Original Article

Diagnostic accuracy of spleen stiffness measurement for detecting esophageal varices and high-risk varices: A systematic review and meta-analysis across elastography modalities

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Abstract

A critical secondary effect of portal hypertension associated with chronic liver disease is the formation of esophageal varices, which act as a main trigger for upper gastrointestinal hemorrhage. Endoscopic screening is recommended to identify patients at risk, but it is invasive, costly, and not widely available. Evaluating splenic stiffness has emerged as a potential non-invasive diagnostic option because it reflects splenic congestion associated with portal hypertension rather than intrahepatic fibrosis alone. Several studies have evaluated spleen stiffness measurement (SSM) using different elastography techniques, reporting heterogeneous diagnostic performances. The aim of this study was to assess the diagnostic precision of SSM in identifying esophageal varices and high-risk esophageal varices (HREV), with secondary analyses comparing performance across elastography modalities. A systematic review alongside a diagnostic test accuracy meta-analysis was performed following Preferred Reporting Items for Systematic Reviews and Meta-Analyses of Diagnostic Test Accuracy Studies (PRISMA-DTA) guidelines, registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD420251207420). Literature searches were performed in PubMed, Google Scholar, ProQuest, and EBSCOhost. Studies were eligible if spleen stiffness served as the index test and esophagogastroduodenoscopy was utilized as the gold standard. Methodological quality was evaluated using Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2). Key endpoints included combined sensitivity and overall specificity. Subgroup analyses examined differences among elastography modalities. This study included 6,322 patients across 50 distinct studies. Diagnostic accuracy was generally consistent across elastography techniques. When identifying esophageal varices, the overall pooled sensitivity was 0.88 (95% confidence interval (CI): 0.85–0.91), and specificity was 0.76 (95%CI: 0.70–0.82). However, HREV provided a slightly enhanced diagnostic yield, achieving a higher sensitivity of 0.91 (95%CI: 0.89–0.93) but a slightly lower specificity of 0.71 (95%CI: 0.66–0.76). SSM showed intermediate specificity and high sensitivity as a non-invasive HREV rule-out method. Its ability to pinpoint high-risk varices underlines its potential as an effective, non-invasive screening strategy for chronic liver disease.

Keywords: Spleen stiffness measurement, portal hypertension, esophageal varices, liver cirrhosis, elastography

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Introduction

Cirrhosis and chronic liver disease represent major global health problems and remain among the leading causes of mortality worldwide [1]. Globally, the mortality of cirrhosis has been reported to account for 14.05 million deaths from the year 1990 to 2019 [2]. A significant proportion of the morbidity related to chronic liver disease arises from portal hypertension, which is defined as an abnormal increase in the hepatic venous pressure gradient resulting from increased intrahepatic vascular resistance. As portal pressure increases, splenic vasodilation follows, collateral circulation develops, and eventually esophageal varices appear [3]. These varices represent one of the most clinically important complications of cirrhosis because rupture may lead to life-threatening upper gastrointestinal bleeding [3,4]. The annual risk of a first variceal bleeding episode approaches 12%, whereas six-week mortality following bleeding remains high, ranging from 15–20% [4]. The probability of hemorrhage may be influenced by several factors, including variceal size, red wale sign on endoscopy, and the severity of hepatic dysfunction measured by the Child–Pugh score. Despite advances in treatment strategies, clinical outcomes remain poor. Therefore, regular screening for esophageal varices is crucial to detect high-risk patients and facilitate prompt preventive measures [3,4].

Esophagogastroduodenoscopy represents the gold standard for identifying esophageal varices. Nevertheless, the procedure entails invasiveness, high costs, and limited availability across numerous clinical environments [4]. Because of this limitation, several non-invasive approaches have been proposed to identify patients who require endoscopic surveillance [5]. However, their diagnostic performance remains inconsistent [6]. The Baveno VI consensus criteria combine liver stiffness measurement (LSM) with platelet count to guide endoscopic screening; patients with LSM >20 kilopascals (kPa) and platelet count <150,000/µL are recommended to undergo endoscopy. This strategy can reduce unnecessary procedures in compensated cirrhosis [5]. Nevertheless, LSM primarily indicates the intrahepatic aspect of portal pressure and may be influenced by inflammation, congestion, or cholestasis. As a result, LSM may not consistently reflect portal hypertension properly [7].

Spleen stiffness measurement (SSM) has been proposed as a more direct marker of portal hemodynamics. Increased portal pressure leads to splenic congestion, alterations in splenic tissue architecture, and elevated splenic blood flow, which collectively contribute to increased spleen stiffness [7]. Because these alterations are more closely related to portal pressure, SSM may better capture the hemodynamic consequences of portal hypertension. Several elastography techniques are used to measure spleen stiffness, including vibration-controlled transient elastography (TE) at 100 Hz or 50 Hz, point shear wave elastography (SWE), two-dimensional shear wave elastography (2D-SWE), as well as magnetic resonance elastography [8].

This research aimed to evaluate the diagnostic efficacy of SSM in identifying esophageal varices alongside high-risk esophageal varices (HREV) in individuals diagnosed with chronic liver disease. In addition, the present study compares diagnostic performance across elastography modalities in order to assess the consistency of SSM and its potential role within non-invasive screening strategies for portal hypertension–related complications.

Methods

Study design

This study was conducted as a systematic review and diagnostic test accuracy meta-analysis. Reporting followed the standards set by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses of Diagnostic Test Accuracy (PRISMA-DTA) 2020 framework. The review protocol had been prospectively archived in the International Prospective Register of Systematic Reviews (PROSPERO) database under registration number CRD420251207420. Registration occurred before data extraction began.

