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ORIGINAL ARTICLE

Endoscopic Ultrasonography-Guided Biopsy for Differentiation of Benign and Malignant Pelvic Lesions: A Systematic Review and Meta-Analysis

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Abstract

Background Preoperative diagnosis of pelvic lesions remains challenging despite advances in imaging technologies. Endoscopic ultrasonography (EUS)-guided biopsy is an effective diagnostic modality for sampling the digestive tract and surrounding areas. However, a meta-analysis summarizing the diagnostic efficacy of EUS-guided biopsy for pelvic lesions has not been published.

Aims We aimed to evaluate the utility of EUS-guided biopsy in the diagnosis of pelvic lesions.

Methods Articles were identified via structured database search; only studies where pelvic lesions were confirmed by surgery or clinical follow-up were included. Data extracted were selected with strict criteria. A fixed-effects model was used to estimate the sensitivity, specificity, positive likelihood ratio (PLR), negative likelihood ratio (NLR), and diagnostic odds ratio (DOR). A summary receiver operating characteristic curve (SROC) was also constructed.

Results Ten studies containing a total of 246 patients were included. The pooled sensitivity of EUS-guided biopsy for differential diagnosis of pelvic masses was 0.89 (95 % CI 0.83–0.94), and the specificity was 0.93 (95 % CI 0.86–0.97). The area under the SROC was 0.9631. The combined PLR, NLR, and DOR were 11.75 (95 % CI 5.90–23.43), 0.12 (95 % CI 0.07–0.20), and 100.06 (95 % CI 37.48–267.10) respectively. There is potential presence of publication bias in this meta-analysis.

Conclusions Our meta-analysis shows that EUS-guided biopsy is a powerful tool for differentiating pelvic masses with a high sensitivity and specificity. Furthermore, it is a safe procedure with low rate of complication, although more high-quality prospective studies are required to be done.

Keywords Endoscopic ultrasound · Biopsy · Meta-analysis · Pelvic lesion

Introduction

Pelvic lesion detection is critical in patients with suspected malignancy and is used to determine choice of treatment. Although many imaging modalities (PET/CT/MRI/US) have been utilized to detect potential malignancies [1, 2], they fail to provide pathologic samples that are required for definitive diagnosis as well as for clinical prognostic management; furthermore, percutaneous biopsy in this area may be challenging due to presence of vital interferential structures [3].

Endoscopic ultrasonography (EUS) is a well-established imaging technique and is routinely used to detect and stage

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colorectal cancers, as well as surrounding organs including the prostate, bladder, ovaries as well as for drainage of pelvic abscesses [4, 5]. EUS-guided biopsy has also been validated as an accurate, minimally invasive technique for differential diagnosis of pancreatic solid or cystic neoplasms [6–8], as well as lesions in the mediastinum [9, 10], intra-abdomen [11, 12] and retroperitoneum [13, 14]. EUS-guided biopsy also provides tissue samples from pelvic lesions, which can guide treatment decisions. However, relatively few studies have been published evaluating the value of EUS-guided biopsy in the diagnosis of pelvic masses, primarily due to the technically challenge of mobilizing the device around the rectosigmoid colon [15]. These reports include a relatively small number of patients and/or report results based on case reports [16, 17]; as a consequence, strong recommendations could not be made. Furthermore, reports documenting the performance and complication rate of EUS-guided biopsy of pelvic lesions are scarce. We created a structured meta-analysis of the available evidence on the potential utility and safety of EUS-guided biopsy in the diagnosis of pelvic masses.

Materials and Methods

Literature Search

This study covered articles published from January 2000 to May 2014. Articles pertaining to EUS-FNA or EUS-TCB were retrieved from Medline(PubMed), Web of Science, Embase, and Cochrane library by using the following search terms: "Endoscopic ultrasound-guided fine-needle aspiration" OR "EUS-FNA" OR "Endoscopic ultrasound-guided trucut biopsy" OR "EUS-TCB" OR "endorectal endoscopic ultrasound fine-needle aspiration" OR "ERUS-FNA" AND "pelvis" OR "pelvic" OR "rectal" OR "perirectal" OR "extrinsic masses of the rectum" OR "rectosigmoid" OR "colorectal" OR "transrectal" OR "extraluminal lesions" OR "sigmoid colon" OR "lower digestive tract" OR "lower GI tract lesions." We followed this methodology for a systematic review of diagnostic accuracy statements, performed according to meta-analysis of observational studies in epidemiology (MOOSE) [18, 19]. Two reviewers independently searched titles and abstracts of all potentially relevant articles and excluded studies that were not relevant, based on a standardized data extraction form. Subsequently, the full text versions of selected articles were retrieved to further determine whether they are eligible for inclusion into the meta-analysis. In addition, we additionally examined relevant studies from the reference lists of all selected articles or review articles to identify any additional articles that were not identified in the initial search. If necessary, authors were contacted for further information. Only full original studies were eligible for inclusion.

