



## Research article

# Diagnostic performance of computed tomography for bowel endometriosis: A systematic review and meta-analysis

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## ABSTRACT

**Purpose:** To perform a systematic review and meta-analysis regarding the performance of CT for diagnosis of bowel endometriosis.

**Materials and methods:** Pubmed and EMBASE were systematically searched up to March 28, 2019. Diagnostic accuracy studies using CT for diagnosis of bowel endometriosis using laparoscopy followed by histopathology as the reference standard were included. Methodological quality of the included studies was evaluated using Quality Assessment of Diagnostic Accuracy Studies-2. Sensitivity and specificity were pooled using hierarchical summary receiver operating modelling. Meta-regression analysis was done to explore heterogeneity.

**Results:** Twelve studies (1091 patients) were included. Pooled sensitivity and specificity were 0.92 (95% confidence interval [CI], 0.83–0.97) and 0.95 (95% CI, 0.88–0.98), respectively. Substantial heterogeneity was present:  $I^2 = 92.38\%$  for sensitivity and  $89.09\%$  for specificity. Deeks' asymmetry test suggested publication bias ( $p = 0.04$ ). At meta-regression analysis, history of prior surgery for endometriosis was the only significant factor affecting heterogeneity ( $p < 0.01$ ). Specifically, studies that included patients with such history demonstrated significantly greater specificity than studies that did not (0.95 [95% CI, 0.91–1.00] vs 0.75 [95% CI, 0.43–1.00]).

**Conclusions:** CT shows excellent performance in the diagnosis of bowel endometriosis. Due to small number of included studies and publication bias, further studies may be needed to validate these results.

## 1. Introduction

Endometriosis, defined as the presence of endometrial stroma and glands outside the uterus, is a common disease usually affecting women of reproductive age causing various symptoms such as pelvic pain and infertility [1]. Although most endometriotic lesions are frequently found in the pelvic peritoneum, they are sometimes located in the bowel, which can be problematic regarding diagnosis and management of the patient. It is estimated that approximately 4–37% of patients with endometriosis have bowel involvement, with the sigmoid colon and rectum being the most common location [2,3]. Endometriotic nodules typically cause gastrointestinal symptoms such as bloating, dyschezia, constipation, or diarrhea—however, these symptoms are nonspecific and it is sometimes uncertain if which symptoms are caused by pelvic or bowel endometriosis [1,4]. Furthermore, it is crucial to assess not only

the presence of bowel involvement, but also the location, and extent before surgery, in order provide the most optimal management plan for the patient.

Until now, several radiological modalities have been used for diagnosing endometriosis, such as transvaginal ultrasonography, magnetic resonance imaging (MRI), and computed tomography (CT). Among them MRI has been acknowledged to play a pivotal role in preoperative assessment of endometriosis, due to its capacity for excellent soft tissue characterization (i.e., detection of hemorrhagic content) [5]. A recent meta-analysis reported that MRI had a sensitivity and specificity of 0.83 and 0.90, respectively, for diagnosis of deep infiltrating endometriosis [6]. Although MRI may be a good modality for evaluating the endometriosis, in general, when it comes to diagnosis of bowel endometriosis, it has been suggested that MRI has several pitfalls. Endometriotic lesions in the bowel often harbor histological

**Abbreviations:** CT, computed tomography; HSROC, hierarchical summary receiver operating characteristic; MRI, magnetic resonance imaging; PICOS, patient, index test, comparator, outcome, and study design; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; QUADAS-2, Quality Assessment of Diagnostic Accuracy Studies-2

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content other than hemorrhage—that is fibrosis, leading to variability in the MRI signal pattern. In addition, lesions more than 8 cm superior to the anal margin may be missed even when using endorectal coils that are required for optimizing image quality [7]. On the other hand, CT may have several advantages over MRI in this regard (i.e., shorter acquisition time, wider coverage). Therefore, investigators have suggested that CT may have a potential role in diagnosis of bowel endometriosis [1]. Despite the fact that various studies have dealt with the subject of CT in patients with bowel endometriosis, the diagnostic performance of CT for diagnosis of bowel endometriosis is still poorly established.

Therefore, the purpose of this study was to perform a systematic review and meta-analysis regarding the performance of CT for diagnosis of bowel endometriosis.

## 2. Materials and methods

We performed the current meta-analysis according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8]. We formulated the research question based on the patient, index test, comparator, outcome, and study design (PICOS) criteria as the following: What is the performance of CT for diagnosis of bowel endometriosis, as compared with histopathology, in original articles?

### 2.1. Literature search

We conducted a computerized search of Pubmed and EMBASE databases up to November 2<sup>nd</sup>, 2017 using the following search query: ("computed tomography" OR "computed tomographic" OR "CT") AND (endometriosis) AND ("sensitivity" OR "specificity" OR "accuracy" OR "predictive"). No filters were applied (i.e., language). The references of the initially identified studies were also examined to identify additional relevant papers.

