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ABDOMINAL IMAGING

ORIGINAL ARTICLE

Diagnostic performance of magnetic resonance imaging for lateral pelvic lymph node metastasis in patients with rectal carcinoma: a meta-analysis and systematic review

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PURPOSE

Accurate identification of lateral pelvic lymph node (LPLN) metastasis is imperative for guiding LPLN dissection to reduce local recurrence in patients with rectal carcinoma. This meta-analysis aimed to investigate the diagnostic performance of magnetic resonance imaging (MRI) for LPLN metastasis in patients with rectal carcinoma.

METHODS

Embase, PubMed, Web of Science, and the Cochrane Library were searched to identify studies related to the diagnostic performance of MRI for LPLN metastasis in patients with rectal carcinoma through June 2024.

RESULTS

This meta-analysis included 12 studies comprising 1,015 patients. The pooled sensitivity [95% confidence interval (CI)] and specificity (95% CI) of MRI for diagnosing LPLN metastasis were 0.66 (0.53, 0.80) and 0.82 (0.76, 0.88), respectively. The pooled positive likelihood ratio (LR) (95% CI) and negative LR (95% CI) were 2.82 (2.14, 3.51) and 0.41 (0.27, 0.55), respectively. The summary receiver operating characteristic curve indicated an area under the curve of 0.824. The quality of the included studies was acceptable according to the Quality Assessment of Diagnostic Accuracy Studies-2 tool. However, publication bias was present, as indicated by Deeks' funnel plot asymmetry test (P = 0.020). Considering that heterogeneity contributed to publication bias, a meta-regression analysis was conducted and revealed that heterogeneity could be influenced by sample size, with sample size negatively associated with sensitivity (coefficient: -0.002, P = 0.009) and positively associated with negative LR (coefficient: 0.002, P = 0.029).

CONCLUSION

Preoperative MRI demonstrates an acceptable ability to identify LPLN metastasis in patients with rectal carcinoma.

CLINICAL SIGNIFICANCE

Clinically, our findings support that preoperative MRI has acceptable diagnostic ability for LPLN metastasis in patients with rectal carcinoma. The preoperative application of MRI may aid in optimizing treatment strategies and improving prognosis in this population.

KEYWORDS

Rectal carcinoma, lateral pelvic lymph node metastasis, magnetic resonance imaging, sensitivity, specificity

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Lateral pelvic lymph node (LPLN) metastasis is considered one of the major causes of local recurrence in patients with rectal carcinoma.[1] In order to reduce local recurrence rates in patients with LPLN metastasis, LPLN dissection should be performed,[2-4] and accurate diagnosis of LPLN metastasis is imperative for guiding this operation.[5-8] Currently, imaging methods such as computed tomography (CT), endorectal ultrasound, and ^{18}F-fluorodeoxyglucose-positron emission tomography (FDG-PET) are used for diagnosing LPLN metastasis, yet each has limitations in sensitivity or specificity.[7,9] Therefore, investigating potential methods for diagnosing LPLN metastasis is essential to improve the management of patients with rectal carcinoma.

Magnetic resonance imaging (MRI), with its outstanding soft tissue contrast resolution, demonstrates good potential for diagnosing LPLN metastasis in patients with rectal carcinoma.[7] Several studies have explored the diagnostic performance of MRI for LPLN metastasis in these patients.[10-21] For instance, one previous study found that when the short-axis cut-off value was 5 mm, the accuracy, sensitivity, and specificity of MRI for diagnosing LPLN metastasis were 77.6%, 68.6%, and 79.7%, respectively; the area under the curve (AUC) was 0.74.[15] Another study applied a 6.8 mm cut-off for the short axis and reported that the sensitivity, specificity, and AUC were 77.8%, 72.1%, and 0.761, respectively.[20] To support the wider application of MRI in patients with rectal carcinoma suspected of LPLN metastasis, it is crucial to conduct a pooled analysis to evaluate the diagnostic performance of MRI for LPLN metastasis in this population. Accordingly, this meta-analysis aimed to provide a comprehensive evaluation of the diagnostic performance of MRI for LPLN metastasis in patients with rectal carcinoma.

