutive patients where detailed sub-classification and distance of tumor extension beyond the wall were compared [46]. In a study by Fernandez-Esparach et al [33] there was similar agreement between high-resolution MRI and endorectal ultrasound (EUS). In another study comparing MRI and TRUS for measurement of the closest radial tumor-mesorectal margin, there was substantial agreement; however, the correlation between observers and modalities was modest, suggesting significant influence of reader performance on the diagnostic accuracy/reproducibility of TRUS [47]. This may be especially true for accuracy in lymph node detection with TRUS [48].

When used as a preoperative tool in advanced tumors, MRI has shown high diagnostic accuracy for both initial staging to determine surgical plan and determining resectability following neoadjuvant treatment [49-53]. Studies have shown MRI sensitivities ranging from 94%–100% and specificities from 85%–88% in assessment of the circumferential resection margin [54,55]. Hence, MRI is valuable in predicting complete resection with negative margins. In a multicenter cohort trial evaluating the use of high-resolution MRI with a phased-array coil in determining resectability, a total of 228 patients underwent curative-intent treatment based on the MRI characterization of tumor extent with 95.6% of patients achieving margin-negative results [50]. High-risk MRI features (extramural vascular invasion, mesorectal tumor depth >5 mm, T4 stage, involved circumferential resection margin) may correlate with higher risk for distant metastases [56,57]. In addition to initial staging prognostic features, MRI response to neoadjuvant treatment has been shown to be an indicator of long-term outcomes, including recurrence and survival [58-61].

Lymph node involvement: The differentiation of benign from metastatic locoregional nodes remains challenging. MRI is sensitive for detecting enlarged lymph nodes, but remains nonspecific for differentiating benign from malignant nodes with accuracies ranging from 59%–83% [33,43,62,63]. However, studies have shown high negative predictive value in the setting of node-negative determination by MRI, with negative predictive value ranging from 78%–87% [33,43,62,63]. Accuracy of lymph node staging may be improved with the use of specific lymph node agents taken up by the reticuloendothelial system; however, these agents are not currently available for clinical use in the United States [64,65].

Computed Tomography

CT was the first "locoregional staging" modality evaluated. Early enthusiastic reports of accuracy ranged between 85%–90% [66], and it was reported to be an excellent preoperative staging method, with the ability to depict both the primary tumor and metastases. Larger, more carefully controlled studies, however, have shown that the overall accuracy of contrast-enhanced CT is in the 50%–70% range, varying directly with the stage of the lesion. A limitation of CT is its inability to resolve the layers of the bowel wall; consequently, high T3 and T4 lesions are more accurately assessed than T2 or T3 lesions [67,68]. A recent study using thin-section multidetector CT (MDCT) demonstrated a higher accuracy of 86% in T-staging [69]. The accuracy of staging with CT may be improved with multiplanar reformats, allowing for true axial images through the rectum [70]. Overstaging, predominately due to desmoplastic peritumoral inflammation remains a challenge on CT, as with the other modalities (TRUS and MRI) [37].

Lymph node involvement: Like all modalities that rely primarily on size as determinant of involvement (ie, TRUS and MRI), CT remains relatively nonspecific for N-stage determination. There is little agreement on the critical cut-off diameter to determine if lymph nodes are involved in the disease process. One study suggests 4.5 mm; however, nodal size is not seen as a predictor of nodal status at surgery [13,30]. Since detection of nodes involved with tumor remains a difficult problem, if a colonic resection is planned, local node groups should be encompassed in a properly performed cancer operation. Accuracies for CT detection of lymph node stage range from 56%–84% [69-73].

Although EUS and MRI are the favored imaging modalities for locoregional staging, CT may be considered an option in instances where patients cannot undergo MRI and a thin-section optimized technique can be performed [69,70]. Locoregional staging is not routinely performed for colon cancer; however, CT is still recommended in the initial evaluation of all patients scheduled for colorectal carcinoma surgery because of its ability to obtain a rapid global evaluation and demonstrate potential complications of the tumor (eg, perforation, obstruction) that may not be clinically apparent [67].

CT Colonography

Virtual colonoscopy (or CT colonography [CTC]) has proven to be a valid tool in identifying both primary and synchronous colonic lesions. CTC is beneficial after incomplete colonoscopy to evaluate the remainder of the colon and is currently being advocated for use as a screening test [15]. More than 95% of patients prefer CTC to routine colonoscopy [16], and its use may increase patient willingness to receive regular screening for colorectal cancer. CTC has a staging accuracy of 81% [17], lower than conventional CT due to the reduced radiation dose used and lack of IV contrast. It has a sensitivity of 93% and a specificity of 97% for detecting polyps >1 cm. Sensitivity and specificity fall to 86% and 86%, respectively, for polyps measuring <1 cm [14]. There are no trials comparing CTC with other imaging modalities. It is likely not an optimal study for assessing local staging of distal rectal tumors due to the greater degree of noise related to reduced radiation and lack of IV contrast making soft tissue contrast less optimal.