### 2.2. Study selection

Two reviewers (S.W. and C.H.S.) independently performed the literature search and study selection process. Disagreements were resolved after discussion with a third reviewer (H.K.) Studies that were relevant to our research question were included according to the following criteria: (a) patients with bowel endometriosis; (b) index test for diagnosis of bowel endometriosis was CT; (c) diagnosis confirmed with laparoscopy followed by histopathological assessment; (d) paper provided sufficient information for tabulating 2 × 2 tables (true positive, false negative, false positive, and true negative); and (e) type of publication was original article. Then we excluded papers that met the following criteria: (1) less than 10 patients; (2) publication type other than original articles (i.e., review articles and conference abstracts); (3) CT used for evaluation of endometriotic lesions other than bowel; (4) overlap of study population; and (5) 2 × 2 table reconstruction not possible.

### 2.3. Data extraction and quality assessment

Data for the included studies were extracted using a standardized form according to the following three attributes: (1) patient characteristics—size of study population, age of patients, location of bowel endometriotic lesions, size of endometriotic lesions, and history of prior surgery for endometriosis; (2) study characteristics—origin of study (first author, institution, and patient enrollment duration), year of publication, study design, interval between CT and laparoscopy, blinding between CT and histopathological diagnosis, and reader characteristics; and (3) CT characteristics—vendor and model of CT scanner, number of detector rows, slice thickness, CT technique, reconstruction methods, whether contrast-enhanced phases were

acquired and details regarding scan time delay after administration of contrast material, and criteria for CT diagnosis of bowel endometriosis.

The quality of the studies in terms of risk of bias and applicability was assessed with the revised Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool [9]. Data extraction and quality assessment were carried out by two independent reviewers (S.W. and C.H.S.) with disagreements resolved by consensus after discussion with a third (H.K.).

### 2.4. Data synthesis and analysis

The raw data were retrieved from the selected studies or reconstructed from the reported sensitivity and specificity. Summary estimates of sensitivity and specificity were obtained with the hierarchical logistic regression modelling including bivariate and hierarchical summary receiver operating characteristic (HSROC) modelling [10,11]. These results were graphically presented using HSROC curves with 95% confidence and prediction regions [12]. Publication bias was assessed two-fold: (1) visual evaluation of the Deeks' funnel plot and (2) calculating of the p value of Deeks' asymmetry test [13].

Heterogeneity was assessed with the following: (1) Cochran's Q-test ( $p < 0.05$  signifying presence of heterogeneity); (2) Higgins I<sup>2</sup> test (inconsistency index [I<sup>2</sup>]: 0%–40%, no important heterogeneity; 30%–60%, moderate heterogeneity; 50%–90%, substantial heterogeneity; and 75%–100%, considerable heterogeneity) [14]; and (3) assessment of the forest plot of sensitivities and specificities of the included studies for a threshold effect, defined as a positive correlation between sensitivity and false positive rate.

For exploration of the possible causes of heterogeneity, meta-regression analysis was performed using several covariates: (1) size of study population ( $\geq 78$  [median of all included studies] vs  $< 78$ ); (2) study design (prospective vs retrospective and multi- vs single-center); (3) history of prior surgery for endometriosis (yes vs no); (4) location of bowel endometriosis (only recto-sigmoid colon vs other bowel segments included [i.e., small bowel or proximal colon]); (5) CT technique (CT colonography vs CT enema/enteroclysis). In addition, the institution from which the study originated from was included as a covariate, as several of the included studies were performed by the same group (Galliera Hospital/San Martino Hospital group vs others institutions).

For statistical analysis, the "metandi" and "midas" modules in Stata 10.0 (StataCorp LP, College Station, TX, USA) and "mada" package in R software version 3.4.1. (R Foundation for Statistical Computing, Vienna, Austria) were used.  $P < 0.05$  was considered to indicate statistical significance.

## 3. Results

### 3.1. Literature search

The computerized search initially yielded 230 papers. After removing 40 duplicate studies, screening the titles and abstracts of the remaining 190 studies yielded 15 potentially eligible original articles. Then, full-text review was done for these and 4 were excluded due to the following reasons: CT was used to evaluate non-bowel endometriotic lesions ( $n = 1$ ) or there was insufficient data to calculate 2 × 2 tables ( $n = 3$ ) [15–18]. After review of the bibliographies of the identified studies, one additional study relevant to our research question was found [19]. Ultimately, 12 original articles comprised with a total of 1091 patients assessing the diagnostic performance of CT for diagnosis of bowel endometriosis were included in this systematic review and meta-analysis [19–30]. Fig. 1 shows the study selection process.