Inclusion and Exclusion Criteria

Two investigators who were not blinded to journal titles, author names, and institutional affiliations independently evaluated the eligibility of selected studies for inclusion in the systematic review; any discrepancies in opinion were resolved by discussion, or adjudicated by a third reviewer. Eligibility assessment was performed independently by two other investigators and then verified reciprocally. Clinical trials, retrospective studies, and prospective studies were considered for inclusion in the meta-analysis. The further details about inclusion and exclusion criteria are shown in Table 1.

Quality Assessment of Studies and Data Extraction

From the selected studies that met the inclusion criteria, two authors independently extracted the following information from each publication: (1) publication year; (2) author; (3) country of origin; (4) number of centers involved; (5) patient demographics (mean age, proportion of male and female patients); (6) study design; (7) total study period; (8) number of passes; (9) lesion size; (10) complications; and (11) the performance indices of EUS-FNA or EUS-TCB (true-positive TP, false-negative FN, true-negative TN, and false-positive FP rates). Methodological quality assessment of diagnostic accuracy studies was evaluated based on the quality assessment of diagnostic accuracy studies (QUADAS) checklist, a validated tool used to evaluate the risk of bias; only those articles in which the 14 questions on the checklist were answered "yes" were deemed to be of good quality [20]. The risk of bias using the QUADAS criteria was performed using the review manager 5.1 tool (Cochrane Diagnostic Accuracy Group, Birmingham, UK) which could depict further detail for each of the 14 items. QUADAS scores were calculated as follows: a score of +2, +1, or 0 was assigned for each item that was answered as "confirm," "uncertain," or "not confirm," respectively. The sum total of all scores generated the final score for each study.

Data Synthesis and Statistical Analysis

We used standard methods published by Deville et al. [21] for meta-analysis of diagnostic test evaluations. A 2×2 diagnostic contingency table was constructed to depict the number of true-positive, true-negative, false-negative, and false-positive results for the diagnosis of pelvic lesions by using Meta-Disc 1.4 software (Ramony Cajal Hospital, Madrid, Spain) [22] and generated forest plots of the pooled sensitivity, specificity, positive likelihood ratio (LR+),

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Search was restricted to studies conducted in human subjects and English literature	Publications based on the same data (e.g., same authors or institutions) were excluded, and only the best quality study was used
Used EUS-FNA or EUS-TCB as diagnostic modality on adult patients (>18 years)	Insufficient data unavailable to reconstruct a diagnostic 2 × 2 table (not completed even after directly contacting first and/or corresponding authors)
Lesions were located in pelvis	Case reports, conference abstracts, editorials and letters
Definitive histopathology of surgical specimens, or clinical follow-up were used as acceptable reference standard	Data reported by earlier studies (before January 2000)
Sufficient data included true-positive TP, false-positive FP, true-negative TN, and false-negative FN were presented or extrapolated	Studies with fewer than 10 patients

negative likelihood ratio (LR−), and diagnostic odds ratios (DOR) with corresponding 95 % confidence intervals. A continuity correction of 0.5 was added to all cells of studies that contained a count of zero in the table. Significant heterogeneity was evaluated by performing the Chi-square (χ^2) test and inconsistency index I^2 which refers to the degree of variability in results used in the meta-analysis [23, 24]. The Chi-square test determines whether differences observed in the results are due to chance alone, and used to detect heterogeneity with a P value <0.1. The inconsistency index is calculated to assess the proportion of variability that can be attributed to heterogeneity rather than chance. Values of I^2 equal to 25, 50, and 75 % were assumed to represent low, moderate, and high heterogeneity, respectively; values ≥50 % indicate substantial heterogeneity. In situations where there is no homogeneity, a fixed-effects model is used to calculate the pooled effects. If heterogeneity exists ($I^2 \geq 50$ %), the DerSimonian-Laird pooling method (random-effects mode) is used in place of the fixed-effects model [25]. In addition, Meta-Disc version 1.4 was used to construct a summary receiver operating characteristic (SROC) curve which was used to calculate the area under the curve (AUC) and estimate the pooled sensitivity and specificity. An AUC value approaching one indicated a well-validated diagnostic test, and AUC value approaching 0.5 indicated a poor test. The effect of potential publication bias was tested using of Deeks' Funnel Plot, which was recommended in published diagnostic tests [26], and conducted using Stata version 10.0 (Stata Corporation, College Station, TX, USA). A slope coefficient of $P < 0.05$ indicated the presence of a publication bias.

Results

Descriptive Assessment and Study Characteristics

Our study selection process is depicted in detail in Fig. 1. The initial study yielded 3892 reference articles; of these, 163 were identified to be relevant after screening titles and abstracts. Data were extracted from 10 studies (a total of 246 patients) [27–36] that met the predefined inclusion and exclusion criteria for EUS-guided biopsy; all ten studies were reviewed in depth and are reported in Table 2. Five studies described results of overall diagnostic accuracy in all lesions, including the pancreas, abdomen, and mediastinum [37–41]; in these studies, it was impossible to extract the data for pelvic lesions alone. Two articles reported the accuracy of EUS in detecting pelvic lesions, however, did not report sufficient data, and lacked detailed diagnostic methods to calculate specific operating characteristics (true positives, true negatives, false negatives and false positives) [42, 43].

