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Ultrasound Imaging Features Associated With Neoplastic Gallbladder Polyps: A Systematic Review and Meta-Analysis

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Objective: Although most gallbladder polyps are benign, some neoplastic polyps may be malignant or may serve as precursors to malignancy. Distinguishing neoplastic and non-neoplastic polyps using imaging examinations remains a major challenge. This meta-analysis aimed to identify the ultrasound (US) features that are significantly associated with neoplastic polyps.

Materials and Methods: The MEDLINE, EMBASE, Cochrane, and KoreaMed databases were searched for articles published up to August 31, 2025. Bivariate random-effects models were used to calculate the meta-analytic pooled diagnostic odds ratios (DORs), sensitivities, and specificities, along with their 95% confidence intervals (CIs), for each US imaging feature in the diagnosis of neoplastic polyps.

Results: Thirty studies evaluating 8,953 patients, including 1,216 (13.6%) patients with neoplastic polyps, were included. Among the nine evaluated US imaging features, namely, size ≥10 mm, sessile morphology, single polyp, coexisting gallstones, hypoechogenicity, heterogeneous echogenicity, gallbladder wall thickening (GBWT), absence of hyperechoic spot, and vascularity, eight were significantly associated with neoplastic polyps: size ≥10 mm (DOR: 6.23 [95% CI: 1.86–20.90]), sessile morphology (DOR: 3.54 [1.93–5.97]), single polyp (DOR: 2.21 [1.76–2.74]), coexisting gallstones (DOR: 1.86 [1.29–2.60]), hypoechogenicity (DOR: 3.55 [1.47–7.30]), GBWT (DOR: 9.38 [1.47–32.20]), absence of hyperechoic spots (DOR: 4.23 [2.46–6.83]), and vascularity (DOR: 9.72 [5.81–15.30]). Of these, size ≥10 mm demonstrated the highest pooled sensitivity (0.79 [95% CI: 0.68–0.87]), whereas hypoechogenicity showed the highest pooled specificity (0.93 [95% CI: 0.82–0.98]).

Conclusion: Eight US imaging features (size ≥10 mm, sessile morphology, single polyp, coexisting gallstones, hypoechogenicity, GBWT, absence of hyperechoic spots, and vascularity) were significantly associated with the presence of neoplastic polyps. These features may facilitate the management of gallbladder polyps.

Keywords: Gallbladder; Neoplastic polyp; Ultrasound; Systematic review; Meta-analysis

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INTRODUCTION

Gallbladder (GB) polyps are commonly detected on abdominal ultrasound (US), with a reported prevalence of 3.3%–9.5% [1-3]. Most GB polyps are benign, whereas a minority (4%–10%) are neoplastic with malignant potential [4,5]. Although the natural history of neoplastic polyps has received limited attention, surgical series indicate a malignancy rate of 37%–55% in neoplastic polyps ≥10 mm in size [5-8]. Therefore, identifying neoplastic polyps and distinguishing them from non-neoplastic lesions is crucial to ensure timely surgical intervention, thereby preventing poor outcomes in patients with advanced GB cancer or missing early-stage malignancies. Although a size threshold of ≥10 mm is widely recognized as a predictor of neoplastic polyps, other imaging features, including sessile morphology, solitary presentation, coexisting gallstones, echogenicity, and gallbladder wall thickening (GBWT), have shown variable and contentious diagnostic utility in the existing literature. Moreover, while various international guidelines provide recommendations for GB polyp management, the supporting evidence base is often limited [9,10], and the relevance of certain risk factors, such as coexisting gallstones, has been inconsistently addressed across guidelines [9,11]. This lack of definitive foundational evidence was a key consideration when formulating the 2025 recommendations from the Korean Society of Abdominal Radiology (KSAR) [12]. Accordingly, the present systematic review and meta-analysis were conducted as part of the 2025 KSAR guideline development process to generate robust quantitative evidence to inform these recommendations and supplement expert consensus.

This systematic review and meta-analysis aimed to address the gaps in the current literature and quantitatively identify the US features that are significantly associated with neoplastic GB polyps.

MATERIALS AND METHODS

This systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [13]. The study protocol was registered with the PROSPERO International Prospective Register of Systematic Reviews (No. CRD420251045356).

Literature Search

A comprehensive literature search was performed on August 31, 2025, using search terms developed collaboratively by methodology experts and members of the KSAR Clinical Practice Guideline Committee, all of whom were fellowship-trained, board-certified body radiologists. The MEDLINE (PubMed), EMBASE, Cochrane, and KoreaMed databases were searched. Methodology experts and committee members participated in all stages of the search process. The detailed search queries are provided in Supplementary Table 1.