### 3.2. Characteristics of included studies

Table 1 shows the patient characteristics. The size of study

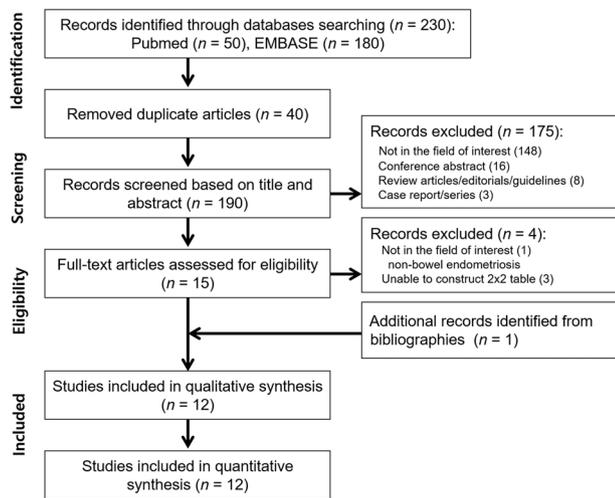


Fig. 1. Flow diagram summarizing study selection process.

population ranged from 33 to 260 patients. The mean age of the patients ranged from 32 to 37. Regarding the location of bowel endometriotic lesions, six studies evaluated those in the rectosigmoid colon [24–26,28,29]. The other six studies included endometriotic lesions in colonic segments other than the rectosigmoid area (i.e., cecum) and in the small bowels (i.e., ileum) [1,19,20,23,30]. The mean size of the endometriotic lesions based on histopathology ranged from 2.5 to 4.0 cm. Most studies included a large proportion of patients that had underwent surgery for endometriosis prior to enrollment in the study, except for two in which patients with a surgery for endometriosis were excluded [25,30] and other two in which this information was not explicit [23,27].

Table 2 summarizes the study characteristics. Among the included studies, five of them originated from the same group of institutions (Galliera Hospital and San Martino Hospital) [19,22–25] while the other seven were reported from various institutions. The study design was prospective in all but two studies [26,28]. Seven were multi-center studies while the other four were single-center studies [20,21,26,29,30]. Patient recruitment was consecutive in all studies. The diagnosis of bowel endometriosis was based on the reference standard of laparoscopic surgery followed by histopathological analysis

Table 1  
Patient characteristics.

Author	Publication year	Characteristics of study population			Characteristics of endometriotic lesions				
		Number of patients (n)	Age (years)		History of prior surgery for endometriosis	Location		Size (cm)	
Mean	Range		Only rectosigmoid colon or includes other bowel segments	Details of other locations		Mean	Range		
Baggio S et al. [20]	2016	37	32	23-45	Some	Includes other	Colon proximal than sigmoid	NR	NR
Belghiti J et al. [21]	2015	85	63	22-49	Some	Includes other	Ileum, cecum	NR	NR
Biscaldi E et al. [22]	2007	98	34*	20-53	Some	Includes other	Small bowel	2.5	0.8-5.1
Biscaldi E et al. [23]	2011	103	32*	18-45	NR	Includes other	Small bowel	NR	NR
Biscaldi E et al. [24]	2014	260	32.6	NR	Some	Rectosigmoid only		2.8	NR
Ferrero S et al. [19]	2011	96	33	NR	Some	Includes other	Ileum, cecum	2.9	NR
Ferrero S et al. [25]	2017	70	36	NR	None	Rectosigmoid only		2.6	NR
Iosca S et al. [26]	2013	64	36	26-46	Some	Rectosigmoid only		NR	NR
Mehedințu C et al. [27]	2018	71	32.1	NR	NR	Rectosigmoid only		3.7	
Roman H et al. [28]	2016	127	32	NR	Some	Rectosigmoid only		4.0	NR
Stabile Ianora AA et al. [29]	2013	33	33	27-39	Some	Rectosigmoid only		2.0	0.4-4.0
Zannoni L et al. [30]	2017	47	37	NR	None	Includes other	Colon proximal than sigmoid	NR	NR

NR = not reported.

in all but one study which was based on intraoperative findings [31]. The interval between CT and reference standard ranged from 1 week to 3 months. CT interpretation was done blinded to histopathological results in all but three studies [26–28].

The CT characteristics are shown in Table 3. CT scanners with 16–64 detector rows were used in the studies. Regarding CT technique, five studies used air distension in order to better assess the bowel segments, using various terminology including CT colonography and CT virtual colonoscopy [20,25,27,28,30]. Seven studies used water as the medium to distend the bowel, using several terminology including CT enteroclysis, CT enema, CT with colon water distension [19,21–24,26,29]. In addition, various reconstruction techniques were applied in the included studies, including multi-planar reconstruction (axial, sagittal, coronal, and curved), 3-dimensional endoluminal-rendered image, 3-dimensional volume-rendered image, and endoluminal fly-through, maximum-intensity-projection. Intravenous contrast material injection was performed with acquisition of portal venous phase images in all but three studies [20,25,28].