The included papers were published between 2000 and 2014. Most studies were retrospective or single-center studies, and two enrolled consecutive patients [32, 33]. Seven studies were conducted in the USA; others were from Germany, Japan, and Korea. The mean study length

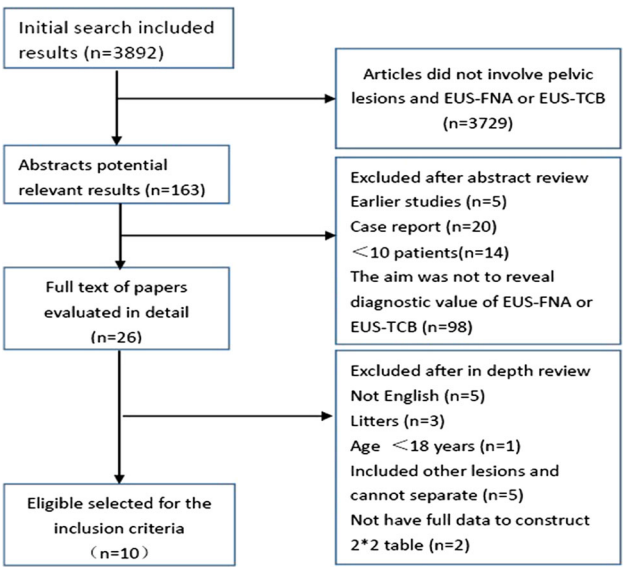

Fig. 1 Flowchart of research selection process for inclusion

Table 2 Characteristics of extracted studies and details in current meta-analysis

References	Country	Year	Length of study (months)	No. of cases	Mean or range of age (years)	Sex (female/male)	Average size of lesions (mm, range)	Mean number of passes (range)
Rzouq et al. [27]	USA	2014	126	20	N/A	11/9	20, N/A	N/A
Knight et al. [29]	USA	2013	123	79	60	33/44	30, 4–90	3 (1–6)
Maleki et al. [30]	USA	2013	264	49	56	25/22	31.5, 6–100	3.5 (1–10)
Sailer et al. [36]	Germany	2002	84	48	66	18/30	26, 7–64	N/A
Mohamadnejad et al. [32]	USA	2012	90	29	59	14/15	40.8, N/A	3 (1–6)
Sasaki et al. [34]	Japan	2005	50	22	59	8/14	25, N/A	N/A (N/A)
Amin et al. [28]	USA	2013	126	38	36–88	17/21	N/A, N/A	N/A (N/A)
Gleeson et al. [31]	USA	2012	113	19	67	1/18	N/A, N/A	3 (1–9)
Vander et al. [35]	USA	2004	30	60	59	24/36	N/A, N/A	N/A (N/A)
Boo et al. [33]	Korea	2011	12	11	54	7/4	30, 25–50	3 (1–5)

References	Country	Year	Type of study	Patient enrollment	No. of centers	Complication	Image study before EUS-guided biopsy	Reference standard
Rzouq et al. [27]	USA	2014	Retrospective	N/A	Single none	CT/US/MRT	Surgical	Pathology
Knight et al. [29]	USA	2013	Retrospective	N/A	Single	N/A	N/A	Surgical pathology
Maleki et al. [30]	USA	2013	Retrospective	N/A	Single	None	CT/MRI/endoscopy	Surgical pathology and follow-up
Sailer et al. [36]	Germany	2002	Retrospective	N/A	Single one post-biopsy	Hemorrhage	CT/MRI	Surgical pathology and follow-up
Mohamadnejad et al. [32]	USA	2012	Retrospective	Consecutive	Single	Two pelvic abscess	CT/MRI/endoscopy	Surgical pathology and follow-up
Sasaki et al. [34]	Japan	2005	Retrospective	N/A	Single	N/A	CT/US/endoscopy	Surgical pathology and follow-up
Amin et al. [28]	USA	2013	Retrospective	N/A	Single	N/A	N/A	Surgical pathology
Gleeson et al. [31]	USA	2012	Retrospective	N/A	Single	One gross hematuria	CT/MRI	Surgical pathology
Vander et al. [35]	USA	2004	Retrospective	N/A	Single	None	N/A	Surgical pathology and follow-up
Boo et al. [33]	Korea	2011	N/A	Consecutive	Single	None	CT/MRI	Surgical pathology and follow-up

N/A not available, *CT* computed tomography, *MRI* magnetic resonance imaging, *US* ultrasonic examination

was 101.8 months (range of 12–264 months), and most patients were male. Other patient characteristics (e.g., number of passes, average mass size) of included studies are detailed in Table 2. None of the articles reported any patient blinding. A manual review of the references of the above selected articles did not yield any additional studies that met the inclusion criteria for our study.