Literature search strategy

A comprehensive systematic search was performed from database inception to November 2025. EBSCO, ProQuest, PubMed, and Google Scholar were explored. Search terms combined keywords

with Medical Subject Headings (MeSH) related to spleen stiffness, elastography, esophageal varices, portal hypertension, and cirrhosis or chronic liver disease. Slight variations in syntax were used for each database. Reference lists of eligible articles were also reviewed manually.

The core strategy included combinations such as ("spleen stiffness" OR "spleen elastography" OR "spleen shear wave") linked to ("esophageal varices" OR "portal hypertension") together with ("chronic liver disease" OR "liver cirrhosis"). Equivalent controlled vocabulary terms were used where applicable. Searches were adapted for EBSCO, ProQuest, PubMed, and Google Scholar. Search strategy in each database was presented in **Table 1**.

Table 1. Search strategy in each database

Database	Search strategy
PubMed	("spleen stiffness"[Title/Abstract] OR "spleen elastography"[Title/Abstract] OR "spleen shear wave"[Title/Abstract]) AND ("esophageal varices"[MeSH Terms] OR "esophageal varices"[Title/Abstract] OR "portal hypertension"[Title/Abstract]) AND ("chronic liver disease"[Title/Abstract] OR "liver cirrhosis"[MeSH Terms])
Google Scholar	("spleen stiffness" OR "spleen elastography") AND ("esophageal varices" OR "portal hypertension") AND ("chronic liver disease" OR "liver cirrhosis")
ProQuest	TI,AB("spleen stiffness" OR "spleen elastography" OR "spleen shear wave") AND TI,AB("esophageal varices" OR "portal hypertension") AND TI,AB("chronic liver disease" OR "liver cirrhosis")
EBSCOhost	(TI "spleen stiffness" OR TI "spleen elastography" OR AB "spleen shear wave") AND (TI "esophageal varices" OR AB "portal hypertension") AND (TI "chronic liver disease" OR AB "liver cirrhosis")

Eligibility criteria

Studies were considered eligible if SSM was used as the index test in patients with chronic liver disease or cirrhosis. Upper gastrointestinal endoscopy served as the reference standard. Outcomes included detection of esophageal varices (any esophageal varices) or HREV. Sufficient data needed to be available to reconstruct a 2×2 contingency table comprising true positives, false positives, true negatives, and false negatives. Studies published in languages other than English were excluded due to limited language proficiency and to minimize the possibility of misinterpretation during data extraction. Studies published more than ten years before the search were excluded to ensure that the included evidence reflected modern elastography technologies and diagnostic methods for portal hypertension and esophageal varices. Case reports, reviews, editorials, and letters were excluded. Studies that did not provide data on diagnostic accuracy were also excluded.

Study selection and data extraction

Study selection was conducted in two stages. First, titles and abstracts were screened, followed by full-text assessment of potentially relevant studies. Two reviewers worked independently throughout the process. Disagreements were discussed until consensus was reached or occasionally resolved with a third reviewer. Extracted data included study design, patient characteristics, elastography modality used for SSM, reported SSM cut-off values, and diagnostic accuracy data for both esophageal varices and HREV outcomes.

Risk of bias assessment

The QUADAS-2 method was utilized to assess the risk of bias with concerns regarding applicability. Four domains were assessed: patient selection, index test, reference standard, flow and timing. Two reviewers performed the assessment independently. Discrepancies were discussed; consensus was reached afterward.

Statistical analysis

Statistical analyses were performed using RevMan software. Diagnostic accuracy meta-analysis was conducted using a bivariate random-effects framework. Pooled sensitivity and specificity were estimated, along with their corresponding 95% confidence intervals (95%CIs). MetaBayesDTA was employed to conduct Bayesian pairwise comparisons of elastography modalities using a bivariate Bayesian model for diagnostic test accuracy. The model jointly estimated sensitivity and specificity while accounting for the correlation between these measures

and between-study heterogeneity. Weakly informative prior distributions were assigned to the model parameters. Posterior estimates were summarized as medians with 95% credible intervals (CrIs). Differences and ratios in sensitivity and specificity were used to express pairwise comparisons. Furthermore, summary receiver operating characteristic curves (SROC) were generated to graphically illustrate total test efficacy. Subgroup analyses were performed according to the elastography modality used to measure SSM. Between-study heterogeneity and the correlation between sensitivity and specificity were explored descriptively. Potential publication bias was evaluated via diagnostic funnel plots, provided a sufficient number of studies were available.

Results

Study selection

The procedure for selecting studies is illustrated in **Figure 1**. A total of 4,696 records were identified through database and register searches, including 36 records from EBSCO, 25 from ProQuest, 207 from PubMed, and 4,428 from Google Scholar. Prior to screening, 1,476 duplicate entries and 200 records eliminated for various reasons were discarded, resulting in 3,020 records available for screening.