Main points

- The ability of magnetic resonance imaging to diagnose lateral pelvic lymph node metastasis was evaluated.
- This meta-analysis included 12 studies with 1,015 patients with rectal carcinoma.
- The pooled sensitivity and specificity were 0.66 and 0.82, respectively.
- The pooled positive and negative likelihood ratios were 2.82 and 0.41, respectively.
- The pooled area under the curve of the summary receiver operating characteristic curve was 0.824.

Methods

The present study is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement and published recommendations. Ethics information and informed consent forms were not required, as systematic reviews typically involve synthesizing and summarizing existing literature rather than directly engaging in human or animal experiments.

Search scheme

Embase, PubMed, Web of Science, and the Cochrane Library were searched to identify studies related to the diagnosis of LPLN metastasis using MRI technology in patients with rectal carcinoma. The keywords used for the search were as follows: "magnetic resonance imaging," "MRI," "MR," "rectal cancer," "rectal carcinoma," and "lateral pelvic lymph node metastasis." The retrieval period was from database inception to June 2024. After excluding duplicate studies, titles and abstracts of the remaining studies were reviewed based on the eligibility criteria. Subsequently, full-text articles were assessed for study eligibility. KL, PW, YG, and YD independently completed this part of the work. In case of disagreement, a decision was made after consultation.

Criteria of the study screen

During the screening process, the inclusion criteria were as follows: i) patients were diagnosed with rectal carcinoma; ii) patients underwent MRI examination for the detection of LPLN metastasis; iii) studies contained complete 2 × 2 contingency tables [including true positive (TP), false positive (FP), false negative (FN), and true negative (TN)] or provided sufficient data to construct 2 × 2 contingency tables for assessing diagnostic efficacy; iv) studies were published in English. The exclusion criteria were as follows: i) case reports, animal experiments, reviews, or meta-analyses; ii) studies lacking or not using histopathological examination as the reference standard; iii) studies by the same authors with overlapping study populations.

Data collection

The first author's name, publication year, study design, sample size, age, gender, and MRI-related information were collected. In addition, 2 × 2 contingency tables were obtained. If the studies did not report direct data on 2 × 2 contingency tables, they were calculated using sensitivity, specificity, positive sample size (PSZ), and negative sample size (NSZ). The formulas used were as follows: TP = Sensitivity × PSZ; FN = PSZ − TP; TN = Specificity × NSZ; FP = NSZ − TN. Data collection was performed independently by KL, PW, YG, and YD. When results were inconsistent, they were resolved through joint discussion.

Statistical analysis

STATA statistical software (version 14.0; StataCorp, College Station, TX, USA) was used for data analyses. Pooled sensitivity, pooled specificity, pooled positive likelihood ratio (LR), and pooled negative LR, each with a 95% confidence interval (CI), were analyzed. Additionally, the summary receiver operating characteristic (SROC) curve was generated. Heterogeneity was assessed using the chi-square test and the I^2 test; $P < 0.05$ indicated significant heterogeneity for the former, and $I^2 \geq 50\%$ for the latter. Deeks' funnel plot was used to evaluate publication bias through Deeks' asymmetry test. Random-effects models were applied in all syntheses. Meta-regression was conducted to further explore sources of heterogeneity. The quality of the included studies was assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 tool[22] by XL and KL independently. Discrepancies in assessment were resolved through discussion. A $P < 0.05$ was considered statistically significant.

Results

Study flow

A total of 260 studies were identified through database searching. After excluding 58 duplicates, 202 studies were screened based on title and abstract. Subsequently, 184 studies were excluded, and the remaining 18 studies were assessed through full-text review. Finally, 6 studies were excluded, and a total of 12 studies related to the diagnosis of LPLN metastasis using MRI in patients with rectal carcinoma[10-21] were included in this meta-analysis (Figure 1).