In the Mohamadnejad et al. [32] study, the final diagnoses in all 29 patients were determined via surgery in 14 patients (48 %), EUS-TCB in 2 patients (7 %), EUS-FNA in 5 patients (17 %), and clinical follow-up in 8 patients (28 %). Surgical and clinical follow-up patients were set as the gold standard to determine the outcome data, as EUS-FNA could also result in false-positive cytological results [44]. The false-positive rate was 5.3 % and increased to 7.2 % when suspicious cases were included [45]. We also removed three additional patients from the analysis because either EUS-FNA or TCB failed to diagnose desmoid tumors, pelvic abscesses, and ovarian cystadenomas [32]. A total of 41 samples from 38 patients were included from the Amin et al. [28] article; however, concurrent or follow-up histologic diagnoses were only available in 20 cases, so the remaining 11 patients were excluded from the analysis. In the Vander et al. [35] study, the objective was to determine the diagnostic utility of EUS-FNA in detecting intramural and extramural GI tract lesions; in this study, there were only 11 lesions located in pelvis. We also identified 79 cases where EUS-FNA was used in 77 patients; histology was used as a reference standard in 27 of 79 cases (29 %), and cytological examinations were not included [29].

Quality Assessment of Studies

The quality of studies included in our analysis, according to QUADAS criteria, is listed in Fig. 2. Overall, the quality of included articles deemed them eligible, with most studies falling into the "high-quality study" (those with a "yes" response) category; the percentage of high-quality studies ranged from 71 to 93 % for each of the 14 items. Thus, the mean QUADAS score was 25 with a range of 21–27 based on our scoring system, which is also outlined in Table 3.

Meta-Analysis

The sensitivity, specificity, and SROC (summary receiver operating characteristic) curve of EUS-guided biopsy for diagnosis of pelvic lesions were calculated using actual numbers of true-positive, false-positive, true-negative, and false-negative results which are listed in Table 3, and the forest plots are shown in Fig. 3. The pooled sensitivity (fixed-effects model) and specificity (fixed-effects model) were 0.89 (values range from 0.71 to 0.94; 95 % CI 0.83–0.94) and 0.93 (values range from 0.67 to 0.98; 95 % CI 0.86–0.97), respectively. Using the SROC curve, overall AUC and Q* index were calculated as 0.9631 (standard error = 0.0138) and 0.9091 (standard error = 0.0207),

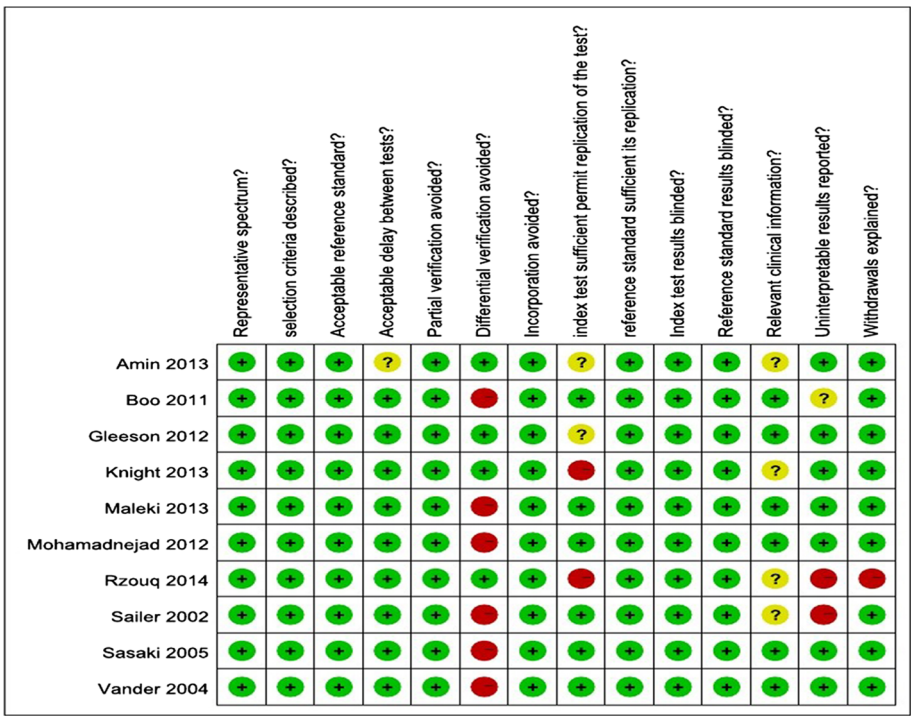

Fig. 2 Quality assessment of included studies using the 14 items included in the QUADAS tool. Each item was scored "yes" if reported, "no" if not reported, or "unclear" if insufficient information to make an accurate decision: +, yes; −, no; ?, unclear