Variant 2: Colorectal cancer. Staging for distant metastases.

Despite differences in locoregional staging between colon and rectal cancer, the evaluation of distant metastases is the same. The most common sites of metastatic involvement in colorectal cancer are the liver and lungs. Approximately 14.5% of patients present with synchronous liver involvement, and the 5-year cumulative metachronous liver metastasis rate is 14.5% (3.7% for stage I, 13.3% for stage II, and 30.4% for stage III [P<0.001]) [74]. The current paradigm of treatment is to remove all liver metastases if feasible because the survival for patients with liver metastases is <1% at 5 years [75]. Hence, accurate depiction of the size, distribution, and number of liver metastases is the primary goal of staging. The most commonly used modalities for staging include CT, MRI, and PET/CT.

It is difficult to determine the best imaging modality for patients with colorectal liver metastases because very few studies have adequately compared the accuracy of MRI to high-quality CT. The available evidence supports that both MRI and CT detect liver lesions with high accuracy. The subsequent sections address CT, MRI, and PET/CT for staging patients.

Computed Tomography

Among a group of 100 patients who underwent contrast-enhanced CT, CT arterioportography (CTAP), and MRI without and with contrast, the sensitivity and specificity for liver metastases were 73% and 96.5% for CT, 87.1% and 89.3% for CTAP, and 81.9% and 93.2% for MRI [68]. In addition, abdominal/pelvic CT with IV contrast has a high negative predictive value of 90% [76]. The false positive rate of CT in a prospective study by Valls et al [77] was 3.9% (10 of 257 findings; 95% CI, 1.9% to 7.1%), with intraoperative ultrasound and histopathology serving as the reference standard. Although CT may have diminished sensitivity compared to MRI in detection of liver lesions, an important determinant of its accuracy is CT technique. The use of MDCT, multiphase imaging, appropriate IV contrast bolus and timing, and optimal imaging parameters significantly narrows the differential between CT and MRI [78,79]. In studies evaluating IV contrast-enhanced optimized CT technique, detection rates for liver metastases range from 85%–91% [77,80]. CT may show more limited sensitivity in detecting metastases in the setting of fatty liver and following neoadjuvant therapy as compared with MRI [81,82]. Particularly in this setting of serial imaging, MDCT has proven an effective tool in assessment of the extent of liver disease in addition to providing a comprehensive assessment of extrahepatic disease. Recent studies have also noted CT morphologic criteria of responses in liver metastasis that have proven to be excellent predictors of overall survival and disease-free survival [20,21].

Detection of possible lung metastases is also an important part of the initial imaging evaluation of patients with colorectal carcinoma. Among patients with potentially resectable liver metastases and a negative initial chest PET, additional imaging with a chest CT revealed pulmonary metastases in only 5% of patients [83]. In another study, approximately one-fourth of the indeterminate lesions on preoperative CT ultimately developed into metastases and 1 in 10 into other lung malignancies [84]. However, in a single institution retrospective study including 200 consecutive patients, the findings at preoperative chest CT altered initial surgical management in only 1 patient [85]. Despite the very low specificity and frequency of indeterminate findings on chest CT, most investigators still advocate its use at baseline and in patients with more advanced-stage rectal carcinomas (T3/T4) [86-88].

Magnetic Resonance Imaging

Most studies show comparable or improved sensitivity for detection of colorectal liver metastases with IV conventional extracellular gadolinium agent-enhanced MRI compared to CT [81,82]. As mentioned in the previous section, MRI is more accurate than CT in detecting liver metastases in the setting of fatty liver and following neoadjuvant therapy [81,82,89]. Many recent studies focus on the value of hepatobiliary contrast agent-enhanced MRI and diffusion-weighted imaging [26,27,90-95]. In a retrospective study of 242 patients undergoing surgical resection for colorectal liver metastases (n=92 with pre-chemotherapy and pre-surgical MRI with a hepatobiliary IV contrast agent and n=150 without both pre-chemotherapy and pre-surgical hepatobiliary IV contrast agent-enhanced MRI), patients who underwent hepatobiliary MRI both pre-chemotherapy and pre-surgically had significantly lower rates of intra-hepatic recurrence (48% versus 65%, P=0.04), and fewer repeat hepatectomies (13% versus 25%, P=0.03) [92]. On the basis of the results of this study, the authors suggested that a hepatobiliary IV contrast agent-enhanced MRI may improve outcomes in the era of highly active neoadjuvant chemotherapy and disappearing lesions. Because of limited sensitivity of MRI for lung nodules, a chest CT with or without contrast can be performed in addition to MRI for complete staging.