### 3.3. Quality assessment

In general, the methodological quality of the included studies was good. All but one study had low risk in at least five of the seven domains (Fig. 2). Specifically, all studies had low risk of bias and concern for applicability in the patient selection domain. With regard to the index test, two studies had high risk of bias, as the index test (CT) was not interpreted blinded to the reference standard (laparoscopy/histopathology) or detailed criteria for bowel endometriosis on CT was not provided [26,28]. There was no study with high concern for applicability in this domain. In the reference standard domain, two studies were at high risk of bias as the operator was aware of the CT findings when performing surgery [27,29] while five studies had unclear risk of bias as it was not clear if the reference standard was established independent of the index test results [20,26,28–30]. One study harbored high concern for applicability regarding the reference standard as it was based on intraoperative findings without histopathological correlation [27]. Regarding the flow and timing domain, there was unclear risk of bias in four studies as the interval between CT and reference standard was not provided [21,26–28].

**Table 2**  
Study characteristics.

Author	Publication year	Period	Institution	Study design		Reference standard		Reader characteristics				
				Prospective	Multicenter	Consecutive enrollment	Method	CT-reference standard interval	Number	Consensus reading	Experience (years)	Blinding
Baggio S et al. [20]	2016	2014.1-2015.6	Borgo Trento Hospital	Yes	No	Yes	Laparoscopy + pathology	1 week	2	NR	Senior	Yes
Belghiti J et al. [21]	2015	2009.2-2012.11	Tenon University Hospital	Yes	No	Yes	Laparoscopy/tomy + pathology	NR	2	Independent	> 7	Yes
Biscaldi E et al. [22]	2007	2004.1-2005.12	Galliera Hospital, San Martino Hospital*	Yes	Yes	Yes	Laparoscopy + pathology	< 20 days	2	Consensus	NR†	Yes
Biscaldi E et al. [23]	2011	NR	Galliera Hospital, San Martino Hospital*	Yes	Yes	Yes	Laparoscopy + pathology	< 1 month	2	Consensus	> 10	Yes
Biscaldi E et al. [24]	2014	NR	Galliera Hospital, San Martino Hospital*	Yes	Yes	Yes	Laparoscopy + pathology	< 1 month	2	Consensus	NR†	Yes
Ferrero S et al. [19]	2011	2008.1-2009.11	Galliera Hospital, San Martino Hospital*	Yes	Yes	Yes	Laparoscopy + pathology	< 1 month	2	Independent	NR†	Yes
Ferrero S et al. [25]	2017	2013.10-2015.8	Galliera Hospital, San Martino Hospital*	Yes	Yes	Yes	Laparoscopy + pathology	1-3 months	1	N/A	NR†	Yes
Iosca S et al. [26]	2013	2007.9-2011.8	Varese University Hospital	No	No	Yes	Laparoscopy + pathology	NR	2	Consensus	NR	No
Mehedintu C et al. [27]	2018	2015.6-2016.5	Rouen University Hospital, Clinique de l'Europe, and Clinique du Cèdre	Yes	Yes	Yes	Intraoperative findings	NR	1	N/A	Extensive experience	No
Roman H et al. [28]	2016	2010.1-2013.3	Rouen University Hospital, Clinique de l'Europe, and Clinique du Cèdre	No	Yes	Yes	Laparoscopy + pathology	NR	Multiple	Independent	NR	No
Stabile Ianora AA et al. [29]	2013	2009.5-2010.12	University of Bari Medical School	Yes	No	Yes	Laparoscopy + pathology	< 4 weeks	2	Independent	15/5	Yes
Zannoni L et al. [30]	2017	2011.5-2013.5	Orsola Hospital	Yes	No	Yes	Laparoscopy + pathology	< 1 month	2	Independent	> 10	Yes

CT = computed tomography; N/A = not available; NR = not reported. † Highly experienced.