Eligibility Criteria

A systematic search was designed to identify studies that met the following inclusion criteria: 1) population: patients with GB polyps who underwent US, 2) index test: US (transabdominal US or endoscopic US [EUS]), and 3) target condition: assessment of the diagnostic accuracy of US imaging features for neoplastic polyps. Studies were excluded if they met any of the following criteria: 1) involved duplicate patients or data, 2) were animal studies, conference proceedings, reviews, meta-analyses, case reports, letters, commentaries, errata, or pictorial essays, 3) were published in languages other than English, 4) provided insufficient data to construct a diagnostic 2 x 2 table, or 5) were not relevant to the scope of this study. KSAR Clinical Practice Guideline Committee members (W.C., S.L., Y-Y.K., J.Y.P., S.K.J., J.E.L., J.Y., S.H., S.H.P., J.H.K., and H.J.P., with 9, 8, 5, 9, 6, 9, 6, 4, 9, 3, and 5 years of experience in abdominal radiology after fellowship training, respectively) independently screened the titles and abstracts, and subsequently reviewed the full texts after removal of duplicates, with each article being evaluated by two members. Discrepancies between the reviewers were resolved by consensus, and confirmation was provided by a third reviewer (J.H.Y., with 13 years of experience in abdominal radiology after fellowship training).

Data Extraction

The following data were extracted from each article: 1) study characteristics (first author, year and country of publication, study design [prospective or retrospective], and patient enrollment [consecutive or selective]), 2) patient cohort characteristics (number of patients, age, and sex), 3) index test details (type of US: transabdominal or EUS), 4) US imaging features associated with neoplastic polyps (including size ≥10 mm, sessile morphology, single polyp,

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coexisting gallstones, hypoechogenicity, heterogeneous echogenicity, presence of GBWT, absence of hyperechoic spot, or vascularity), 5) reference standard for neoplastic and non-neoplastic polyps (pathology alone or pathology plus clinical follow-up), and 6) outcome data (numbers of true positives, false positives, false negatives, and true negatives for each US imaging feature). Data extraction was independently conducted by two reviewers (S.L. and J.H.Y.), and discrepancies were resolved through a consensus discussion.

Definition of Neoplastic Polyps

In this study, the pathologically confirmed neoplastic polyps included adenomas with or without dysplasia, intracystic papillary neoplasms with or without dysplasia or invasive carcinoma, adenocarcinomas, adenosquamous carcinomas, squamous carcinomas, and small cell carcinomas.

Study Quality Assessment

The Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool was used to assess the risk of bias and concerns regarding the applicability of individual studies [14]. The evaluated domains included patient selection, index tests, reference standards, and flow and timing [14].

Statistical Analysis

Bivariate random-effects models were used to calculate the meta-analytic pooled diagnostic odds ratios (DORs), sensitivities, and specificities, together with their 95% confidence intervals (CIs) for each US imaging feature associated with neoplastic polyps [15]. We assessed heterogeneity among studies using I^2 values (I^2 > 50% indicated substantial heterogeneity), which were obtained using the Zhou and Dendukuri approach [16] as well as the Holling sample size–adjusted method [17]. Meta-regression analyses included the following covariates: country (East Asia vs. others), study design (prospective vs. retrospective), patient enrollment (consecutive vs. selective), type of US examination (transabdominal US vs. EUS), reference standard (pathology only vs. pathology or clinical follow-up), and proportion of neoplastic polyps >30% (yes vs. no). Publication bias was evaluated using Deeks' funnel plots and Deeks' asymmetry test [18]. A *P*-value <0.05 was considered to indicate significant differences. Statistical analyses were performed using the "mada" package in R version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

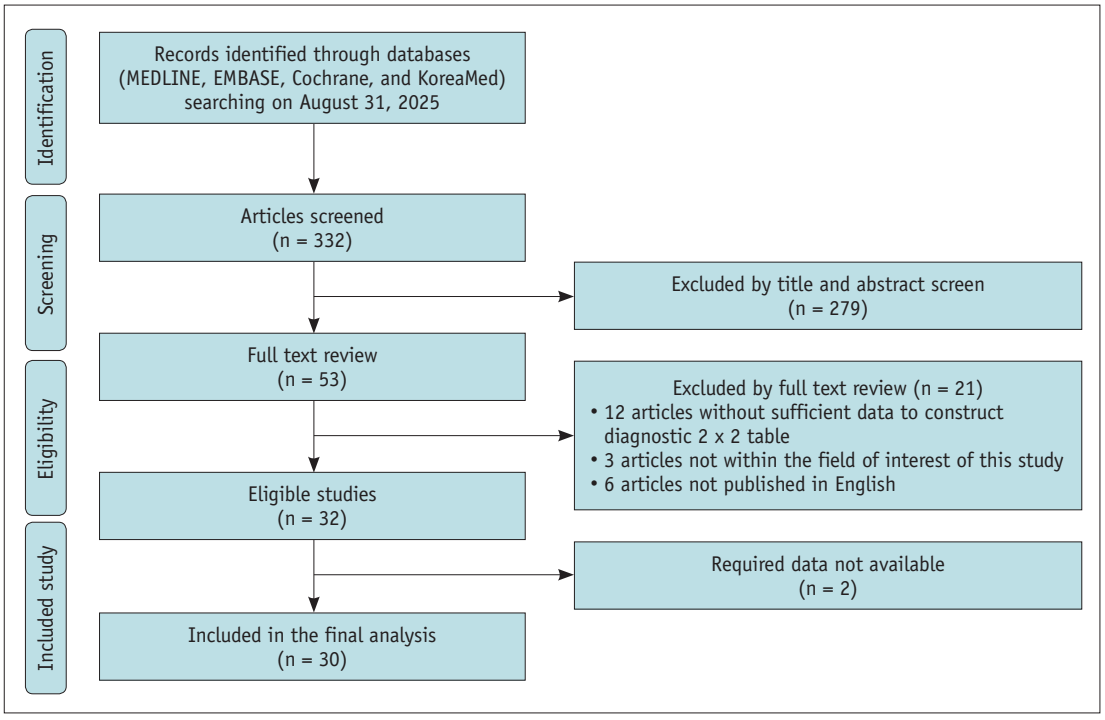

Fig. 1. Flow diagram of study selection.