Nuclear Medicine

Although there is some evidence to support the use of PET/CT in the local staging of patients with rectal carcinoma, the more common clinical application of PET/CT is in identifying nodal and distant metastases [96-98]. PET/CT is useful for determining overall stage and identifying patients with metastatic disease (sensitivity of 89% and specificity of 64%); however, the accuracy on a lesion-by-lesion basis is relatively low compared to contrast-enhanced CT and MRI for liver metastases (55% versus 89% in a study comparing PET/CT to MDCT) [99,100]. PET/CT may help to exclude other sites of disease beyond the liver or, in complex cases, to improve staging accuracy where it has been shown to result in a change in management in up to 8%–11% of patients [99,101-103]. Caution should be exercised, however, as the findings of PET/CT may be nonspecific, and could result in negative impact on patient care in up to 9% of patients [99]. Additionally, PET/CT has further reduced sensitivity for lesions in the setting of neoadjuvant therapy and should be used in conjunction with contrast CT or

MRI for presurgical planning of liver metastases [104]. PET/CT may add value in the positive predictive value of avid lymph nodes as it has a higher specificity than other modalities. The sensitivity of detecting nodal metastases is only 43% with a specificity of 80%, and again size is not a helpful characteristic.

There is also a potential role for PET/CT in restaging colorectal cancer after chemoradiation therapy by measuring the pretreatment and post-treatment standard uptake volume (SUV) and assessing response by decreasing SUV [105]. Limitations of PET include decreased sensitivity in detecting small colonic lesions ≤10 mm in diameter and decreased fluorine-18-2-fluoro-2-deoxy-D-glucose uptake by mucinous tumors [100].

Summary of Recommendations

- *Locoregional Staging of Rectal Cancer:* TRUS and high-resolution MRI are accurate modalities for evaluating local extent of tumor. TRUS may perform better for early stage tumors (T1-T2) and MRI for more advanced (T3 and above). High-resolution MRI with phased-array coil has high specificity for determining involvement of the circumferential resection margin (94%), which is an essential factor in presurgical planning. MRI holds advantages over TRUS in lateral pelvic lymph node and superior perirectal lymph node detection.
    - *Special circumstances:* In patients with advanced stage rectal carcinoma who cannot undergo MRI and for whom TRUS would be inadequate for evaluating nodes, CT may be appropriate to detect enlarged nodes or local organ invasion.
- *Evaluation of Distant Metastases:* Liver tumor involvement is best done with multi-phase contrast-enhanced MRI or contrast-enhanced CT (with both modalities, optimization of technique is essential for accuracy). The routine use of PET/CT is likely not indicated; however, it may provide guidance in cases of advanced, bi-lobar liver disease to exclude extrahepatic metastases prior to surgical intent to cure. The use of chest CT in preoperative planning is controversial, yet still widely performed along with abdomen pelvis CT or MRI.
    - *Special circumstances:* In patients with renal dysfunction who cannot undergo a contrast enhanced MRI or CT, either PET/CT or noncontrast MRI may be options to evaluate for metastatic liver disease. Noncontrast CT for liver staging is usually not indicated. However, there is little evidence to support an optimal/standardized-imaging algorithm in these patients. Discussion with a radiologist regarding local contrast administration policies and appropriate next steps is recommended.

Summary of Evidence

Of the 105 references cited in the *ACR Appropriateness Criteria® Pretreatment Staging Colorectal Cancer* document, 89 are categorized as diagnostic references including 4 well designed studies, 34 good quality studies, and 29 quality studies that may have design limitations. Additionally, 10 references are categorized as therapeutic references including 2 well designed studies and 5 good quality studies. There are 25 references that may not be useful as primary evidence. There are 6 references that are meta-analysis studies.

The 105 references cited in the *ACR Appropriateness Criteria® Pretreatment Staging Colorectal Cancer* document were published from 1991-2015.