Features of enrolled studies

This meta-analysis included 4 prospective studies and 8 retrospective studies. The MRI findings were all preoperative in the included studies. The MRI modality included T2-weighted imaging (T2WI); T1-weighted imaging and T2WI; and T2WI and diffusion-weighted imaging; however, Dev et al.[16] did not report this information. The cut-off value of the short-axis or long-axis diameter of the LPLN used to distinguish positive and negative samples ranged from 4 to 10 mm. The complete features of all studies are presented in Table 1.

Sensitivity and specificity of magnetic resonance imaging for diagnosing lateral pelvic lymph node metastasis

Heterogeneity existed in the sensitivity data (I^2 = 83.0%, P < 0.001). The pooled sensitivity (95% CI) was 0.66 (0.53, 0.80; Figure 2a). The specificity data were also heterogeneous (I^2 = 92.5%, P < 0.001). The pooled specificity (95% CI) was 0.82 (0.76, 0.88; Figure 2b).

Positive likelihood ratio and negative likelihood ratio of magnetic resonance imaging for diagnosing lateral pelvic lymph node metastasis

Data on the positive LR of MRI showed no significant heterogeneity (I^2 = 29.6%, P = 0.155). The pooled positive LR (95% CI) was 2.82 (2.14, 3.51; Figure 3a). Heterogeneity was present in the negative LR data (I^2 = 74.1%, P < 0.001). The pooled negative LR (95% CI) was 0.41 (0.27, 0.55; Figure 3b).

Summary receiver operating characteristic curve of magnetic resonance imaging for diagnosing lateral pelvic lymph node metastasis

An SROC curve was constructed to assess the overall ability of MRI to diagnose LPLN metastasis in patients with rectal carcinoma. The AUC of MRI for diagnosing LPLN metastasis was 0.824. The standard error of the AUC was 0.023 (Figure 4).

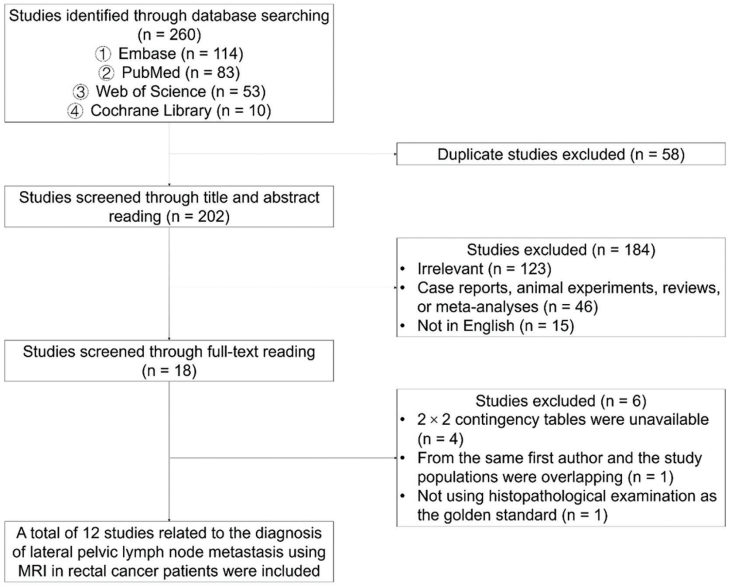

Figure 1. Study screen. MRI, magnetic resonance imaging.

Quality assessment

All studies had a low risk of bias regarding the reference standard, as well as follow-up and timing. More than 50% of the studies had an unclear risk of bias regarding patient selection and index test, whereas the remaining studies were assessed as having a low risk of bias. All studies had low applicability concerns regarding the reference standard. More than 50% of the studies had low applicability concerns regarding patient selection, and the others were assessed as having unclear applicability concerns. Moreover, more than 50% of the studies had unclear applicability concerns regarding the index test, whereas the remaining studies were assessed as having low applicability concerns (Figure 5a). Detailed information on each study with high, unclear, or low risk of bias or applicability concerns is shown in Figure 5b.