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RESULTS

Systematic Review and Quality Assessment

The initial search yielded 332 studies, of which 53 full-text articles were reviewed. After full-text assessment, 23 studies were excluded, and the remaining 30 articles were included in the final analysis [4,19-47]. The flow diagram of the study selection process is shown in Figure 1. The characteristics of the included studies are summarized in Table 1. The final analysis consisted of 30 studies with 8,953 patients, of whom 1216 (13.6%) had neoplastic polyps. Among these studies, 27 were retrospective and three were prospective. Twenty-six studies used transabdominal US, while four used EUS. The methodological quality of the included studies, as assessed using the QUADAS-2 tool, is summarized in Supplementary Figure 1. Of the four domains evaluated, the reference standard domain was most frequently associated with quality concerns, with 40.0% (12/30) of the studies rated as having a high or unclear risk of bias because they did not describe whether the reference standard results were interpreted without knowledge of the results of the index test. In the index test domain, 26.7% (8/30) of the studies had a high or unclear risk of bias, because they did not describe whether the index test results were interpreted

Table 1. Characteristics of the included studies

References	Country	Study design	Patient enrollment	No. of patients (M:F)	Patient age (year)*	Type of US	Reference standard for neoplastic polyps
Kubota et al., 1995 [19]	Japan	Retrospective	Consecutive	72 (40:32)	51	TUS	Pathology only
Choi et al., 2000 [20]	South Korea	Retrospective	Selective	79 (NR)	50	EUS	Pathology only
Akatsu et al., 2006 [21]	Japan	Retrospective	Selective	29 (16:13)	50 (30–80)	EUS	Pathology only
Cho et al., 2009 [22]	South Korea	Retrospective	Selective	88 (38:50)	50 (23–76)	EUS	Pathology only
Park et al., 2009 [23]	South Korea	Retrospective	Consecutive	1,558 (850:708)	49 (15–86)	TUS	Pathology or clinical F/U
Shin et al., 2009 [25]	South Korea	Retrospective	Consecutive	145 (85:60)	48 (25–75)†	TUS	Pathology only
Shah, 2010 [24]	Nepal	Retrospective	Consecutive	31 (8:23)	40 (22–69)	TUS	Pathology only
Cha et al., 2011 [26]	South Korea	Retrospective	Selective	210 (109:101)	52	TUS	Pathology only
Fei et al., 2015 [27]	China	Prospective	Selective	122 (57:65)	49 (20–72)	TUS	Pathology only
Liu et al., 2015 [28]	China	Retrospective	Consecutive	83 (37:46)	50 (25–78)	TUS	Pathology only
Kim et al., 2016 [29]	South Korea	Retrospective	Selective	53 (26:27)	54 (28–81)	TUS	Pathology or clinical F/U
Yang et al., 2018 [30]	South Korea	Retrospective	Selective	979 (542:437)	52	TUS	Pathology only
Sun et al., 2019 [4]	China	Retrospective	Selective	686 (303:383)	46 (31–60)	TUS	Pathology only
Pickering et al., 2020 [31]	UK, Ireland	Retrospective	Consecutive	134 (56:78)	53 (12–89)	TUS	Pathology only
Bao et al., 2021 [32]	China	Retrospective	Selective	520 (267:253)	42	TUS	Pathology only
Fei et al., 2021 [33]	China	Retrospective	Selective	94 (42:52)	41 (19–78)†	TUS	Pathology only
Yuan et al., 2021 [34]	China	Prospective	Selective	89 (38:51)	54 (23–89)	TUS	Pathology only
Zhu et al., 2021 [35]	China	Retrospective	Selective	164 (85:69)	40 (18–73)	TUS	Pathology only
Candia et al., 2022 [36]	Chile	Retrospective	Consecutive	748 (194:554)	49†	TUS	Pathology or clinical F/U
Güneş et al., 2022 [37]	Turkey	Retrospective	Consecutive	173 (75:98)	48	TUS	Pathology only
Han et al., 2022 [38]	South Korea	Retrospective	Consecutive	239 (126:113)	49	TUS	Pathology only
Zhu et al., 2022 [39]	China	Retrospective	Selective	107 (55:52)	41 (18–70)	TUS	Pathology only
Ma et al., 2022 [40]	China	Retrospective	Consecutive	522 (220:302)	48†	TUS	Pathology only
Wang et al., 2022 [41]	China	Retrospective	Selective	89 (40:49)	45 (24–78)†	TUS	Pathology only
Zhang et al., 2022 [42]	China	Retrospective	Consecutive	250 (116:134)	50	TUS	Pathology only
Zhu et al., 2023 [43]	China	Retrospective	Selective	143 (62:81)	42	TUS	Pathology only
Cho et al., 2024 [44]	South Korea	Prospective	Consecutive	53 (19:34)	59†	EUS	Pathology only
Chai et al., 2025 [45]	USA	Retrospective	Selective	450 (NR)	NR	TUS	Pathology or clinical F/U
He et al., 2025 [46]	China	Retrospective	Consecutive	924 (335:589)	46†	TUS	Pathology only
Jiang et al., 2025 [47]	China	Retrospective	Selective	119 (69:50)	50	TUS	Pathology only