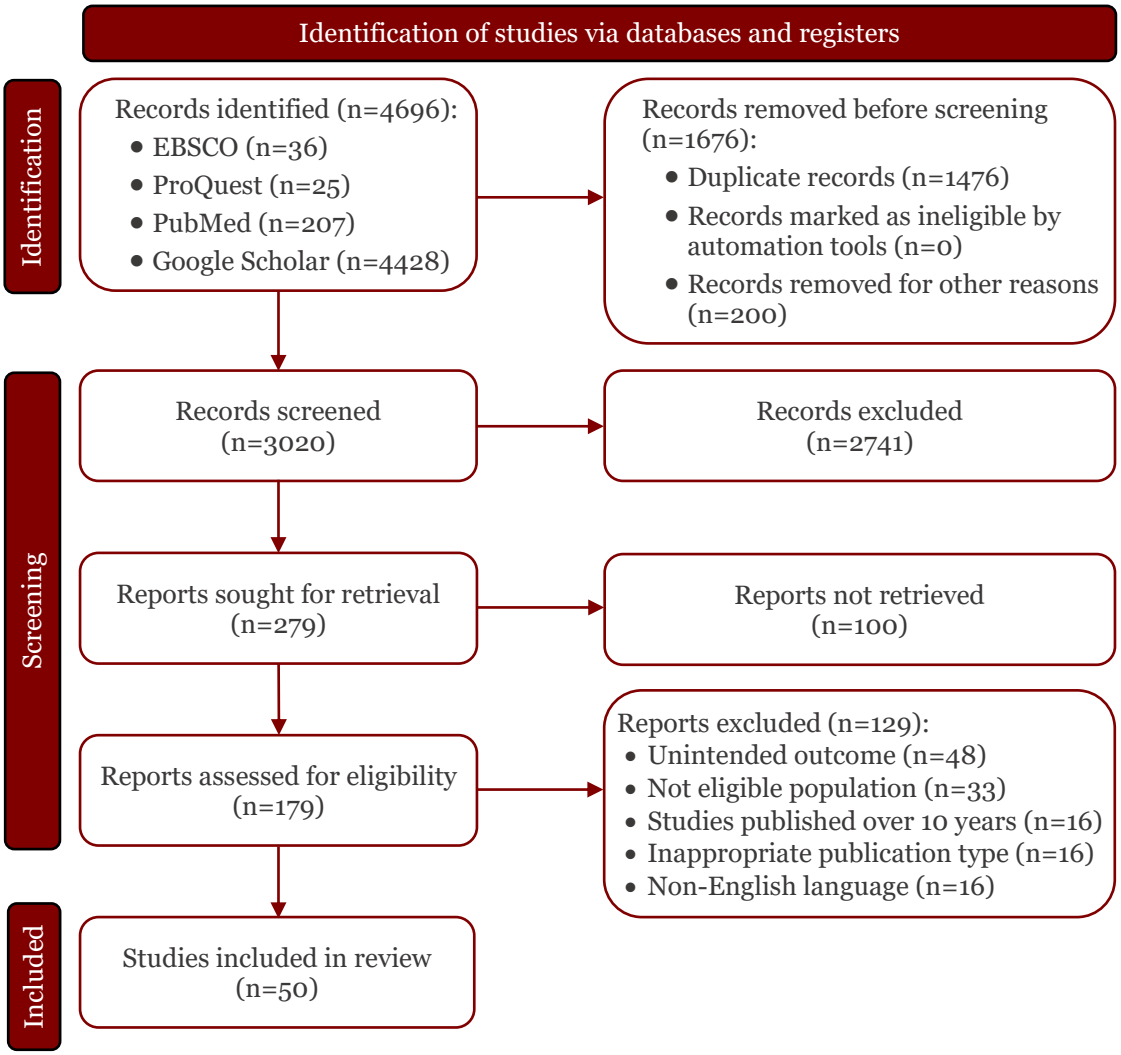


Figure 1. PRISMA flow diagram.

During title and abstract screening, 2,741 records were excluded because they did not meet the predefined eligibility requirements. The main reasons for exclusion were ineligible populations, index tests unrelated to spleen stiffness measurement, outcomes unrelated to

esophageal varices, and ineligible study designs. Conference abstracts, case reports, case series, review articles, and non-human studies were also excluded. A total of 279 reports were sought for retrieval, of which 100 reports could not be retrieved. The remaining 179 full-text reports were assessed for eligibility. Following full-text assessment, 129 papers were excluded due to unintended outcomes (n=48), ineligible populations (n=33), publication more than 10 years prior (n=16), improper publication type (n=16), and non-English language (n=16). Finally, 50 studies were included in the systematic review.

Risk of bias assessment

In general, most studies showed minimal risk of bias in several critical areas, particularly the reference standard and flow and timing. This finding reflects the consistent use of upper gastrointestinal endoscopy (esophagogastroduodenoscopy) as the reference standard and an appropriate interval between SSM and endoscopic assessment. These findings support the reliability of outcome assessment for the primary outcomes, specifically esophageal varices and HREV.

Conversely, patient selection was the domain in which the risk of bias was most commonly identified. Numerous investigations utilized cross-sectional methodologies or sourced participants from specialized referral centers, which may have led to selection bias due to the disproportionate inclusion of individuals with more severe conditions or an elevated risk of varices. Furthermore, certain studies lacked adequate information on whether participants were recruited in a consecutive or random manner, leading to evaluations of either significant or ambiguous bias risk in this area.

In the index test domain, several studies showed a high or unclear risk of bias, primarily due to insufficient reporting of blinding to endoscopic results or the application of SSM cut-off values established post hoc. Such procedures might result in overestimation of diagnostic precision. Nonetheless, research utilizing prospective cohort methodologies and standardized elastography methods exhibited a diminished risk of bias in this area. The trend illustrated in **Figure 2** reveals that the risk of bias was primarily focused on the patient selection and index test domains, whereas the reference standard and flow and timing were uniformly evaluated as having a minimal risk of bias. These results indicate that the primary constraints of the existing evidence are methodological rather than related to the validity of outcome evaluation.