Table 3 Derived 2 × 2 tables and diagnostic performance for included articles

References	Diagnostic method	TP	FP	FN	TN	QUADAS
Rzouq et al. [27]	EUS-FNA	9	0	1	10	21
Knight et al. [29]	EUS-FNA	16	2	2	7	25
Maleki et al. [30]	EUS-FNA	28	0	4	17	26
Sailer et al. [36]	EUS-TCB	22	0	3	23	23
Mohamadnejad et al. [32]	EUS-FNA or TCB	6	0	0	13	26
Sasaki et al. [34]	EUS-FNA	14	0	1	7	26
Amin et al. [28]	EUS-FNA	9	0	1	10	25
Gleeson et al. [31]	EUS-FNA or TCB	17	0	1	1	27
Vander et al. [35]	EUS-FNA	6	1	0	4	26
Boo et al. [33]	EUS-FNA or TCB	5	0	2	4	25

EUS-FNA EUS-guided FNA, *EUS-TCB* EUS-guided TCB, *TP* true-positive, *FP* false-positive, *TN* true-negative, *FN* false-negative, *QUADAS* quality assessment of diagnostic accuracy studies

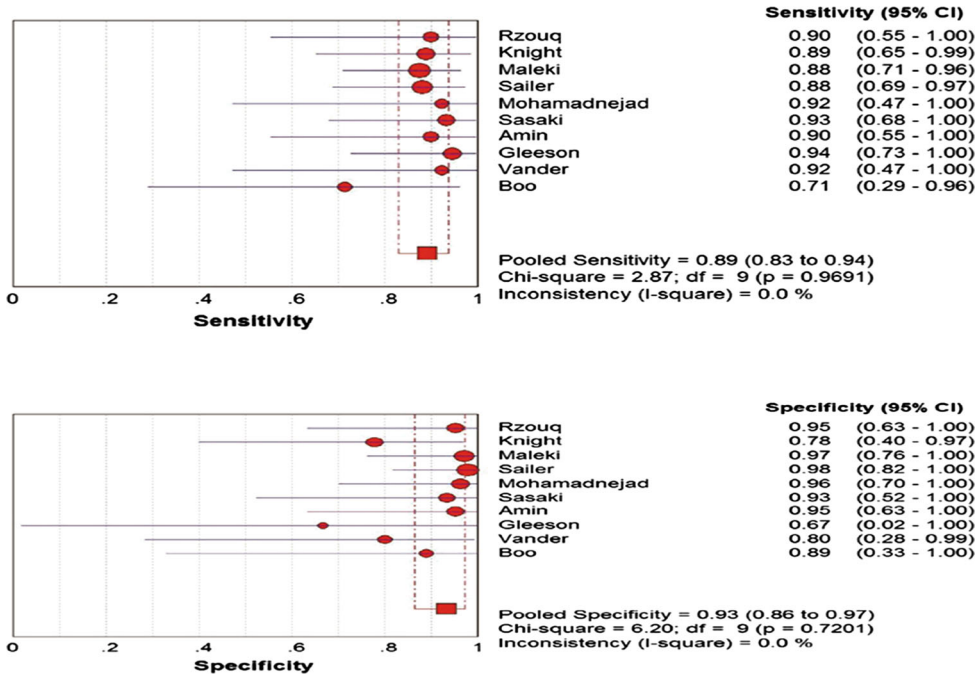

Fig. 3 Forest plots of sensitivity and specificity of EUS-guided biopsy in differentiation of benign and malignant pelvic masses. *CI* confidence interval; *df* degrees of freedom

indicating good diagnostic accuracy (Fig. 4). The pooled positive LR, negative LR, and diagnostic OR results (fixed-effects model) for diagnosing pelvic lesions were 11.75 (values range from 2.83 to 41.36; 95 % CI 5.90–23.43), 0.12 (values range from 0.07 to 0.32; 95 % CI 0.07–0.20), and 100.06 (values range from 20.00 to 337.33; 95 % CI 37.48–267.10), respectively (Figs. 5, 6).

Heterogeneity and Publication Bias

Substantial heterogeneity was not observed in either sensitivity (Cochran's Q test = 2.87, $df = 9$, $P = 0.9691$, $I^2 = 0.0$ %) or specificity (Cochran's Q test = 6.20, $df = 9$, $P = 0.7201$, $I^2 = 0.0$ %) and was also not found in PLR (Cochran's Q test = 7.54, $df = 9$, $P = 0.5808$, $I^2 = 0.0$ %), or NLR (Cochran's Q test = 3.10, $df = 9$, $P = 0.9601$, $I^2 = 0.0$ %). Deeks' funnel plot, depicting ln of diagnostic log odds ratio (DOR, x) versus the inverse sqrt of effective sample size (ESS, y), showed significant asymmetry ($P = 0.03$), indicating that there is a potential presence of publication bias in this meta-analysis (Fig. 7).