Articles are listed according to year of publication and alphabetical order of the name of the first author within the same year of publication.
*Otherwise specified, data are mean with the range in parentheses when available, †Data are median with the range in parentheses when available.
M = male, F = female, US = ultrasound, TUS = transabdominal US, NR = not reported, EUS = endoscopic US, F/U = follow-up

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without knowledge of the results for the reference standard. In the flow and timing domains, 20.0% (6/30) of the studies had a high or unclear risk of bias owing to inappropriate intervals between the index tests and the reference standard.

US Imaging Features Associated With Neoplastic Polyps

Table 2 summarizes the meta-analytic pooled estimates of the diagnostic accuracy measures for the US imaging features. Among the nine US features assessed, eight were significantly associated with neoplastic polyps: size ≥10 mm (DOR: 6.23, 95% CI: 1.86–20.90), sessile morphology (DOR: 3.54, 95% CI: 1.93–5.97), single polyp (DOR: 2.21, 95% CI: 1.76–2.74), coexisting gallstones (DOR: 1.86, 95% CI: 1.29–2.60), hypoechogenicity (DOR: 3.55, 95% CI: 1.47–7.30), GBWT (DOR: 9.38, 95% CI: 1.47–32.20), absence of hyperechoic spots (DOR: 4.23, 95% CI: 2.46–6.83), and vascularity (DOR: 9.72, 95% CI: 5.81–15.30). However, heterogeneous echogenicity (DOR: 1.30, 95% CI: 0.21–4.41) was not significantly associated with neoplastic polyps. Notably, substantial heterogeneity was observed for heterogeneous echogenicity (I^2 = 69.4%) and GBWT (I^2 = 62.1%), according to the Zhou and Dendukuri approach (Supplementary Table 2). Figure 2 shows the forest plots of the DORs of the eight US imaging features that were significantly associated with neoplastic polyps. Among the eight US features, size ≥10 mm demonstrated the highest pooled sensitivity (0.79, 95% CI: 0.68–0.87), whereas hypoechogenicity showed the highest pooled specificity (0.93, 95% CI: 0.82–0.98) (Table 2, Supplementary Fig. 2).

Meta-Regression Analysis

Supplementary Tables 3-10 present the results of meta-regression analysis for the eight significant US imaging features. Among the six covariates, the study country (East Asia vs. others) was significantly associated with the pooled DOR for GBWT (P = 0.032). For the pooled sensitivity and specificity estimates, the study country showed significant associations with the meta-analysis results for coexisting gallstones (P = 0.004), GBWT (P = 0.001), and vascularity (P = 0.036). Patient enrollment was significantly associated with the meta-analysis results for size ≥10 mm (P = 0.048) and coexisting gallstones (P = 0.043). The reference standard was significantly associated with the meta-analysis results for vascularity (P = 0.036). In addition, the proportion of neoplastic GBPs >30% was significantly associated with the meta-analysis results for hypoechogenicity (P = 0.029) and the absence of a hyperechoic spot (P = 0.032).

Publication Bias

Deeks' asymmetry test showed no evidence of publication bias for size ≥10 mm (P = 0.075), sessile morphology (P = 0.972), single polyp (P = 0.085), heterogeneous echogenicity (P = 0.094), and vascularity (P = 0.914). However, evidence of publication bias was observed for coexisting gallstones (P = 0.004), hypoechogenicity (P = 0.044), GBWT (P = 0.014), and the absence of hyperechoic spots (P = 0.027) (Supplementary Fig. 3).

DISCUSSION

In this systematic review and meta-analysis, we investigated the diagnostic accuracy of B-mode US features for identifying neoplastic polyps. Our findings indicated that size ≥10 mm, sessile morphology, and GBWT were significantly associated with neoplastic polyps. The pooled

Table 2. Summary of the meta-analysis results with the pooled DOR, sensitivity, and specificity of US imaging features for neoplastic gallbladder polyps