**Table 3**  
CT characteristics.

Author	Publication year	Scanner	Technical parameters		Technique	Reconstruction methods		Contrast material		Criteria for bowel endometriosis	
			Manufacturer	Model		No. of detector rows	Slice thickness (mm)	Multi-planar	Others		Used
Baggio S et al. [20]	2016	Philips	Brilliance	64	NR	Colonography	A, C, S	3D endoluminal rendering, 3D volume rendering	No	N/A	Extrinsic mass effect on bowel wall, shortening/ tethering/ flattening of bowel wall, retraction of mucosa
Belghiti J et al. [21]	2015	GE	LightSpeed VCT	64	NR	Enema	A, C, S	N/A	Yes	Portal	Enhancing mass penetrating intestinal wall with bulging/ flattening/ crenulation
Biscaldi E et al. [22]	2007	GE	LightSpeed	16	NR	Enteroclysis	A, C, S	N/A	Yes	Portal (40 sec after arterial peak)	Solid enhancing nodule, contiguous or penetrating thickened colon wall
Biscaldi E et al. [23]	2011	GE	LightSpeed	16	5	Enteroclysis	A, C, S	Maximum intensity projection	Yes	Portal (40 sec after arterial peak)	Solid rounded nodule with inhomogeneous enhancement contiguous or penetrating thickened colon wall
Biscaldi E et al. [24]	2014	GE	LightSpeed VCT	64	NR	Enema	A, C, S	N/A	Yes	Portal (40 sec after arterial peak)	Solid nodule contiguous or penetrating thickened colon wall
Ferrero S et al. [19]	2011	GE	LightSpeed	16	NR	Enteroclysis	A, C, S	N/A	Yes	Portal (40 sec after arterial peak)	Solid enhancing nodule, contiguous or penetrating thickened colon wall
Ferrero S et al. [25]	2017	GE	LightSpeed	16	NR	Colonography	A, C, S	3D endoluminal fly-through, virtual dissection, 3D transparent view	No	N/A	Stricture involving variable part of circumference of bowel wall constant on supine and prone positions
Iosca S et al. [26]	2013	Toshiba	Aquilion 64	64	NR	Enema	A, C, S, curved	N/A	Yes	Portal (90 s after contrast administration)	NR
Mehedintu C et al. [27]	2018	NR	NR	NR	3	Colonography	A, C, S	3D endoluminal fly-through, 3D transparent view	Yes	NR	NR
Roman H et al. [28]	2016	NR	NR	NR	≤1.5	Colonography	A, C, S	Fly-through	No	N/A	NR
Stabile Ianora AA et al. [29]	2013	Toshiba	Aquilion 64	64	NR	Enema	A, C, S, curved	N/A	Yes	Portal (55 s after peak enhancement at abdominal aorta)	Enhancing nodule, contiguous with or penetrating intestine wall
Zamoni L et al. [30]	2017	GE	LightSpeed VCT	64	NR	Colonography	A, C, S, curved	N/A	Yes	Portal (80-90 s after contrast administration)	Enhancing nodule, contiguous with or penetrating intestine wall

A = axial; C = coronal; N/A = not available; NR = not reported; S = sagittal; 3D = three-dimensional.

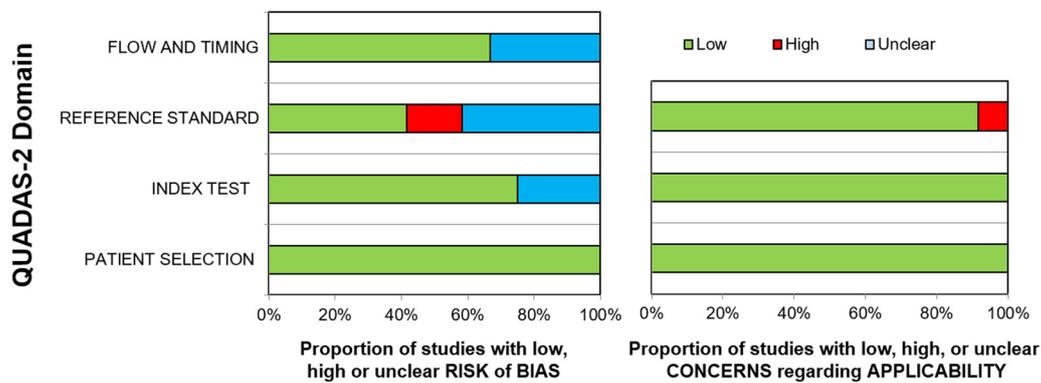


Fig. 2. Grouped bar charts with risk of bias (left) and concern for applicability (right) based on QUADAS-2 tool.

### 3.4. Diagnostic accuracy

The sensitivity and specificity of the included studies ranged from 37% to 100% and from 50% to 100%, respectively. Cochran’s Q-test demonstrated that significant heterogeneity was present ( $Q = 9.832$ ,  $p = 0.004$ ), the Higgins  $I^2$  statistics suggested that substantial heterogeneity may be present with regard to both the sensitivity ( $I^2 = 92.38\%$ ) and specificity ( $I^2 = 89.09\%$ ). The coupled forest plot of sensitivity and specificity did not suggest that a threshold effect was present (Fig. 3) with a correlation coefficient between sensitivity and false positive rate of  $-0.411$  (95% CI,  $-0.797-0.214$ ).