Publication bias and factors related to heterogeneity

Publication bias was present among the included studies (P = 0.020; Supplementary Figure 1). Considering that heterogeneity among studies may contribute to publication bias, a meta-regression analysis was conducted to examine factors potentially influencing heterogeneity. It was found that sample size was negatively associated with sensitivity (coefficient: -0.002, P = 0.009). Additionally, sample size was positively associated with negative LR (coefficient: 0.002, P = 0.029). Study type, cut-off value, and sample size were not significantly associated with specificity or positive LR (all P > 0.05; Table 2).

Table 1. Features of included studies

Study ID	Study type	Sample size	Age (years)	Men (n)	MRI findings	Modality of MRI	Cut-off value† (mm)	TP	FP	FN	TN
Matsuoka et al.[10]	Prospective	51	63.0[a]	35	Preoperative	T2WI	5	10	9	5	27
Akasu et al.[11]	Prospective	104	58.0[b]	82	Preoperative	T2WI	4	13	12	2	77
Ogawa et al.[12]	Retrospective	77	(-)	(-)	Preoperative	T1WI and T2WI	5	8	29	2	38
Akiyoshi et al.[13]	Retrospective	77	61.0[b]	55	Preoperative	T2WI	8	21	7	10	39
Ishibe et al.[14]	Prospective	84	62.0[a]	53	Preoperative	T1WI and T2WI	10	12	21	4	47
Ogawa et al.[15]	Retrospective	268	(-)	(-)	Preoperative	T1WI and T2WI	10	14	2	37	215
Dev et al.[16]	Prospective	43	(-)	21	Preoperative	Not mentioned	8	4	3	5	31
Kim et al.[17]	Retrospective	57	57.0[b]	33	Preoperative	T2WI and DWI	7.5	20	10	3	24
Amano et al.[18]	Retrospective	184‡	65.0[b]	25	Preoperative	T1WI and T2WI	6	6	5	11	162
Sekido et al.[19]	Retrospective	60	60.0[b]	40	Preoperative	T2WI	7	9	6	3	42
Ishizaki et al.[20]	Retrospective	61	62.0[b]	37	Preoperative	T2WI	6.8	14	12	4	31
Zhang et al.[21]	Retrospective	87	58.7[a]	48	Preoperative	T2WI	7	14	15	7	51

†Cut-off value refers to the short-axis or long-axis diameter of lateral pelvic lymph nodes used to distinguish between positive and negative samples.
‡Indicates that 184 was the number of regions, not the number of patients.
For age: superscript [a]indicates mean age; superscript [b]indicates median age.
MRI, magnetic resonance imaging; TP, true positive; FP, false positive; FN, false negative; TN, true negative; T2WI, T2-weighted imaging; T1WI, T1-weighted imaging; DWI, diffusion-weighted imaging.

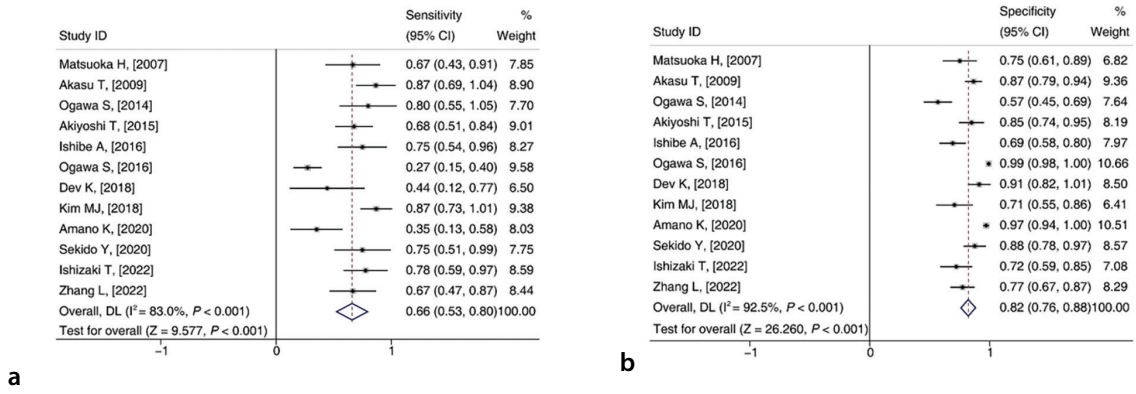

Figure 2. Forest plots of sensitivity and specificity. Pooled sensitivity (**a**) and pooled specificity (**b**) of MRI for diagnosing LPLN metastasis in patients with rectal carcinoma. MRI, magnetic resonance imaging; LPLN, lateral pelvic lymph node, CI, confidence interval.