US features	No. of studies	No. of neoplastic polyps	No. of non-neoplastic polyps	Meta-analysis summary estimate		
				Pooled DOR	Pooled sensitivity	Pooled specificity
Size ≥10 mm	8	188	1,220	6.23 [1.86–20.90]	0.79 [0.68–0.87]	0.62 [0.43–0.78]
Sessile	12	338	1,890	3.54 [1.93–5.97]	0.64 [0.55–0.71]	0.66 [0.58–0.73]
Single	25	1,111	6,434	2.21 [1.76–2.74]	0.66 [0.61–0.71]	0.53 [0.47–0.58]
Coexisting gallstones	19	784	5,994	1.86 [1.29–2.60]	0.24 [0.20–0.30]	0.85 [0.80–0.89]
Hypoechogenicity	11	574	2,359	3.55 [1.47–7.30]	0.19 [0.11–0.31]	0.93 [0.82–0.98]
Heterogeneous echogenicity	6	362	1,569	1.30 [0.21–4.41]	0.50 [0.15–0.85]	0.49 [0.07–0.92]
GBWT	6	344	2,326	9.38 [1.47–32.20]	0.42 [0.26–0.59]	0.91 [0.73–0.97]
Absence of hyperechoic spot	9	296	765	4.23 [2.46–6.83]	0.75 [0.68–0.82]	0.57 [0.41–0.72]
Vascularity	11	500	2,267	9.72 [5.81–15.30]	0.56 [0.39-0.72]	0.88 [0.80–0.93]

Values in bracket are 95% confidence intervals.
DOR = diagnostic odds ratio, US = ultrasound, GBWT = gallbladder wall thickening

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DORs were 9.38 (95% CI: 1.47–32.20) for GBWT, 6.23 (95% CI: 1.86–20.90) for size ≥10 mm, and 3.54 (95% CI: 1.93–5.97) for sessile polyps. Among the three features, size ≥10 mm demonstrated the highest pooled sensitivity (0.79, 95% CI: 0.68–0.87), while GBWT (0.91, 95% CI: 0.73–0.97) showed pooled specificity over 90%. The results of this study underscore the critical importance of specific US characteristics for risk stratification of GB polyps and provide foundational evidence for the risk-stratification approach adopted in the 2025 KSAR guidelines.

The significant association between polyp size ≥10 mm and neoplastic changes is the cornerstone of most current management strategies [9,11,12,48]. Our meta-analysis demonstrated that this size threshold offers higher pooled sensitivity (0.79) than other US features for identifying neoplastic lesions, indicating its effectiveness in capturing a large proportion of at-risk polyps. However, the pooled specificity for the ≥10-mm criterion was modest (0.62, 95% CI: 0.43–0.78), indicating that while this threshold is sensitive, relying on size alone may result in the inclusion of a substantial number of non-neoplastic polyps. This finding supports the tiered recommendations in the KSAR and Society of Radiologists in Ultrasound (SRU) guidelines, which differentiate management within the ≥10-mm group: cholecystectomy is recommended for polyps ≥15 mm, and optional cholecystectomy is suggested for polyps between