While there are references that report on studies with design limitations, 45 well designed or good quality studies provide good evidence.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2015. *CA Cancer J Clin.* 2015;65(1):5-29.
2. Dighe S, Blake H, Koh MD, et al. Accuracy of multidetector computed tomography in identifying poor prognostic factors in colonic cancer. *Br J Surg.* 2010;97(9):1407-1415.
3. Dighe S, Purkayastha S, Swift I, et al. Diagnostic precision of CT in local staging of colon cancers: a meta-analysis. *Clin Radiol.* 2010;65(9):708-719.
4. Dighe S, Swift I, Magill L, et al. Accuracy of radiological staging in identifying high-risk colon cancer patients suitable for neoadjuvant chemotherapy: a multicentre experience. *Colorectal Dis.* 2012;14(4):438-444.
5. Smith NJ, Bees N, Barbachano Y, Norman AR, Swift RI, Brown G. Preoperative computed tomography staging of nonmetastatic colon cancer predicts outcome: implications for clinical trials. *Br J Cancer.* 2007;96(7):1030-1036.
6. Pricolo VE. Rectal cancer: the good, the bad, and the ugly. *Arch Surg.* 2011;146(5):544.
7. Middleton PF, Sutherland LM, Maddern GJ. Transanal endoscopic microsurgery: a systematic review. *Dis Colon Rectum.* 2005;48(2):270-284.
8. Nogue M, Salud A, Vicente P, et al. Addition of bevacizumab to XELOX induction therapy plus concomitant capecitabine-based chemoradiotherapy in magnetic resonance imaging-defined poor-prognosis locally advanced rectal cancer: the AVACROSS study. *Oncologist.* 2011;16(5):614-620.
9. Velenik V, Ocvirk J, Music M, et al. Neoadjuvant capecitabine, radiotherapy, and bevacizumab (CRAB) in locally advanced rectal cancer: results of an open-label phase II study. *Radiat Oncol.* 2011;6:105.
10. Boland PM, Fakih M. The emerging role of neoadjuvant chemotherapy for rectal cancer. *J Gastrointest Oncol.* 2014;5(5):362-373.
11. Glynne-Jones R, Tan D, Goh V. Pelvic MRI for guiding treatment decisions in rectal cancer. *Oncology (Williston Park).* 2014;28(8):667-677.
12. Barbaro B, Fiorucci C, Tebala C, et al. Locally advanced rectal cancer: MR imaging in prediction of response after preoperative chemotherapy and radiation therapy. *Radiology.* 2009;250(3):730-739.
13. Perez RO, Pereira DD, Proscurshim I, et al. Lymph node size in rectal cancer following neoadjuvant chemoradiation--can we rely on radiologic nodal staging after chemoradiation? *Dis Colon Rectum.* 2009;52(7):1278-1284.
14. Halligan S, Altman DG, Taylor SA, et al. CT colonography in the detection of colorectal polyps and cancer: systematic review, meta-analysis, and proposed minimum data set for study level reporting. *Radiology.* 2005;237(3):893-904.
15. Kim DH, Pickhardt PJ, Hanson ME, Hinshaw JL. CT colonography: performance and program outcome measures in an older screening population. *Radiology.* 2010;254(2):493-500.