Study characteristics and population

A total of 50 studies met the inclusion criteria and were included in the quantitative synthesis, accounting for 6,322 patients with chronic liver disease or cirrhosis. Approximately 52% of the included studies used a cross-sectional design. The studies differed in terms of cirrhosis etiology, disease severity, and, in some cases, geographic location, contributing to the overall heterogeneity of the data. In addition, SSM was assessed using several elastography techniques. TE was the most frequently used modality, including both the 100 Hz and 50 Hz configurations, followed by point shear wave elastography and 2D-SWE. A summary of the specific study characteristics is presented in **Table 2**.

Spleen stiffness cut-off values

The reported SSM cut-off values for identifying any esophageal varices varied considerably among studies (**Table 3**). With TE at 100 Hz, the cut-off values ranged from approximately 18 to 75 kPa, with most studies reporting values between 30 and 55 kPa. TE at 50 Hz exhibited a narrower range of approximately 30–52 kPa. For pSWE, the reported thresholds were generally lower, ranging from approximately 13 to 46 kPa. For 2D-SWE, the thresholds ranged from approximately 8 to 62 kPa, with most values falling between 20 and 35 kPa. This considerable variability suggests that no universal SSM threshold for identifying any esophageal varices has been established.

For HREV, the threshold values were generally higher than those reported for any esophageal varices, although considerable overlap was observed (**Table 4**). TE at 100 Hz exhibited thresholds of approximately 28–75 kPa, with most studies reporting values between 40 and 55 kPa. For pSWE, the reported range was approximately 23–46 kPa, whereas 2D-SWE exhibited a wider range of 13–52 kPa, with most values falling between 15 and 35 kPa.

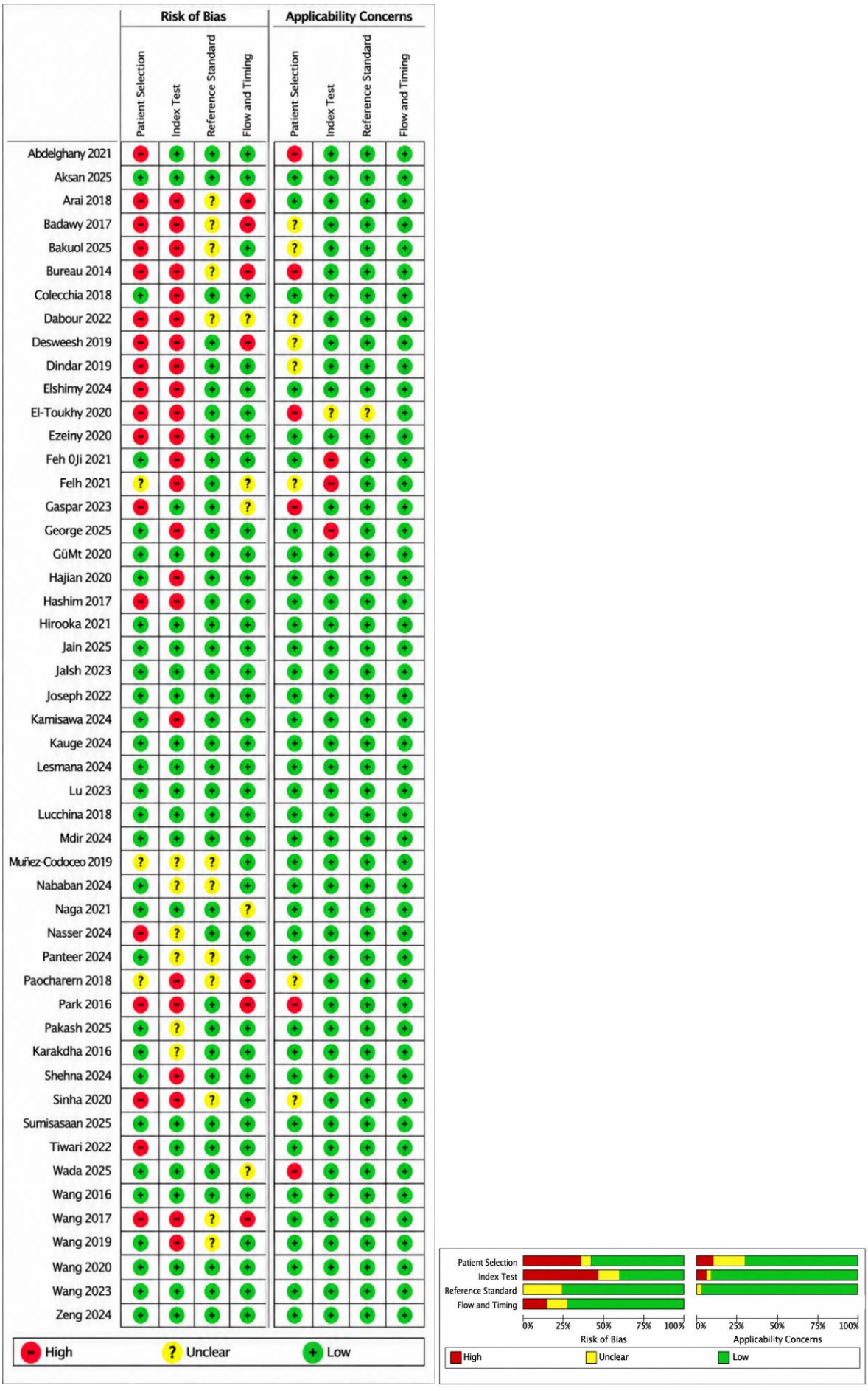


Figure 2. Risk of bias assessment using QUADAS-2.