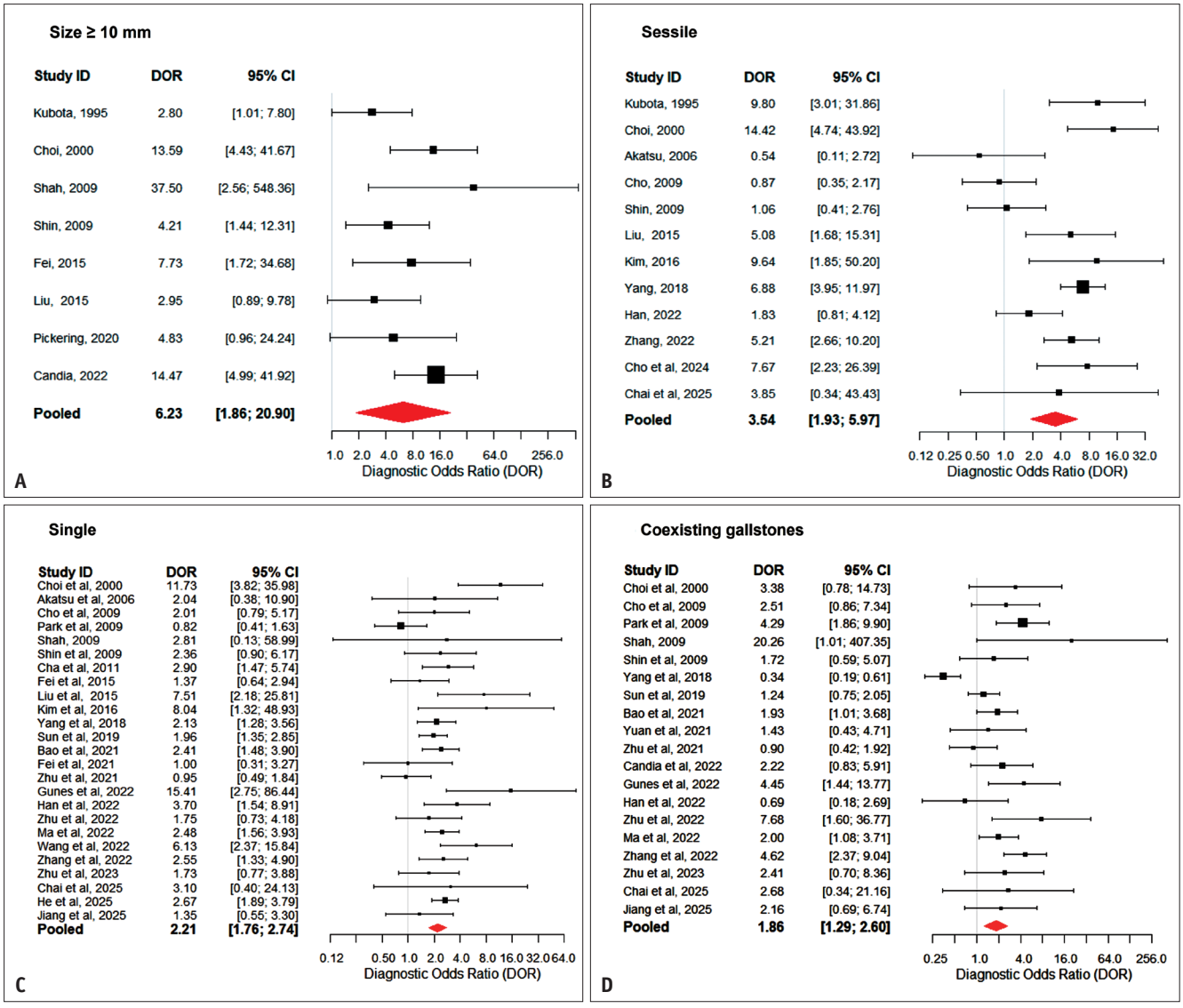

Fig. 2. Forest plots of the DORs with 95% CIs of the ultrasound features associated with neoplastic gallbladder polyps. **A:** Size ≥10 mm. **B:** Sessile morphology. **C:** Single polyp. **D:** Coexisting gallstones. **E:** Hypoechogenicity. **F:** GBWT. **G:** Absence of hyperechoic spots. **H:** Vascularity. DOR = diagnostic odds ratio, CI = confidence interval, GBWT = gallbladder wall thickening

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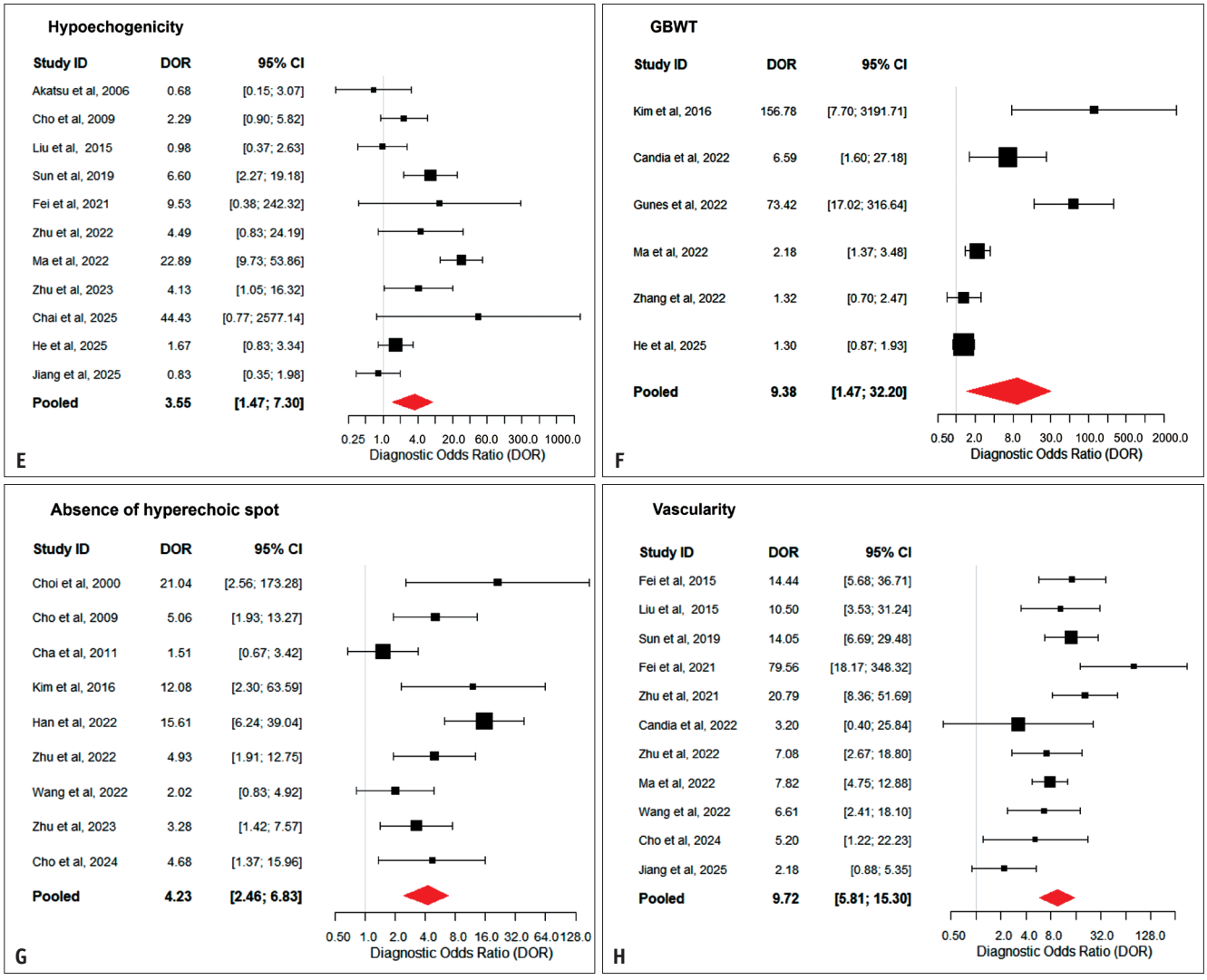