16. Moawad FJ, Maydonovitch CL, Cullen PA, Barlow DS, Jenson DW, Cash BD. CT colonography may improve colorectal cancer screening compliance. *AJR Am J Roentgenol.* 2010;195(5):1118-1123.
17. Morrin MM, Farrell RJ, Raptopoulos V, McGee JB, Bleday R, Kruskal JB. Role of virtual computed tomographic colonography in patients with colorectal cancers and obstructing colorectal lesions. *Dis Colon Rectum.* 2000;43(3):303-311.
18. Lowenthal D, Zeile M, Lim WY, et al. Detection and characterisation of focal liver lesions in colorectal carcinoma patients: comparison of diffusion-weighted and Gd-EOB-DTPA enhanced MR imaging. *Eur Radiol.* 2011;21(4):832-840.
19. Scharitzer M, Ba-Ssalamah A, Ringl H, et al. Preoperative evaluation of colorectal liver metastases: comparison between gadoxetic acid-enhanced 3.0-T MRI and contrast-enhanced MDCT with histopathological correlation. *Eur Radiol.* 2013;23(8):2187-2196.
20. Brouquet A, Abdalla EK, Kopetz S, et al. High survival rate after two-stage resection of advanced colorectal liver metastases: response-based selection and complete resection define outcome. *J Clin Oncol.* 2011;29(8):1083-1090.
21. Shindoh J, Loyer EM, Kopetz S, et al. Optimal morphologic response to preoperative chemotherapy: an alternate outcome end point before resection of hepatic colorectal metastases. *J Clin Oncol.* 2012;30(36):4566-4572.
22. Chung WS, Kim MJ, Chung YE, et al. Comparison of gadoxetic acid-enhanced dynamic imaging and diffusion-weighted imaging for the preoperative evaluation of colorectal liver metastases. *J Magn Reson Imaging.* 2011;34(2):345-353.
23. Kim YK, Lee MW, Lee WJ, et al. Diagnostic accuracy and sensitivity of diffusion-weighted and of gadoxetic acid-enhanced 3-T MR imaging alone or in combination in the detection of small liver metastasis (</= 1.5 cm in diameter). *Invest Radiol.* 2012;47(3):159-166.
24. Wu LM, Hu J, Gu HY, Hua J, Xu JR. Can diffusion-weighted magnetic resonance imaging (DW-MRI) alone be used as a reliable sequence for the preoperative detection and characterisation of hepatic metastases? A meta-analysis. *Eur J Cancer.* 2013;49(3):572-584.
25. Yu MH, Lee JM, Hur BY, et al. Gadoxetic acid-enhanced MRI and diffusion-weighted imaging for the detection of colorectal liver metastases after neoadjuvant chemotherapy. *Eur Radiol.* 2015.
26. Koh DM, Collins DJ, Wallace T, Chau I, Riddell AM. Combining diffusion-weighted MRI with Gd-EOB-DTPA-enhanced MRI improves the detection of colorectal liver metastases. *Br J Radiol.* 2012;85(1015):980-989.
27. Macera A, Lario C, Petracchini M, et al. Staging of colorectal liver metastases after preoperative chemotherapy. Diffusion-weighted imaging in combination with Gd-EOB-DTPA MRI sequences increases sensitivity and diagnostic accuracy. *Eur Radiol.* 2013;23(3):739-747.
28. American College of Radiology. *Manual on Contrast Media*. Available at: http://www.acr.org/~/media/37D84428BF1D4E1B9A3A2918DA9E27A3.pdf.
29. Yimei J, Ren Z, Lu X, Huan Z. A comparison between the reference values of MRI and EUS and their usefulness to surgeons in rectal cancer. *Eur Rev Med Pharmacol Sci.* 2012;16(15):2069-2077.
30. Ju H, Xu D, Li D, Chen G, Shao G. Comparison between endoluminal ultrasonography and spiral computerized tomography for the preoperative local staging of rectal carcinoma. *Biosci Trends.* 2009;3(2):73-76.
31. Jurgensen C, Teubner A, Habeck JO, Diener F, Scherubl H, Stolzel U. Staging of rectal cancer by EUS: depth of infiltration in T3 cancers is important. *Gastrointest Endosc.* 2011;73(2):325-328.
32. Badger SA, Devlin PB, Neilly PJ, Gilliland R. Preoperative staging of rectal carcinoma by endorectal ultrasound: is there a learning curve? *Int J Colorectal Dis.* 2007;22(10):1261-1268.
33. Fernandez-Esparrach G, Ayuso-Colella JR, Sendino O, et al. EUS and magnetic resonance imaging in the staging of rectal cancer: a prospective and comparative study. *Gastrointest Endosc.* 2011;74(2):347-354.
34. Ashraf S, Hompes R, Slater A, et al. A critical appraisal of endorectal ultrasound and transanal endoscopic microsurgery and decision-making in early rectal cancer. *Colorectal Dis.* 2012;14(7):821-826.
35. Lin S, Luo G, Gao X, et al. Application of endoscopic sonography in preoperative staging of rectal cancer: six-year experience. *J Ultrasound Med.* 2011;30(8):1051-1057.
36. Ravizza D, Tamayo D, Fiori G, et al. Linear array ultrasonography to stage rectal neoplasias suitable for local treatment. *Dig Liver Dis.* 2011;43(8):636-641.
37. Low G, Tho LM, Leen E, et al. The role of imaging in the pre-operative staging and post-operative follow-up of rectal cancer. *Surgeon.* 2008;6(4):222-231.