Table 2. Baseline characteristics of the included studies

Author (year)	Country	Study design	Cirrhosis	Age (years)	SSM method	EV	HREV	SSM (kPa)
			n	Mean±SD		n	n	Mean±SD
Wong *et al.* (2016) [25]	China	Cross-sectional	144	59.00±9.00	TE 100 Hz	35	NR	43.50±22.70
Rewisha *et al.* (2016) [14]	Egypt	Cross-sectional	110	47.91±6.30	TE 100 Hz	55	25	62.85±12.71
Buechter *et al.* (2016) [16]	Germany	Retrospective cohort	75	NR	TE 100 Hz	50	34	35.30±7.06
Park *et al.* (2016) [17]	Korea	Prospective cohort	366	55.92±12.80	pSWE	194	NR	40.00±15.59
Badawy *et al.* (2017) [18]	Egypt	Case-control	78	53.50±7.50	TE 100 Hz	45	NR	64.50±12.90
Hashim *et al.* (2017) [15]	Egypt	Case-control	100	54.40±6.30	2D-SWE	59	40	61.20±14.20
Colecchia *et al.* (2018) [10]	Italy	Retrospective cohort	258	60.50±4.50	TE 100 Hz	129	54	55.00±11.00
Lucchina *et al.* (2018) [20]	Italy	Cross-sectional	42	NR	pSWE	21	NR	20.38±4.08
Paocharern *et al.* (2018) [21]	Thailand	Cross-sectional	38	54.58±10.15	TE 50 Hz	34	NR	52.30±46.20
Arribas *et al.* (2018) [22]	Spain	Prospective cohort	60	59.60±2.40	TE 100 Hz	28	NR	51.20±6.10
Dwidar *et al.* (2019) [23]	Egypt	Cross-sectional	120	NR	TE 100 Hz	90	30	32.41±7.24
Wang *et al.* (2019) [19]	Taiwan	Cross-sectional	85	57.11±11.23	pSWE	26	18	17.14±1.92
Wang *et al.* (2019) [24]	China	Retrospective cohort	124	NR	TE 100 Hz	102	58	50.95±7.45
Darweesh *et al.* (2019) [26]	Egypt	Cross-sectional	200	54.90±8.00	pSWE	90	NR	NR
Giuffrè *et al.* (2020) [27]	Italy	Cross-sectional	210	68.00±4.75	pSWE	84	NR	48.00±9.60
Hajiani *et al.* (2020) [28]	Iran	Cross-sectional	110	51.37±10.64	TE 100 Hz	72	NR	43.04±21.25
Sindhu *et al.* (2020) [29]	India	Prospective cohort	106	50.00±5.00	pSWE	79	NR	31.10±25.50
El-Toukhy *et al.* (2020) [30]	Egypt	Case-control	100	47.71±6.85	TE 100 Hz	80	NR	56.03±6.12
Elzeiny *et al.* (2020) [31]	Egypt	Case-control	60	55.50±10.25	pSWE	30	NR	44.74±17.94
Abdelghany *et al.* (2021) [32]	Egypt	Prospective cohort	150	52.50±11.25	2D-SWE	150	63	44.70±8.94
Muñoz-Codoceo *et al.* (2021) [33]	Spain	Cross-sectional	97	63.00±4.00	TE 100 Hz	37	6	46.00±9.20
Hirooka *et al.* (2021) [34]	Japan	Retrospective cohort	201	69.00±4.50	TE 100 Hz	94	63	46.40±27.85
Fofiu *et al.* (2021) [35]	Romania	Prospective cohort	98	59.00±9.47	pSWE	40	40	14.36±3.39
Fofiu *et al.* (2021) [36]	Romania	Prospective cohort	124	59.00±12.50	2D-SWE	101	41	16.78±3.38
Wang *et al.* (2021) [37]	China	Prospective cohort	341	48.00±3.50	TE 100 Hz	199	70	39.20±32.10
Nagai *et al.* (2022) [38]	Japan	Cross-sectional	60	71.30±13.20	TE 100 Hz	60	NR	57.10±18.90
Dabour *et al.* (2022) [39]	Egypt	Cross-sectional	50	53.10±6.00	TE 100 Hz	32	7	59.60±13.50
Tiwari *et al.* (2022) [40]	Nepal	Cross-sectional	78	49.79±10.92	TE 100 Hz	58	32	49.70±9.94
Joseph *et al.* (2022) [41]	India	Cross-sectional	201	48.40±10.00	2D-SWE	60	26	50.60±34.10
Liu *et al.* (2023) [43]	China	Prospective cohort	171	58.00±4.00	TE 100 Hz	171	110	54.70±20.52
Jain *et al.* (2023) [61]	India	Cross-sectional	90	55.00±4.31	pSWE	78	31	3.20±0.45
Jaishi *et al.* (2023) [44]	Nepal	Cross-sectional	94	51.10±11.90	TE 100 Hz	77	48	22.26±4.60
Gaspar *et al.* (2023) [42]	Portugal	Prospective cohort	209	61.90±9.90	TE 100 Hz	88	14	46.70±23.10
Madir *et al.* (2024) [45]	Croatia	Cross-sectional	61	63.00±3.50	TE 100 Hz	23	9	40.90±8.18
Nababan *et al.* (2024) [46]	Indonesia	Cross-sectional	86	52.00±11.40	TE 100 Hz	86	52	56.80±11.36
Tahir *et al.* (2024) [47]	Indonesia	Retrospective cohort	102	52.00±0.50	TE 100 Hz	102	23	90.90±7.19
Elshimy *et al.* (2024) [48]	Egypt	Cross-sectional	72	55.45±10.69	TE 100 Hz	72	30	51.64±11.36
Kurniawan *et al.* (2024) [50]	Indonesia	Cross-sectional	141	52.00±4.13	TE 100 Hz	116	54	59.30±31.00
Zhang *et al.* (2024) [51]	China	Cross-sectional	173	51.00±3.00	2D-SWE	173	41	27.70±12.10
Shehata *et al.* (2024) [52]	Egypt	Cross-sectional	100	52.53±5.35	2D-SWE	60	40	65.56±15.44
Kwape *et al.* (2024) [6]	South Africa	Cross-sectional	50	46.70±15.00	TE 100 Hz	34	NR	47.10±21.30
Nasser *et al.* (2024) [53]	Iraq	Case-control	30	51.83±14.97	2D-SWE	30	20	26.84±14.49