Fig. 2. Forest plots of the DORs with 95% CIs of the ultrasound features associated with neoplastic gallbladder polyps. **A:** Size ≥10 mm. **B:** Sessile morphology. **C:** Single polyp. **D:** Coexisting gallstones. **E:** Hypoechogenicity. **F:** GBWT. **G:** Absence of hyperechoic spots. **H:** Vascularity. DOR = diagnostic odds ratio, CI = confidence interval, GBWT = gallbladder wall thickening

10 and 14 mm [9,12], thereby potentially reducing unnecessary surgical interventions.

Furthermore, sessile morphology was also associated with neoplastic polyps. Current guidelines from the KSAR, SRU, and World Federation for Ultrasound in Medicine and Biology (WFUMB) consider sessile morphology a risk factor for neoplastic polyps and frequently recommend more aggressive management or intensive follow-up strategies in such cases [9,10,12]. Although the association between sessile morphology and neoplastic polyps is well-recognized in the literature, systematic evidence to support these recommendations is lacking. Our meta-analysis confirms the relevance of sessile polyps and supports the inclusion of morphological assessment as an important component of GB polyp risk stratification.

In our study, GBWT was a particularly strong predictor of neoplastic polyps, with a high pooled DOR (9.38) and specificity (0.91), although the sensitivity remained modest (0.42). This suggests that when GBWT is present, the likelihood of an underlying neoplastic polyp increases substantially. While GBWT is less frequently highlighted as a primary standalone risk factor in comparison with size, it is generally recognized as a concerning feature in clinical guidelines: the 2025 KSAR recommendations consider adjacent GBWT as one of three "concerning imaging features," alongside sessile morphology and significant growth, warranting specific management [12]. The SRU also classifies GB polyps with adjacent

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GBWT into an intermediate-risk group [9]. Our findings strongly support the KSAR and SRU guidelines and suggest that GBWT warrants the attention of radiologists during US evaluations. Notably, the meta-regression analysis revealed that the study country (East Asia vs. others) was a significant source of heterogeneity in the diagnostic performance of the GBWT, with significant associations with the pooled DOR and specificity. Non-East Asian studies demonstrated a substantially higher specificity (97.6%) than East Asian studies (72.1%). This discrepancy appears to be largely attributable to differences in GBWT definitions across studies rather than true geographic variations in diagnostic performance. Studies from Western countries explicitly used "focal GBWT" focusing on localized GBWT [36,37]. In contrast, only one of four East Asia studies used "adjacent GBWT" [29] while others used the broader term "GBWT" without specification [40,42,46], potentially including benign inflammatory changes and resulting in lower specificity. These findings underscore the importance of using precise terminology and definitions for risk assessment of GB polyps.

Beyond standardization of terminology, another important consideration is how "concerning imaging features" should be weighted relative to each other in clinical decision-making. During the development of the KSAR guidelines, these three features were weighted equally to maintain simplicity in the management algorithm, given the limited evidence available at the time to definitively assign differential risk weights [49]. Even weighting of risk factors was also observed in European guidelines [48]. However, our meta-analysis, which demonstrated a substantially higher DOR for GBWT than for sessile morphology, provides evidence that adjacent GBWT may carry a greater risk than other features in predicting neoplastic potential. The SRU guidelines suggest optional cholecystectomy even for smaller polyps (≤6 mm) if focal GBWT is present and recommend cholecystectomy for larger polyps (≥7 mm) with this feature, showing that GBWT can significantly alter risk assessment even for polyps smaller than the traditional 10-mm threshold [9]. Taken together, our findings provide quantitative evidence that adjacent GBWT may warrant greater weight than other US features in risk-stratification algorithms, a consideration that should be incorporated into future guideline refinements.

Notably, vascularity was another key imaging predictor of neoplastic polyps in our meta-analysis, demonstrating the highest DOR (9.72; 95% CI: 5.81–15.30) among all evaluated features. The existing guidelines include different recommendations regarding polyp vascularity: the SRU guidelines explicitly concluded that polyp vascularity should not influence risk stratification due to limited evidence; both European guidelines and KSAR recommendations did not incorporate vascularity in risk stratification; and the WFUMB guidelines suggested that the combination of B-mode and Doppler finding may distinguish neoplastic polyps [9,10,12,48]. We believe that our findings provide quantitative evidence for this issue. The high specificity (0.88) in this study, despite the moderate sensitivity (0.56), indicates that the presence of intralesional vascularity can be a critical "rule-in" sign for neoplastic polyps, in addition to B-mode features. Although the absence of flow does not exclude neoplastic polyps, owing to the limitations of conventional Doppler imaging in detecting slow flow in small lesions, the presence of vascularity seems to carry significant weight and should be considered a high-risk feature that warrants active management.