The summary sensitivity and specificity of the 12 studies were 0.92 (95% CI, 0.83-0.97) and 0.95 (95% CI, 0.88-0.98), respectively. The HSROC curve demonstrated a notable difference between the 95% confidence region and the 95% prediction region, also signified heterogeneity between included studies (Fig. 4). The area under the HSROC curve was 0.98 (95% CI, 0.96-0.99). The Deeks’ funnel plot

(Fig. 5) and Deeks’ asymmetry test suggested that publication bias may be present ( $p = 0.04$  for slope coefficient).

### 3.5. Exploration of heterogeneity

The results of meta-regression analyses are demonstrated in Table 4. Among the several evaluated covariates, only history of prior surgery for endometriosis was shown to be a significant factor affecting heterogeneity ( $p < 0.01$ ). When comparing the sensitivity and specificity estimates, studies in which at least some of the patients had a prior history of surgery for endometriosis had significantly greater specificity than those in which no patient had such a history (0.95 [95% CI, 0.91-1.00] vs 0.75 [95% CI, 0.43-1.00]). All other covariates, including size of study population, study design (prospective vs retrospective and multi- vs single-center), CT technique (colonography vs enteroclysis/enema), location of bowel endometriosis, and institution from which the study originated were not significant factors ( $p = 0.09$ -

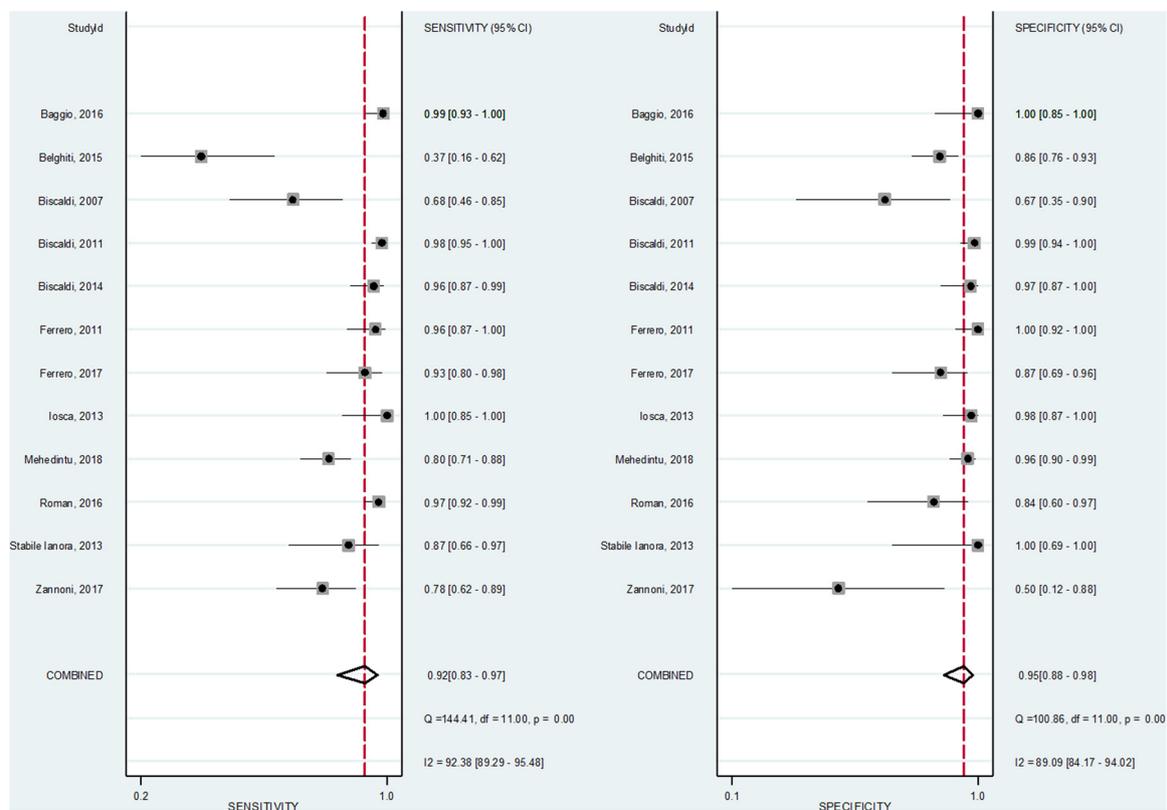


Fig. 3. Coupled forest plots of sensitivity and specificity. Numbers are summary estimates with 95% confidence intervals (CI) in parentheses. Heterogeneity statistics for sensitivity and specificity are shown at bottom right. Horizontal lines indicate 95% CIs.