Author (year)	Country	Study design	Cirrhosis	Age (years)	SSM method	EV	HREV	SSM (kPa)
			n	Mean±SD		n	n	Mean±SD
Suttitossatam *et al.* (2025) [54]	Thailand	Cross-sectional	92	61.63±12.21	TE 100 Hz	52	33	67.75±16.92
Wang *et al.* (2025) [49]	China	Prospective cohort	35	50.00±3.38	2D-SWE	24	18	32.40±6.48
Balouch *et al.* (2025) [56]	Pakistan	Cross-sectional	340	33.90±12.90	2D-SWE	184	84	36.60±20.60
Panthee *et al.* (2025) [57]	India	Cross-sectional	121	47.61±12.78	2D-SWE	74	33	31.40±7.15
Wada *et al.* (2025) [58]	Japan	Retrospective cohort	85	68.90±12.40	2D-SWE	42	NR	15.60±3.12
George *et al.* (2025) [59]	India	Cross-sectional	96	45.00±13.42	2D-SWE	59	42	16.45±3.59
Ahsam *et al.* (2025) [60]	Pakistan	Cross-sectional	272	43.60±12.40	TE 100 Hz	198	85	41.90±25.10
Prakash *et al.* (2025) [55]	India	Prospective cohort	116	45.30±15.30	TE 100 Hz	86	33	41.00±18.00

2D-SWE: two-dimensional shear wave elastography; EV: esophageal varices; HREV: high-risk esophageal varices; kPa: kilopascal; NR: not reported; pSWE: point shear wave elastography; SSM: spleen stiffness measurement; TE: transient elastography

For studies reporting more than one eligible diagnostic threshold, the threshold corresponding to the primary diagnostic analysis was used to derive the 2×2 diagnostic accuracy data. When multiple thresholds were reported for different elastography techniques, each technique-specific threshold was analyzed separately. All SSM cut-off values were expressed in kPa. The differences in cut-off values across studies and elastography techniques underscore the absence of a uniform criterion for detecting HREV.

Table 3. Area under the curve (AUC) and spleen stiffness measurement (SSM) cut-off values for the detection of any esophageal varices

Author (year)	SSM modalities	AUC	Cut-off (kPa)
Madir *et al.* (2024) [45]	TE 100 Hz	0.78	40.90
	TE 50 Hz	0.84	41.80
Nagai *et al.* (2022) [38]	TE 100 Hz	0.94	43.80
	TE 50 Hz	0.84	31.00
Badawy *et al.* (2017) [18]	TE 100 Hz	0.86	39.50
Elshimy *et al.* (2024) [48]	TE 100 Hz	0.89	36.50
Dwidar *et al.* (2019) [23]	TE 100 Hz	0.62	18.25
Gaspar *et al.* (2023) [42]	TE 100 Hz	0.80	20.65
Giuffrè *et al.* (2020) [27]	pSWE	0.95	31.00
Muñoz-Codoceo *et al.* (2021) [33]	TE 100 Hz	0.62	27.00
Wang *et al.* (2019) [19]	pSWE (ARFI)	0.57	18.90
Rewisha *et al.* (2016) [14]	TE 100 Hz	0.97	43.20
Hashim *et al.* (2017) [15]	2D-SWE	0.95	42.70
Kurniawan *et al.* (2024) [50]	TE 100 Hz	0.89	40.00
Hajiani *et al.* (2020) [28]	TE 100 Hz	0.66	48.00
Fofiu *et al.* (2021) [35]	2D-SWE	0.84	13.20
	pSWE	0.90	25.40
Sindhu *et al.* (2020) [29]	pSWE	0.76	13.60
Lucchina *et al.* (2018) [20]	pSWE	0.67	23.87
Paocharern *et al.* (2018) [21]	TE 50 Hz	0.51	46.00
El-Toukhy *et al.* (2020) [30]	TE 100 Hz	0.98	46.40
Shehata *et al.* (2024) [52]	2D-SWE	0.56	62.22
Kwape *et al.* (2024) [6]	TE 100 Hz	0.97	34.50
Jaishi *et al.* (2023) [44]	TE 100 Hz	0.92	16.15
Elzeiny *et al.* (2020) [31]	pSWE	NR	32.00
Dabour *et al.* (2022) [39]	TE 100 Hz	0.97	55.50
Tiwari *et al.* (2022) [40]	TE 100 Hz	0.96	26.00
Panthee *et al.* (2025) [57]	2D-SWE	0.88	27.30
Wada *et al.* (2025) [58]	2D-SWE	0.71	8.00
George *et al.* (2025) [59]	2D-SWE	0.94	16.90
Ahsam *et al.* (2025) [60]	TE 100 Hz	0.86	31.00
Jain *et al.* (2023) [61]	pSWE	0.70	27.72
Wang *et al.* (2019) [24]	pSWE (ARFI)	0.69	23.86
Park *et al.* (2016) [17]	pSWE	0.86	29.90
Arribas *et al.* (2018) [22]	TE 100 Hz	0.80	48.00
Darweesh *et al.* (2019) [26]	pSWE	0.76	31.69