38. Landmann RG, Wong WD, Hoepfl J, et al. Limitations of early rectal cancer nodal staging may explain failure after local excision. *Dis Colon Rectum.* 2007;50(10):1520-1525.
39. Moriya Y, Sugihara K, Akasu T, Fujita S. Importance of extended lymphadenectomy with lateral node dissection for advanced lower rectal cancer. *World J Surg.* 1997;21(7):728-732.
40. Kim SH, Lee JM, Lee MW, Kim GH, Han JK, Choi BI. Diagnostic accuracy of 3.0-Tesla rectal magnetic resonance imaging in preoperative local staging of primary rectal cancer. *Invest Radiol.* 2008;43(8):587-593.
41. Sani F, Foresti M, Parmiggiani A, et al. 3-T MRI with phased-array surface coil in the local staging of rectal cancer. *Radiol Med.* 2011;116(3):375-388.
42. Wong EM, Leung JL, Cheng CS, Lee JC, Li MK, Chung CC. Effect of endorectal coils on staging of rectal cancers by magnetic resonance imaging. *Hong Kong Med J.* 2010;16(6):421-426.
43. Karatag O, Karatag GY, Ozkurt H, et al. The ability of phased-array MRI in preoperative staging of primary rectal cancer: correlation with histopathological results. *Diagn Interv Radiol.* 2012;18(1):20-26.
44. Maas M, Lambregts DM, Lahaye MJ, et al. T-staging of rectal cancer: accuracy of 3.0 Tesla MRI compared with 1.5 Tesla. *Abdom Imaging.* 2012;37(3):475-481.
45. Al-Sukhni E, Milot L, Fruitman M, et al. Diagnostic accuracy of MRI for assessment of T category, lymph node metastases, and circumferential resection margin involvement in patients with rectal cancer: a systematic review and meta-analysis. *Ann Surg Oncol.* 2012;19(7):2212-2223.
46. Rafaelsen SR, Vagn-Hansen C, Sorensen T, Ploen J, Jakobsen A. Transrectal ultrasound and magnetic resonance imaging measurement of extramural tumor spread in rectal cancer. *World J Gastroenterol.* 2012;18(36):5021-5026.
47. Phang PT, Gollub MJ, Loh BD, et al. Accuracy of endorectal ultrasound for measurement of the closest predicted radial mesorectal margin for rectal cancer. *Dis Colon Rectum.* 2012;55(1):59-64.
48. Li JC, Liu SY, Lo AW, et al. The learning curve for endorectal ultrasonography in rectal cancer staging. *Surg Endosc.* 2010;24(12):3054-3059.
49. Del Vescovo R, Trodella LE, Sansoni I, et al. MR imaging of rectal cancer before and after chemoradiation therapy. *Radiol Med.* 2012;117(7):1125-1138.
50. Engelen SM, Maas M, Lahaye MJ, et al. Modern multidisciplinary treatment of rectal cancer based on staging with magnetic resonance imaging leads to excellent local control, but distant control remains a challenge. *Eur J Cancer.* 2013;49(10):2311-2320.
51. Extramural depth of tumor invasion at thin-section MR in patients with rectal cancer: results of the MERCURY study. *Radiology.* 2007;243(1):132-139.
52. Kim SH, Lee JM, Park HS, Eun HW, Han JK, Choi BI. Accuracy of MRI for predicting the circumferential resection margin, mesorectal fascia invasion, and tumor response to neoadjuvant chemoradiotherapy for locally advanced rectal cancer. *J Magn Reson Imaging.* 2009;29(5):1093-1101.
53. Wieder HA, Rosenberg R, Lordick F, et al. Rectal cancer: MR imaging before neoadjuvant chemotherapy and radiation therapy for prediction of tumor-free circumferential resection margins and long-term survival. *Radiology.* 2007;243(3):744-751.
54. Purkayastha S, Tekkis PP, Athanasiou T, Tilney HS, Darzi AW, Heriot AG. Diagnostic precision of magnetic resonance imaging for preoperative prediction of the circumferential margin involvement in patients with rectal cancer. *Colorectal Dis.* 2007;9(5):402-411.
55. Videhult P, Smedh K, Lundin P, Kraaz W. Magnetic resonance imaging for preoperative staging of rectal cancer in clinical practice: high accuracy in predicting circumferential margin with clinical benefit. *Colorectal Dis.* 2007;9(5):412-419.
56. Chang GJ, You YN, Park IJ, et al. Pretreatment high-resolution rectal MRI and treatment response to neoadjuvant chemoradiation. *Dis Colon Rectum.* 2012;55(4):371-377.
57. Hunter CJ, Garant A, Vuong T, et al. Adverse features on rectal MRI identify a high-risk group that may benefit from more intensive preoperative staging and treatment. *Ann Surg Oncol.* 2012;19(4):1199-1205.
58. Patel UB, Taylor F, Blomqvist L, et al. Magnetic resonance imaging-detected tumor response for locally advanced rectal cancer predicts survival outcomes: MERCURY experience. *J Clin Oncol.* 2011;29(28):3753-3760.
59. Shihab OC, Taylor F, Salerno G, et al. MRI predictive factors for long-term outcomes of low rectal tumours. *Ann Surg Oncol.* 2011;18(12):3278-3284.