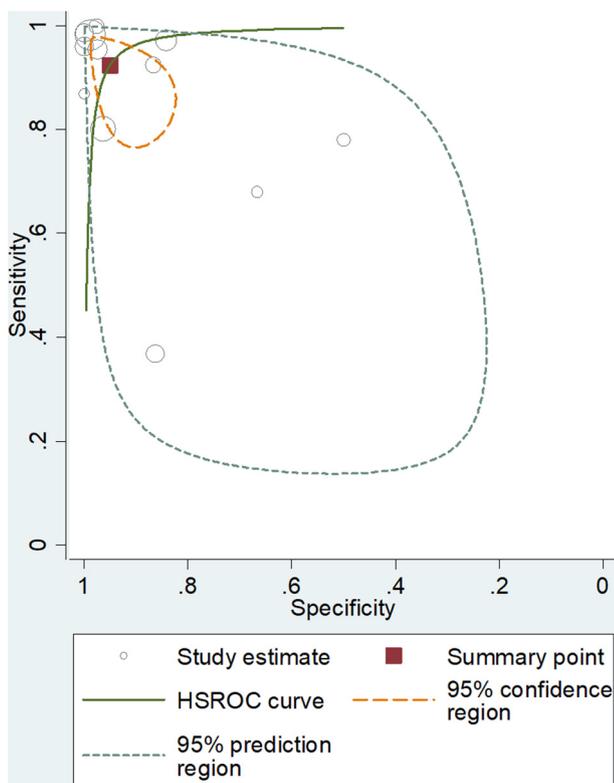


Fig. 4. Hierarchical summary receiver operating characteristic curve of performance of CT for diagnosing bowel endometriosis.

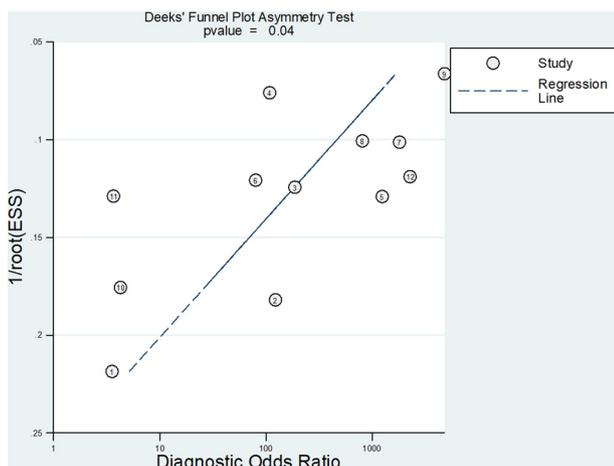


Fig. 5. Deeks' funnel plot of 12 included studies suggest that publication bias may be present ( $p = 0.04$  in Deeks' asymmetry test). ESS = effective sample size.

0.97).

4. Discussion

In this systematic review and meta-analysis, we assessed the performance of CT for diagnosis of bowel endometriosis. The results of our study show that the diagnostic performance of CT for this clinical setting was excellent. Specifically, the summary sensitivity and specificity of the 12 included studies were 0.92 (95% CI, 0.83-0.97) and 0.95 (95% CI 0.88-0.98), respectively, with an area under the HSROC curve of 0.98 (95% CI, 0.96-0.99). Although CT is not considered to be an initial diagnostic modality (as compared with MRI) in patients suffering from endometriosis, due to its inherent limitation of ionizing radiation which

may be more problematic in women in the reproductive ages, the results from our study suggest that CT could play an important role in the diagnostic process of bowel endometriosis when considering the following issues: (1) despite the high accuracy of MRI for diagnosing endometriotic lesions in general, it shows poorer performance for bowel lesions, especially more than 8 cm superior to the anal margin [7]; (2) acquisition of optimal MRI for bowel endometriosis requires endorectal coils which may not be easily tolerated by some patients [1]; (3) some patients may not be able to undergo MRI examinations for various reasons (i.e., claustrophobia, metallic implants, and etc.); and (4) CT has some advantages over MRI in that the examination time is significantly shorter and CT has greater spatial resolution. Still, as there is only a limited number of studies assessing the diagnostic performance of CT for bowel endometriosis—that is, only 12 studies included in this meta-analysis—and future studies may be needed for validation.

There was substantial heterogeneity among the included studies. Upon exploration of potential causes of heterogeneity by using meta-regression analysis, we found that only whether the patient had a prior history of surgery for endometriosis or not was a significant factor affecting heterogeneity. Especially, studies that included patients with a history of surgery for endometriosis showed significantly greater specificity than studies that did not (0.95 [95% CI, 0.91-1.00] vs 0.75 [95% CI, 0.43-1.00]). It is unclear as to why such history of surgery may have affected the diagnostic performance, but we speculate that patients who already have had surgery could be patients suffering from more severe bowel endometriosis in terms of number, size, and depth of lesions.