AUC: area under the curve; kPa: kilopascal; NR: not reported; pSWE: point shear wave elastography; SSM: spleen stiffness measurement; TE: transient elastography

Table 4. Area under the curve (AUC) and spleen stiffness measurement (SSM) cut-off values for the detection of high-risk esophageal varices (HREV)

Author (year)	SSM modalities	AUC	Cut-off (kPa)
Suttitossatam *et al.* (2025) [54]	TE 100 Hz	0.80	40.00
Madir *et al.* (2024) [45]	TE 50 Hz	0.77	52.00
Nababan *et al.* (2024) [46]	TE 100 Hz	0.75	40.90
Abdelghany *et al.* (2021) [32]	2D-SWE	0.75	41.80
Tahir *et al.* (2024) [47]	TE 100 Hz	NR	40.00
Elshimy *et al.* (2024) [48]	TE 100 Hz	0.93	47.50
Dwidar *et al.* (2019) [23]	TE 100 Hz	0.90	70.00
Colecchia *et al.* (2018) [10]	TE 100 Hz	0.93	47.50
Gaspar *et al.* (2023) [42]	TE 100 Hz	0.86	28.75
Wang *et al.* (2019) [24]	TE 100 Hz	0.85	46.00
Giuffrè *et al.* (2020) [27]	pSWE	0.71	53.25
Wang *et al.* (2019) [19]	pSWE (ARFI)	0.92	55.20
Liu *et al.* (2023) [43]	TE 100 Hz	0.95	46.00
Hashim *et al.* (2017) [15]	2D-SWE	0.79	18.57

Author (year)	SSM modalities	AUC	Cut-off (kPa)
Kurniawan *et al.* (2024) [50]	TE 100 Hz	0.88	43.40
Hirooka *et al.* (2021) [34]	2D-SWE	0.95	51.50
Prakash *et al.* (2025) [55]	TE 100 Hz	0.76	53.10
Fofiu *et al.* (2021) [36]	2D-SWE	0.84	13.20
Wang *et al.* (2021) [37]	TE 100 Hz	0.85	35.00
Zhang *et al.* (2024) [51]	2D-SWE	0.84	13.20
Balouch *et al.* (2025) [56]	TE 100 Hz	NR	46.00
Dabour *et al.* (2022) [39]	TE 100 Hz	0.83	28.90
Tiwari *et al.* (2022) [40]	TE 100 Hz	0.84	33.00
Nasser *et al.* (2024) [53]	2D-SWE	0.93	74.50
Panthee *et al.* (2025) [57]	2D-SWE	0.98	40.00
Joseph *et al.* (2022) [41]	2D-SWE	NR	15.12
Buechter *et al.* (2016) [16]	TE 100 Hz	0.92	33.80
Suttitossatam *et al.* (2025) [54]	2D-SWE	0.89	48.70
Madir *et al.* (2024) [45]	TE 100 Hz	NR	42.60

AUC: area under the curve; kPa: kilopascal; NR: not reported; pSWE: point shear wave elastography; SSM: spleen stiffness measurement; TE: transient elastography

Diagnostic accuracy of SSM for detecting esophageal varices

In the pooled analysis, SSM demonstrated good diagnostic performance for detecting esophageal varices (any EV). The sensitivity was 0.88 (95%CI: 0.85–0.91), whereas the specificity was 0.76 (95%CI: 0.70–0.82). The diagnostic odds ratio was 24.52. The positive likelihood ratio was 3.76, and the negative likelihood ratio was 0.15 (**Table 5**). The SROC curve showed a reasonably consistent pattern across studies despite the observed variability (**Figure 3**).

Sensitivity was higher when the outcome focused on HREV, reaching 0.91 (95%CI: 0.89–0.93), while specificity was 0.71 (95%CI: 0.66–0.76). The diagnostic odds ratio was 26.06. The positive likelihood ratio (LR+) was 3.14, whereas the negative likelihood ratio (LR–) was 0.12. These findings suggested a stronger ability to rule out clinically significant varices.

Sensitivity analyses were then performed after excluding studies considered to have a high risk of bias in at least one QUADAS-2 domain. A total of 50 studies were included in the systematic review. However, the number of studies contributing to each analysis varied according to the availability of relevant outcome and diagnostic accuracy data. For the esophageal varices outcome, 15 studies provided sufficient data for the diagnostic accuracy analysis, whereas 18 studies were included for the HREV outcome. The remaining eligible studies were used for descriptive and qualitative synthesis of the available SSM cut-off values and study characteristics but were not included in the corresponding pooled diagnostic accuracy analyses.

The overall diagnostic performance remained consistent, despite modest changes in the pooled estimates. For any esophageal varices, pooled sensitivity increased to 0.91 (95%CI: 0.86–0.94), while specificity was 0.73 (95%CI: 0.65–0.80). The diagnostic odds ratio increased to 27.15, with a positive likelihood ratio (LR+) of 3.39 and a negative likelihood ratio (LR–) of 0.12. For HREV, sensitivity increased further to 0.94 (95%CI: 0.90–0.97), with a specificity of 0.65 (95%CI: 0.56–0.73). The diagnostic odds ratio increased to 30.32, with an LR+ of 2.69 and an LR– of 0.09.