60. Strassburg J, Ruppert R, Ptok H, et al. MRI-based indications for neoadjuvant radiochemotherapy in rectal carcinoma: interim results of a prospective multicenter observational study. *Ann Surg Oncol.* 2011;18(10):2790-2799.
61. Taylor FG, Quirke P, Heald RJ, et al. Preoperative high-resolution magnetic resonance imaging can identify good prognosis stage I, II, and III rectal cancer best managed by surgery alone: a prospective, multicenter, European study. *Ann Surg.* 2011;253(4):711-719.
62. Kim DJ, Kim JH, Ryu YH, Jeon TJ, Yu JS, Chung JJ. Nodal staging of rectal cancer: high-resolution pelvic MRI versus (1)(8)F-FDGPET/CT. *J Comput Assist Tomogr.* 2011;35(5):531-534.
63. Mizukami Y, Ueda S, Mizumoto A, et al. Diffusion-weighted magnetic resonance imaging for detecting lymph node metastasis of rectal cancer. *World J Surg.* 2011;35(4):895-899.
64. Koh DM, George C, Temple L, et al. Diagnostic accuracy of nodal enhancement pattern of rectal cancer at MRI enhanced with ultrasmall superparamagnetic iron oxide: findings in pathologically matched mesorectal lymph nodes. *AJR Am J Roentgenol.* 2010;194(6):W505-513.
65. Lambregts DM, Beets GL, Maas M, et al. Accuracy of gadofosveset-enhanced MRI for nodal staging and restaging in rectal cancer. *Ann Surg.* 2011;253(3):539-545.
66. Bernini A, Deen KI, Madoff RD, Wong WD. Preoperative adjuvant radiation with chemotherapy for rectal cancer: its impact on stage of disease and the role of endorectal ultrasound. *Ann Surg Oncol.* 1996;3(2):131-135.
67. Farouk R, Nelson H, Radice E, Mercill S, Gunderson L. Accuracy of computed tomography in determining resectability for locally advanced primary or recurrent colorectal cancers. *Am J Surg.* 1998;175(4):283-287.
68. Bhattacharjya S, Bhattacharjya T, Baber S, Tibballs JM, Watkinson AF, Davidson BR. Prospective study of contrast-enhanced computed tomography, computed tomography during arterioportography, and magnetic resonance imaging for staging colorectal liver metastases for liver resection. *Br J Surg.* 2004;91(10):1361-1369.
69. Ahmetoglu A, Cansu A, Baki D, et al. MDCT with multiplanar reconstruction in the preoperative local staging of rectal tumor. *Abdom Imaging.* 2011;36(1):31-37.
70. Anderson EM, Betts M, Slater A. The value of true axial imaging for CT staging of colonic cancer. *Eur Radiol.* 2011;21(6):1286-1292.
71. da Fonte AC, Chojniak R, de Oliveira Ferreira F, Pinto PN, dos Santos Neto PJ, Bitencourt AG. Inclusion of computed tomographic colonography on pre-operative CT for patients with colorectal cancer. *Eur J Radiol.* 2012;81(3):e298-303.
72. Duman M, Tas S, Mecit EA, et al. Preoperative local staging of colorectal cancer patients with MDCT. *Hepatogastroenterology.* 2012;59(116):1108-1112.
73. Stabile Ianora AA, Moschetta M, Pedote P, Scardapane A, Angelelli G. Preoperative local staging of colosigmoideal cancer: air versus water multidetector-row CT colonography. *Radiol Med.* 2012;117(2):254-267.
74. Manfredi S, Lepage C, Hatem C, Coatmeur O, Faivre J, Bouvier AM. Epidemiology and management of liver metastases from colorectal cancer. *Ann Surg.* 2006;244(2):254-259.
75. Alberts SR, Poston GJ. Treatment advances in liver-limited metastatic colorectal cancer. *Clin Colorectal Cancer.* 2011;10(4):258-265.
76. Cance WG, Cohen AM, Enker WE, Sigurdson ER. Predictive value of a negative computed tomographic scan in 100 patients with rectal carcinoma. *Dis Colon Rectum.* 1991;34(9):748-751.
77. Valls C, Andia E, Sanchez A, et al. Hepatic metastases from colorectal cancer: preoperative detection and assessment of resectability with helical CT. *Radiology.* 2001;218(1):55-60.
78. Numminen K, Isoniemi H, Halavaara J, et al. Preoperative assessment of focal liver lesions: multidetector computed tomography challenges magnetic resonance imaging. *Acta Radiol.* 2005;46(1):9-15.
79. Onishi H, Murakami T, Kim T, et al. Hepatic metastases: detection with multi-detector row CT, SPIO-enhanced MR imaging, and both techniques combined. *Radiology.* 2006;239(1):131-138.
80. Soyer P, Poccard M, Boudiaf M, et al. Detection of hypovascular hepatic metastases at triple-phase helical CT: sensitivity of phases and comparison with surgical and histopathologic findings. *Radiology.* 2004;231(2):413-420.
81. Kulemann V, Schima W, Tamandl D, et al. Preoperative detection of colorectal liver metastases in fatty liver: MDCT or MRI? *Eur J Radiol.* 2011;79(2):e1-6.