Although they were not proven to be statistically significant, two covariates that were assessed with meta-regression warrant mention. First, there were two types of CT techniques with regard to the medium for bowel distension used (CT colonography and CT enteroclysis/enema). Despite differences in the CT technique, the sensitivity estimates were virtually identical (0.93 [95% CI, 0.84-1.00] vs 0.92 [95% CI, 0.83-1.00]) and specificity estimates were similar (0.91 [95% CI, 0.81-1.00] vs 0.97 [95% CI, 0.93-1.00]). Based on these similar diagnostic performance, we speculate that when CT is considered to evaluate bowel endometriosis, either technique may be chosen based on the clinician's discretion and patient's preferences. Second, half of the included studies originated from the same group of institutions (Galliera Hospital and San Martino Hospital). There was a possibility that such a group continuously conducting research on this topic would have high expertise and show potentially greater diagnostic performance. However, at meta-regression analysis, this covariate was not a significant factor of heterogeneity ( $p = 0.81$ ) and there were no significant differences in the sensitivity (0.94 [95% CI, 0.87-1.00] vs 0.90 [95% CI, 0.81-1.00]) and specificity (0.96 [95% CI, 0.81-1.00] vs 0.95 [95% CI, 0.88-1.00]) between studies that originated from this group and other institutions.

The current meta-analysis had a few limitations. First, there were only a small number of included studies ( $n = 12$ ). This is speculated to be due to the fact that CT is not one of the primary modalities for diagnosis and management of endometriosis. Furthermore, we focused on "bowel" endometriosis, in which CT has potential to play an incremental role compared with MRI, which has already been recognized as having a pivotal role in the management of patients with endometriosis [1,6]. Second, there was significant publication bias ( $p = 0.04$ ). This may have been attributed to the fact that the number of included studies was small and that almost half of them originated from the same group of institutions albeit no overlap in patient population. Still, we used up-to-date and validated methods for performing diagnostic test accuracy meta-analysis (i.e., PRISMA guidelines) and the quality of most of the included studies were overall good based on low risk using QUADAS-2 tool and prospective design. Moreover, as our study is the first to systematically review and provide meta-analytic information regarding the performance of CT for diagnosing bowel endometriosis, it would serve as a general overview of the existing literature on this

**Table 4**  
Results of meta-regression analysis.

Parameter	Category	No. of studies	Sensitivity (95% CI)	Specificity (95% CI)	LRT Chi-Square	p
Institution	Galliera/San Martino	5	0.94 [0.87 - 1.00]	0.96 [0.90 - 1.00]	0.41	0.81
	Others	7	0.90 [0.81 - 1.00]	0.95 [0.88 - 1.00]		
Size of study population	> 83	6	0.92 [0.82 - 1.00]	0.95 [0.89 - 1.00]	0.06	0.97
	≤83	6	0.93 [0.85 - 1.00]	0.95 [0.89 - 1.00]		
Location of bowel endometriosis	Rectosigmoid only	6	0.90 [0.79 - 1.00]	0.94 [0.87 - 1.00]	0.5	0.78
	Others included	6	0.94 [0.88 - 1.00]	0.96 [0.90 - 1.00]		
Prior surgery for endometriosis	Some	8	0.93 [0.86 - 1.00]	0.95 [0.91 - 1.00]	26.96	< 0.01
	None	2	0.88 [0.65 - 1.00]	0.75 [0.43 - 1.00]		
Study design	Prospective	10	0.90 [0.82 - 0.98]	0.95 [0.91 - 1.00]	4.92	0.09
	Retrospective	2	0.99 [0.96 - 1.00]	0.94 [0.82 - 1.00]		
Study design	Multi-center	7	0.94 [0.87 - 1.00]	0.95 [0.90 - 1.00]	0.47	0.79
	Single-center	5	0.90 [0.77 - 1.00]	0.95 [0.88 - 1.00]		
CT technique	Colonography	5	0.93 [0.84 - 1.00]	0.91 [0.81 - 1.00]	2.35	0.31
	Enteroclysis/enema	7	0.92 [0.83 - 1.00]	0.97 [0.93 - 1.00]		

CI = confidence interval; LRT = likelihood ratio test.

topic. Third, there was substantial heterogeneity among the studies; even so, by using meta-regression analysis of several covariates, we were able to find some insight regarding possible sources of heterogeneity. Fourth, we were unable to provide separate pooled estimates for each bowel segments (i.e., rectum, sigmoid colon, more proximal colon, small bowel, etc.) as the majority of the included studies did not provide detailed information. Nevertheless, we used location (rectosigmoid colon only vs other bowel segments included) as a covariate in meta-regression analysis for exploration of heterogeneity.

In conclusion, CT shows excellent performance in the diagnosis of bowel endometriosis. Due to small number of included studies and publication bias, further studies may be needed to validate these results.

#### Declaration of Competing Interest

The authors have no conflict of interest.

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