Complication and Safety

Among 246 patients involved in this meta-analysis, four patients developed a procedure-related complication. One gross hematuria developed following FNA of a bladder mass in an 82-year-old male with a history of a transitional

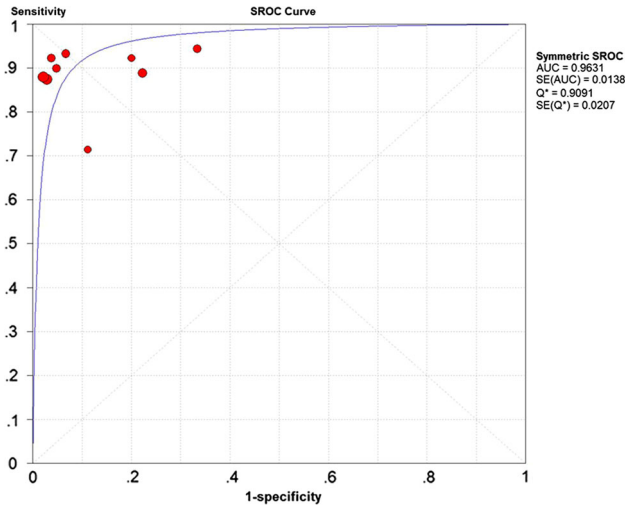

Fig. 4 *SROC* summary receiver operating characteristic for differentiation of benign and malignant pelvic masses. *AUC* area under the curve, *Q** the point at which sensitivity and specificity are equal. *SE* standard error

cell bladder cancer [31]. One post-biopsy hemorrhage was reported, which was managed conservatively with no transfusion requirement [36]. Two additional patients with cystic lesions developed abscesses after EUS-FNA and required percutaneous drainage [32]. The total complication rate was 1.69 % (4/236) among reported studies. Although the current American Society for Gastrointestinal Endoscopy guidelines are generally not recommended prophylactic antibiotics for EUS-biopsy only on the cases with cystic lesions, no consensus on the usage of prophylactic antibiotics has been achieved [46, 47].The rate of prophylactic antibiotics use is relatively high (22.0 %; 11/50) among reported studies.

Discussion

EUS-guided biopsy has been considered as a valuable tool in differential diagnosis of benign and malignant lesions located within, or in close proximity to the wall of the upper gastrointestinal tract; furthermore, it has shown to be effective in the staging of malignancies [48, 49], the accuracy of which has already presented in the form of a meta-analysis. Systematic review of pooled sensitivity or specificity data of EUS-guided biopsy has been reported to be 88.0 % (95 % CI 85.8–90.0) or 96.4 % (95 % CI 95.3–97.4) for mediastinal lymphadenopathy [50], and 0.89 (95 % CI 0.88–0.90) or 0.96 (95 % CI 0.95–0.97), respectively, for pancreatic lesions [51]. EUS-guided biopsy in the pelvis can not only detect primary, local