82. van Kessel CS, van Leeuwen MS, van den Bosch MA, et al. Accuracy of multislice liver CT and MRI for preoperative assessment of colorectal liver metastases after neoadjuvant chemotherapy. *Dig Surg.* 2011;28(1):36-43.
83. Kronawitter U, Kemeny NE, Heelan R, Fata F, Fong Y. Evaluation of chest computed tomography in the staging of patients with potentially resectable liver metastases from colorectal carcinoma. *Cancer.* 1999;86(2):229-235.
84. Christoffersen MW, Bulut O, Jess P. The diagnostic value of indeterminate lung lesions on staging chest computed tomographies in patients with colorectal cancer. *Dan Med Bull.* 2010;57(1):A4093.
85. Grossmann I, Avenarius JK, Mastboom WJ, Klaase JM. Preoperative staging with chest CT in patients with colorectal carcinoma: not as a routine procedure. *Ann Surg Oncol.* 2010;17(8):2045-2050.
86. Choi DJ, Kwak JM, Kim J, Woo SU, Kim SH. Preoperative chest computerized tomography in patients with locally advanced mid or lower rectal cancer: its role in staging and impact on treatment strategy. *J Surg Oncol.* 2010;102(6):588-592.
87. McQueen AS, Scott J. CT staging of colorectal cancer: what do you find in the chest? *Clin Radiol.* 2012;67(4):352-358.
88. Kirke R, Rajesh A, Verma R, Bankart MJ. Rectal cancer: incidence of pulmonary metastases on thoracic CT and correlation with T staging. *J Comput Assist Tomogr.* 2007;31(4):569-571.
89. Berger-Kulemann V, Schima W, Baroud S, et al. Gadoxetic acid-enhanced 3.0 T MR imaging versus multidetector-row CT in the detection of colorectal metastases in fatty liver using intraoperative ultrasound and histopathology as a standard of reference. *Eur J Surg Oncol.* 2012;38(8):670-676.
90. Hammerstingl R, Huppertz A, Breuer J, et al. Diagnostic efficacy of gadoxetic acid (Primovist)-enhanced MRI and spiral CT for a therapeutic strategy: comparison with intraoperative and histopathologic findings in focal liver lesions. *Eur Radiol.* 2008;18(3):457-467.
91. Kim YK, Park G, Kim CS, Yu HC, Han YM. Diagnostic efficacy of gadoxetic acid-enhanced MRI for the detection and characterisation of liver metastases: comparison with multidetector-row CT. *Br J Radiol.* 2012;85(1013):539-547.
92. Knowles B, Welsh FK, Chandrakumaran K, John TG, Rees M. Detailed liver-specific imaging prior to pre-operative chemotherapy for colorectal liver metastases reduces intra-hepatic recurrence and the need for a repeat hepatectomy. *HPB (Oxford).* 2012;14(5):298-309.
93. Kim SH, Lee JM, Hong SH, et al. Locally advanced rectal cancer: added value of diffusion-weighted MR imaging in the evaluation of tumor response to neoadjuvant chemo- and radiation therapy. *Radiology.* 2009;253(1):116-125.
94. Koh DM, Collins DJ. Diffusion-weighted MRI in the body: applications and challenges in oncology. *AJR Am J Roentgenol.* 2007;188(6):1622-1635.
95. Sugita R, Ito K, Fujita N, Takahashi S. Diffusion-weighted MRI in abdominal oncology: clinical applications. *World J Gastroenterol.* 2010;16(7):832-836.
96. Mainenti PP, Iodice D, Segreto S, et al. Colorectal cancer and 18FDG-PET/CT: what about adding the T to the N parameter in loco-regional staging? *World J Gastroenterol.* 2011;17(11):1427-1433.
97. Kinner S, Antoch G, Bockisch A, Veit-Haibach P. Whole-body PET/CT-colonography: a possible new concept for colorectal cancer staging. *Abdom Imaging.* 2007;32(5):606-612.
98. Veit-Haibach P, Kuehle CA, Beyer T, et al. Diagnostic accuracy of colorectal cancer staging with whole-body PET/CT colonography. *Jama.* 2006;296(21):2590-2600.
99. Ramos E, Valls C, Martinez L, et al. Preoperative staging of patients with liver metastases of colorectal carcinoma. Does PET/CT really add something to multidetector CT? *Ann Surg Oncol.* 2011;18(9):2654-2661.
100. Shin SS, Jeong YY, Min JJ, Kim HR, Chung TW, Kang HK. Preoperative staging of colorectal cancer: CT vs. integrated FDG PET/CT. *Abdom Imaging.* 2008;33(3):270-277.
101. Briggs RH, Chowdhury FU, Lodge JP, Scarsbrook AF. Clinical impact of FDG PET-CT in patients with potentially operable metastatic colorectal cancer. *Clin Radiol.* 2011;66(12):1167-1174.
102. Eglinton T, Luck A, Bartholomeusz D, Varghese R, Lawrence M. Positron-emission tomography/computed tomography (PET/CT) in the initial staging of primary rectal cancer. *Colorectal Dis.* 2010;12(7):667-673.
103. Llamas-Elvira JM, Rodriguez-Fernandez A, Gutierrez-Sainz J, et al. Fluorine-18 fluorodeoxyglucose PET in the preoperative staging of colorectal cancer. *Eur J Nucl Med Mol Imaging.* 2007;34(6):859-867.

104. Spatz J, Holl G, Sciuk J, Anthuber M, Arnholdt HM, Markl B. Neoadjuvant chemotherapy affects staging of colorectal liver metastasis--a comparison of PET, CT and intraoperative ultrasound. *Int J Colorectal Dis*. 2011;26(2):165-171.
105. Capirci C, Rubello D, Pasini F, et al. The role of dual-time combined 18-fluorodeoxyglucose positron emission tomography and computed tomography in the staging and restaging workup of locally advanced rectal cancer, treated with preoperative chemoradiation therapy and radical surgery. *Int J Radiat Oncol Biol Phys*. 2009;74(5):1461-1469.