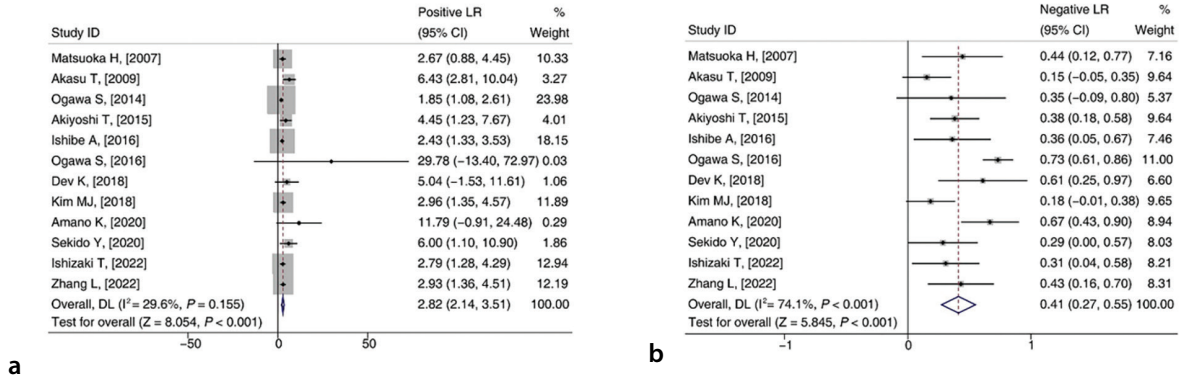

Figure 3. Forest plots of positive and negative likelihood ratios (LRs). Pooled positive LR (**a**) and negative LR (**b**) of MRI for diagnosing LPLN metastasis in patients with rectal carcinoma. MRI, magnetic resonance imaging; LPLN, lateral pelvic lymph node, CI, confidence interval.

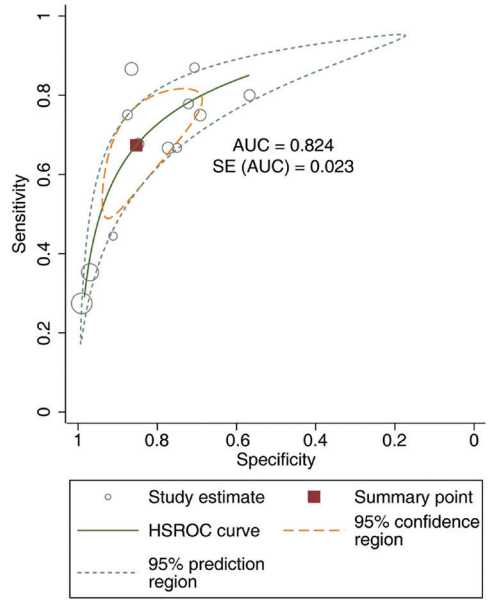

Figure 4. Summary receiver operating characteristic curve of the diagnostic performance of MRI. MRI, magnetic resonance imaging; AUC, area under the curve; HSROC, hierarchical summary receiver operating characteristic.