Our study also suggested that polyp echogenicity is associated with the risk of developing neoplastic polyps. Hypoechogenicity demonstrated a moderate association (DOR: 3.55; 95% CI: 1.47–7.30) but was notable for having the highest pooled specificity (0.93) among all evaluated features. Thus, while hypoechogenicity is an infrequent finding (sensitivity, 0.19), it increases the risk of neoplastic polyps when present, likely reflecting glandular epithelial proliferation [50]. Complementing this, the absence of hyperechoic spots showed a DOR of 4.23 (95% CI: 2.46–6.83) with a sensitivity of 0.75. Because hyperechoic spots are characteristic of benign cholesterol polyps due to the accumulation of foamy histiocytes containing cholesterol [50], their absence effectively removes a key benign feature, thereby elevating the suspicion of neoplasia. Thus, when combined, these echogenicity patterns may help distinguish neoplastic from non-neoplastic polyps. This underscores the importance of careful attention to internal echo characteristics during routine US examination of GB polyps and supports the KSAR attempts to standardize polyp-echo assessment [12]. However, caution is needed since the criteria for echo assessment are heterogeneous or not clearly specified in the literature, and publication bias was noted for both features. Furthermore, their DORs were relatively modest, indicating that the optimal utility of these features may be ancillary.

In the present meta-analysis, solitary polyps were significantly associated with neoplastic characteristics.

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However, the pooled specificity for single GB polyps was modest (0.53), indicating that most single polyps were benign. This finding aligns with the rationale likely considered by the KSAR guidelines, which do not include "single GB polyp" among the "concerning imaging features" driving specific management decisions [12]. The results of our meta-analysis, particularly the modest specificity, justify this approach. Thus, while determining whether a GB polyp is solitary is part of a comprehensive assessment, this feature is likely the most informative when considered in conjunction with other, more specific, high-risk characteristics.

The association between neoplastic polyps and coexisting gallstones remains a matter of debate in the literature, and its impact on management decisions varies among guidelines [9,11,12]. In our study, coexisting gallstones were significantly associated with the presence of neoplastic polyps (DOR, 1.86; 95% CI: 1.29–2.60). However, the DOR for coexisting gallstones was the lowest among the eight significant US features and the pooled sensitivity was poor (0.24). Thus, while a statistical association exists, which may reflect shared risk factors for stone formation and neoplasia, the presence of stones is a weaker independent predictor than others. A recent study demonstrated that gallstones, cholecystitis, and polyps commonly coexist as comorbidities in individuals with biliary tract diseases, and gallstones do not increase the risk of biliary tract cancer without evidence of cholecystitis [51]. Consequently, although coexisting stones may add to the overall clinical picture, they should not be weighed as heavily as other high-risk features. This finding aligns with the management approaches endorsed by KSAR and SRU, which do not prioritize coexisting gallstones as a primary driver for surgical intervention in the absence of other concerning features [9,12].

This study had several limitations that require consideration. First, publication bias was detected for coexisting gallstones, GBWT, hypoechogenicity, and the absence of hyperechoic spots, which may have affected the generalizability of our summary estimates. Moreover, the analysis of GBWT is complicated by inconsistent terminology and definitions across studies, as discussed above, which may have contributed to the observed heterogeneity. Additionally, the criteria for polyp echogenicity assessment varied among the studies. These inconsistencies require further validation using standardized criteria. Third, during the quality assessment using QUADAS-2, a substantial proportion of studies demonstrated methodological concerns regarding the risk of bias, which may have limited the reliability of our meta-analysis results.

In conclusion, this meta-analysis, which was conducted as a foundational component of the 2025 KSAR guideline development process, identified eight US imaging features (size ≥10 mm, sessile morphology, single polyp, coexisting gallstones, hypoechogenicity, GBWT, absence of hyperechoic spot, and vascularity) that were significantly associated with neoplastic polyps. These included the key US features endorsed in the KSAR 2025 guidelines: size ≥10 mm, sessile morphology, and adjacent GBWT. In addition, this study highlighted the potential roles of polyp vascularity and echogenicity in refining risk stratification for GB polyps, whereas the findings indicated that the presence of a single polyp and coexisting gallstones had less incremental value. These findings provide quantitative support for the 2025 KSAR recommendations and offer higher-level evidence for refining the existing risk-stratification strategies in the future.

Supplement

The Supplement is available with this article at https://doi.org/10.3348/kjr.2025.1126.

Availability of Data and Material

All data generated or analyzed during this study are included in this published article and its supplementary information files.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Sunyoung Lee, Jeong Hee Yoon. Data curation: all authors. Formal analysis: Sunyoung Lee, Hyun-Soo Zhang. Funding acquisition: Jeong Hee Yoon. Investigation: all authors. Methodology: Sunyoung Lee, Hyun-Soo Zhang, Jeong Hee Yoon. Project administration: Jeong Hee Yoon. Software: Sunyoung Lee, Hyun-Soo Zhang. Supervision: Jeong Hee Yoon. Visualization: Sunyoung Lee. Writing—original draft: Sunyoung Lee, Jeong Hee Yoon. Writing—review & editing: all authors.

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