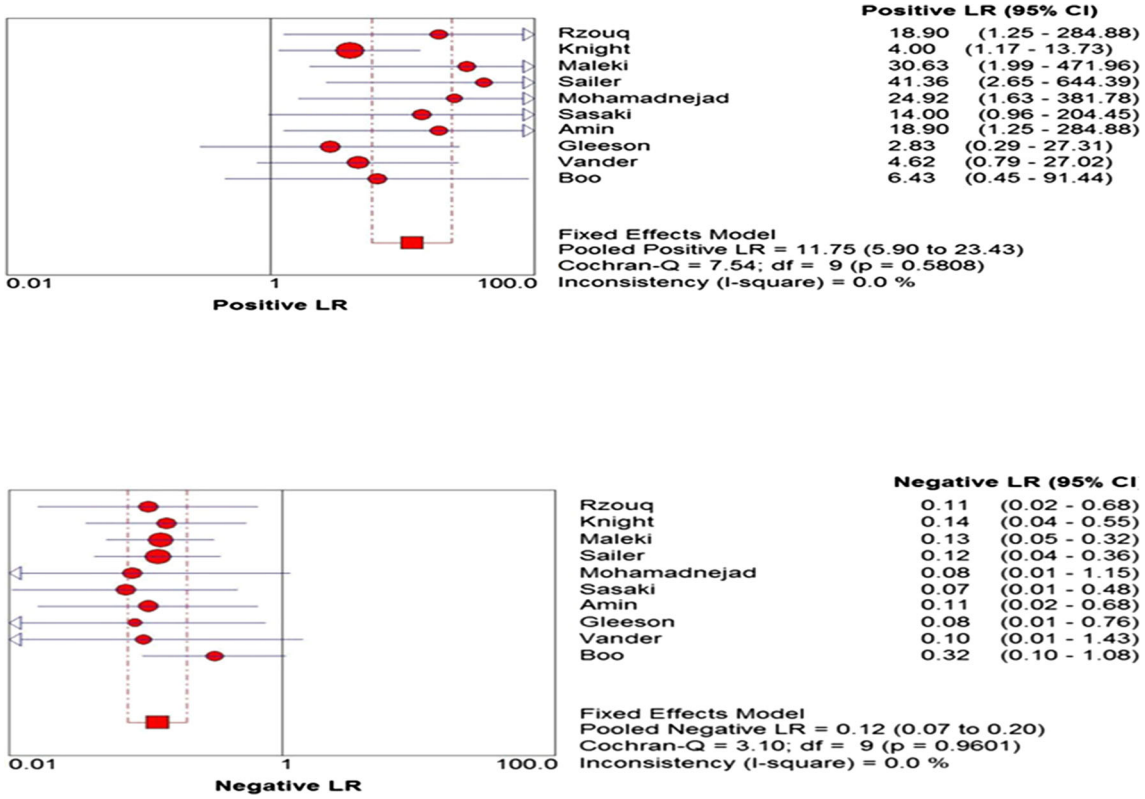

Fig. 5 Forest plots of positive LR and negative LR of EUS-guided biopsy in differentiation of benign and malignant pelvic masses. *CI* confidence interval; *df* degrees of freedom

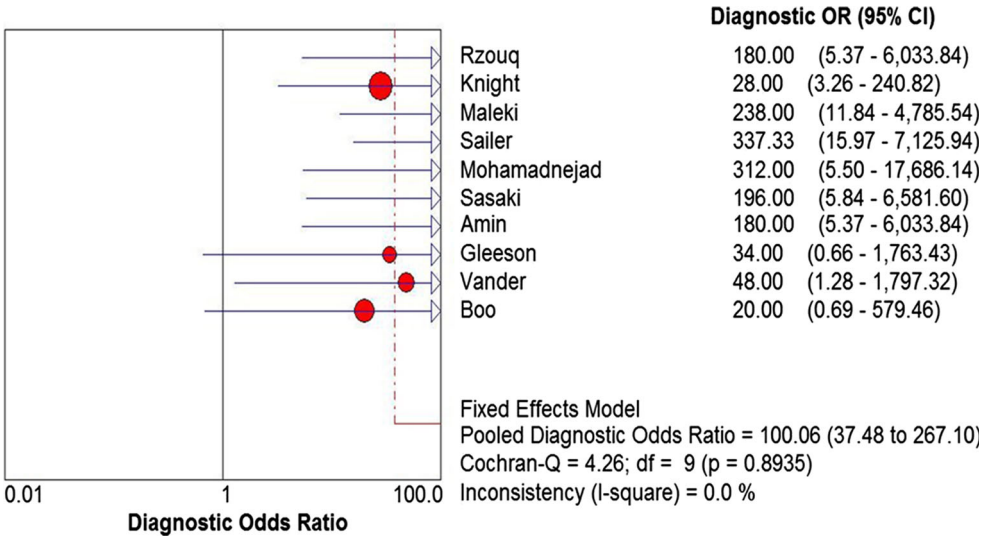

Fig. 6 Forest plots of diagnostic odds ratio of EUS-guided biopsy in differentiation of benign and malignant pelvic masses. *CI* confidence interval; *df* degrees of freedom

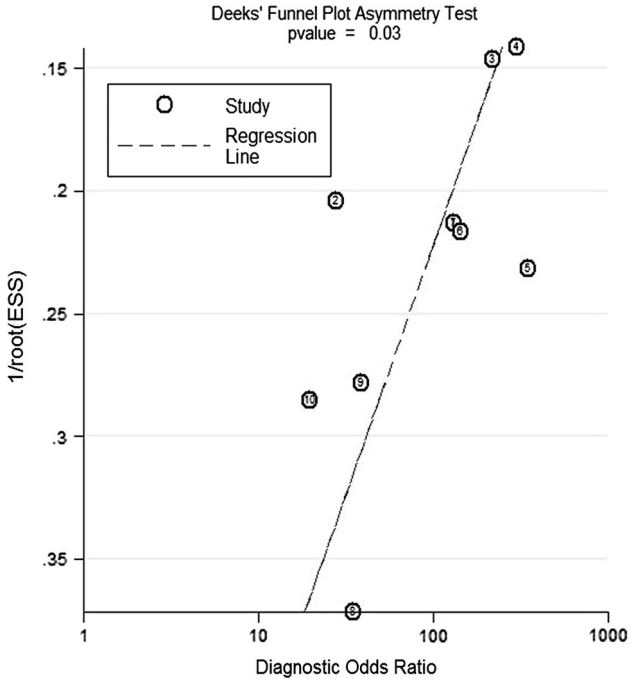

Fig. 7 Funnel plot which was constructed by Deeks' asymmetry test suggested a significant publication bias for EUS-guided biopsy studies looking at pelvic masses ($P = 0.03$)

recurrences of colorectal malignancies, or pelvic metastases from other organs, but also idiopathic pelvic and abdominal masses adjacent to the rectum [17, 52]. In addition, EUS-guided sampling can easily be performed in perirectal lesions or lymph nodes, due to their proximity to the rectum, and the convex tip of the device can be set around the lesions [34]. This report is the first study focusing on evaluating the available evidence supporting the diagnostic performance of EUS-guided biopsy to differentiate and characterize pelvic lesions. Our study has shown that EUS-guided biopsy can be used as a reliable diagnostic test for pelvic lesions, with a pooled sensitivity of 89 % (95 % CI 83–94 %),a pooled specificity of 93 % (95 % CI 86–97 %), and an area under the SROC curve of 0.96. In addition, EUS-guided biopsy has a high combined DOR of 100.06 (95 % CI 37.48–267.10), indicating high accuracy of EUS-guided biopsy in diagnosing pelvic masses. The observed complication rate was also low at 1.69 %; complications seem to occur more frequently when EUS-guided biopsy was performed on cystic lesions rather than on solid lesions.