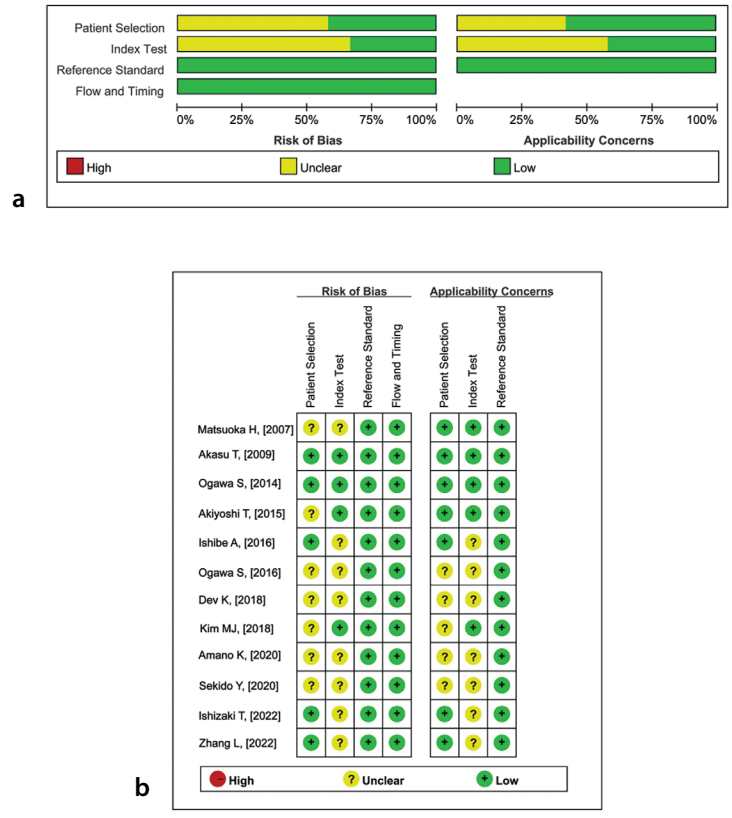

Figure 5. Quality assessment by QUADAS-2 tools. The proportion of studies with high, unclear, and low risk of bias, as well as applicability concerns (**a**). Detailed information for each study with high, unclear, and low risk of bias, as well as applicability concerns (**b**).

Table 2. Heterogeneity source analysis via meta-regression

Items	Coefficient	Standard error	95% CI	*P* value for t-test
Sensitivity				
Study type	0.010	0.092	(-0.202, 0.222)	0.916
Cut-off value	-0.019	0.024	(-0.073, 0.036)	0.459
Sample size	-0.002	0.198	(-0.003, -0.001)	0.009
P value for F-test	0.018			
Specificity				
Study type	-0.043	0.075	(-0.217, 0.130)	0.579
Cut-off value	0.002	0.019	(-0.043, 0.047)	0.924
Sample size	0.001	0.001	(-0.001, 0.002)	0.061
P value for F-test	0.223			
Positive LR				
Study type	-0.273	1.036	(-2.661, 2.116)	0.799
Cut-off value	-0.100	0.279	(-0.743, 0.542)	0.728
Sample size	0.035	0.027	(-0.029, 0.098)	0.244
P value for F-test	0.650			
Negative LR				
Study type	-0.007	0.107	(-0.253, 0.240)	0.953
Cut-off value	0.025	0.027	(-0.037, 0.088)	0.380
Sample size	0.002	0.001	(0.001, 0.003)	0.029
P value for F-test	0.040			

CI: confidence interval; LR: likelihood ratio.

Discussion

LPLN metastasis occurs in approximately 10% to 25% of patients with rectal carcinoma, which is associated with increased local recurrence rates.[4,23] Of note, two previous meta-analyses found that the pooled sensitivity (95% CI) of MRI for diagnosing LPLN metastasis in patients with rectal carcinoma was 0.72 (0.66, 0.78)[24] and 0.88 (0.85, 0.91)[25]; the pooled specificity (95% CI) was 0.80 (0.73, 0.85)[24] and 0.85 (0.78, 0.90).[25] In the current meta-analysis, we found that the pooled sensitivity (95% CI) and specificity (95% CI) of MRI for diagnosing LPLN metastasis were 0.66 (0.53, 0.80) and 0.82 (0.76, 0.88), respectively, in patients with rectal carcinoma. The pooled sensitivity differed between our meta-analysis and previous meta-analyses.[24,25] A potential reason may be that the cut-off value for lymph node size used to identify LPLN metastasis varied among studies, which contributed to differences in MRI sensitivity and ultimately affected the pooled analysis.

LR refers to the probability ratio of a specific test result between diseased and non-diseased individuals, and the value of LR has important implications.[26-28] In general, a higher positive LR and a lower negative LR suggest superior diagnostic performance of a specific test.[28,29] The present meta-analysis observed that the positive LR and negative LR of MRI for diagnosing LPLN metastasis were 2.82 and 0.41, respectively, in patients with rectal carcinoma. Therefore, our findings suggest that MRI possesses moderate diagnostic performance for LPLN metastasis in patients with rectal carcinoma.

The receiver operating characteristic curve is applied to evaluate the overall diagnostic performance of a test.[30,31] Generally, an AUC value greater than 0.8 indicates good overall diagnostic performance.[30,32] A previous meta-analysis reported that the AUC of MRI for diagnosing LPLN metastasis was 0.88 in patients with rectal carcinoma.[25] Similarly, in our meta-analysis, the AUC was 0.82. Hence, our findings indicate that MRI is useful for diagnosing LPLN metastasis in patients with rectal carcinoma.

Publication bias refers to the tendency for studies with favorable or statistically significant results to be more likely to be published than those with non-substantial results, which may affect the conclusions of a meta-analysis.[33-35] In the current meta-analysis, Deeks' funnel plot asymmetry test showed that publication bias existed regarding the diagnostic performance of MRI for LPLN metastasis in patients with rectal carcinoma. We speculated that a potential contributor to this bias might be heterogeneity among the included studies.[35,36] To further explore the factors influencing heterogeneity, we conducted a meta-regression analysis. It was found that heterogeneity could be influenced by sample size, as sample size was negatively related to sensitivity but positively related to negative LR. Due to the presence of publication bias and heterogeneity in the enrolled studies, our findings should be interpreted with caution. Further rigorous studies are needed to verify the diagnostic performance of MRI for LPLN metastasis in patients with rectal carcinoma.

Several limitations should be noted in this meta-analysis. (1) The cut-off value of the short-axis or long-axis diameter of the LPLN used to distinguish positive and negative samples ranged from 4 to 10 mm in the included studies. Therefore, our meta-analysis could not determine the optimal cut-off value of lymph node size for identifying LPLN metastasis, which should be further investigated. (2) A comparison of the diagnostic performance of MRI with other imaging methods, such as CT and ^{18}F-FDG-PET, could be further explored. (3) Most of the included studies were conducted in Japan, which may limit the generalizability of the findings.

In conclusion, preoperative MRI is recommended for identifying LPLN metastasis in patients with rectal carcinoma, which may further assist in optimizing treatment strategies in this population.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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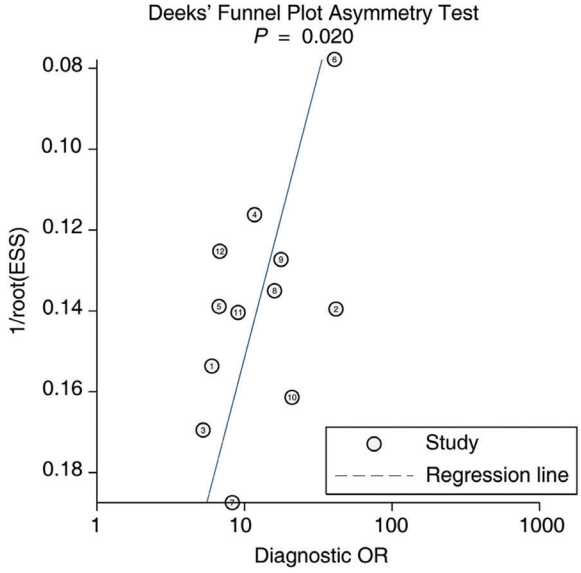

Supplementary Figure 1. Deeks' funnel plot asymmetry test. EES, expected effect size; OR, odds ratio.