As a meta-analysis compiles results of multiple researches, the outcomes are as accurate as those of the initial studies feeding the meta-analysis. If one of those studies were poorly managed, the quality of our meta-analysis would be affected. Thus, we ensured the studies we included had a minimal bias by using the QUADAS questionnaire. Four studies were not described in sufficient detail to permit replication of the index test (EUS-guided biopsy) [27–29, 31]. A withdrawal bias could be present in the study published by Rzouq et al. [27]. The number six item (Did patients receive the same reference standard regardless of the index test result?) of differential verification bias could impracticable in most eligible studies and occurred in about 60 % of the 10 studies. As we used varying reference standards, including surgical pathology and clinical follow-up, the risk of differential verification bias (verification using different reference standards) could not be avoided. The overall quality of the 10 studies was good, with most items being satisfied and, as a consequence, received high scores.

However, our systematic review does have several limitations which should be taken into consideration: First, this study is limited by the relatively small number of patients enrolled, which results in many of the cell counts

being zero; we added 0.5 to these cell counts to facilitate the analysis. The estimates of sensitivity and specificity may be biased downwards which could affect statistical power. The reasons why the small number of patients enrolled are as follows: (1) There may be a relatively low incidence rate of tumors in the pelvis, which comprised only 1.9–4.6 % of all indications for EUS-FNA examinations in each institution [34]; (2) other than lesions in close proximity to the rectum, some physicians may avoid using EUS-guided biopsies; when a lesion is located in the sigmoid colon, or when a suspected lesion is found in an unusual site, it could be challenging to sample tissue in these areas as most linear scopes have an oblique view; it is dangerous to insert a linear echo endoscope in the tortuous sigmoid colon without direct visualization [53]; (3) due to the anatomical structural challenges, the study of EUS in diagnosing pelvic mass lesions has been limited to several case reports and small series of patients [53, 54]; we limited the study population of included reports to those with greater than 10 patients, since very small studies may be vulnerable to selection bias; (4) larger studies describe the biopsy of pelvic lesions as one of many sites, and we are unable to extract data specific to pelvic lesions [37]; (5) And finally, the properties of pelvic lesions are largely dependent on the results of EUS-guided biopsy [55, 56]. We followed our strict inclusion and exclusion criteria to only allow cases with either surgical or clinical follow-up, as EUS-guided biopsy may result in false-positive cytology. This accounts for a large proportion of potential relevant articles. As a consequence, a large number of patient results need to be excluded due to the above reasons.

Moreover, among the included studies, there are very few multicenter trials; most reports are based on single-center studies or retrospective studies. In addition, unpublished studies would not be identified in our search, and as a consequence, important articles may have been left out; investigators in future studies would need to analyze these data to fully understand the ability of EUS-guided biopsy to detect pelvic lesions. Finally, Deeks' bias indicators did show a considerable publication bias ($P = 0.03$); this may arise from the fact that: (1) All included studies had a relatively low number of participants ($n = 11$–49); (2) studies with statistically significant results are more likely to be published than studies with nonsignificant findings [18]; this is particularly apparent in this study which involves difficult and complex technology and procedures; (3) the aim of this meta-analysis was focused on the utility of EUS-guided biopsy to differentiate benign and malignant pelvic lesions; failed attempts at detecting lesions are not valid. This would result in high DOR as the majority of included articles' results showed malignancy and Deeks' funnel plot plotted by ln(diagnostic log odds ratio, DOR) (x) versus 1/sqrt (effective sample size, ESS) (y) [26]; (4) published results are based on the skill and expertise of a handful of highly skilled physicians, and it may be difficult to generalize these results across endoscopists with less experience; (5) no attempt was made to include articles in other languages, and only fully published studies were included, also adding to the potential for bias.

To summarize, EUS-guided biopsy has emerged as a powerful modality to acquire tissue from pelvic masses. Our findings demonstrate that EUS-guided biopsy provides an accurate diagnostic technique for the investigation of pelvic masses and is able to diagnose suspected neoplastic lesions with high sensitivity and specificity. Furthermore, it is a safe procedure with low complication rates, although more high-quality, prospective, or larger-scale studies attempting to diagnose pelvic lesions, as well as systematic evaluations to further understand the efficacy of EUS-guided biopsy to detect pelvic lesions, are required.

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Compliance with ethical standards

Conflict of interest All authors state that they have no conflict of interest.

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