Table 5. Diagnostic accuracy of spleen stiffness measurement (SSM) for the detection of esophageal varices and high-risk esophageal varices (HREV) based on the bivariate random effects model

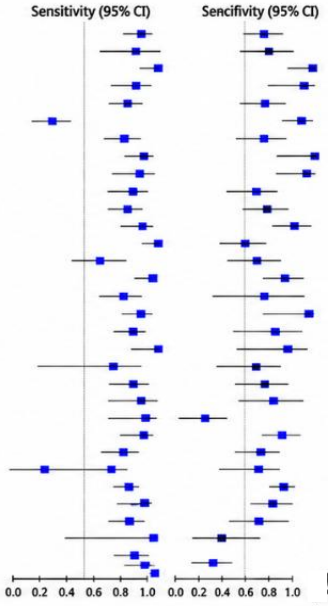
Analysis	Sensitivity (95%CI)	Specificity (95%CI)	DOR	LR+	LR-	RE corr
Esophageal varices (n=15 studies)						
Main analysis	0.88 (0.85–0.91)	0.76 (0.70–0.82)	24.52	3.76	0.15	0.11
Sensitivity analysis	0.91 (0.86–0.94)	0.73 (0.65–0.80)	27.15	3.39	0.12	0.08
High-risk esophageal varices (n=18 studies)						
Main analysis	0.91 (0.89–0.93)	0.71 (0.66–0.76)	26.06	3.14	0.12	–0.46
Sensitivity analysis	0.94 (0.90–0.97)	0.65 (0.56–0.73)	30.32	2.69	0.09	–0.27

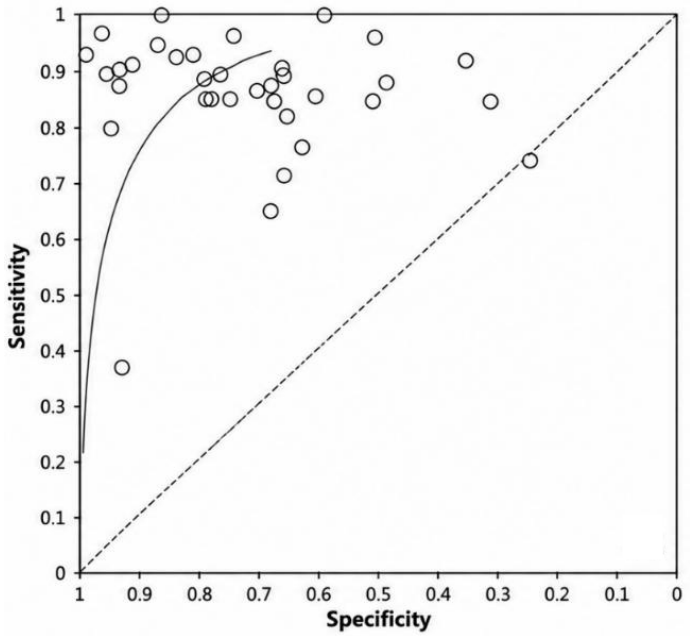
95%CI: 95% confidence interval; DOR: diagnostic odds ratio; LR+: positive likelihood ratio; LR–: negative likelihood ratio; RE corr: random-effects correlation

Sungkar et al. Narra X 2026; 4 (3): e359 - http://doi.org/10.52225/narrax.v4i3.359

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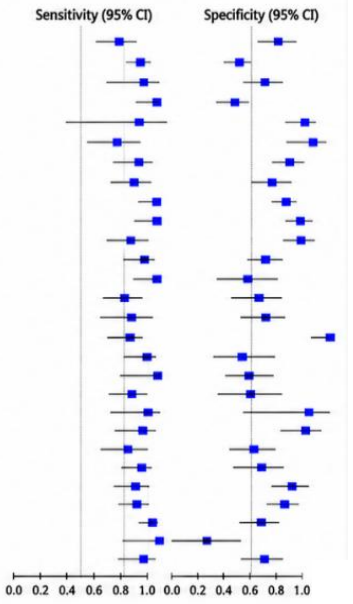
Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Ahsan 2025	177	24	21	48	0.89 [0.84, 0.93]	0.67 [0.55, 0.77]
Arai 2018	22	10	4	22	0.85 [0.65, 0.96]	0.69 [0.50, 0.84]
Badawy 2017	44	1	1	32	0.98 [0.88, 1.00]	0.97 [0.84, 1.00]
Dabour 2022	28	1	4	17	0.88 [0.71, 0.96]	0.94 [0.73, 1.00]
Darweesh 2019	77	46	13	73	0.86 [0.77, 0.92]	0.61 [0.52, 0.70]
Dawdar 2019	33	2	57	28	0.37 [0.27, 0.47]	0.93 [0.78, 0.99]
Elshimy 2024	59	16	13	32	0.82 [0.71, 0.90]	0.67 [0.52, 0.80]
El-Toukhy 2020	75	0	5	20	0.90 [0.73, 0.98]	1.00 [0.83, 1.00]
Ezéiny 2020	27	1	3	29	0.90 [0.73, 0.98]	0.97 [0.83, 1.00]
Fefu 2021	35	18	5	40	0.88 [0.73, 0.96]	0.69 [0.55, 0.80]
Fehl 2021	34	14	6	44	0.85 [0.70, 0.94]	0.76 [0.63, 0.86]
George 2025	54	3	5	34	0.92 [0.81, 0.97]	0.92 [0.78, 0.98]
GüMt#232; 2020	60	29	0	43	1.00 [0.94, 1.00]	0.60 [0.47, 0.71]
Hajjan 2020	46	12	26	26	0.64 [0.52, 0.75]	0.68 [0.51, 0.82]
Hashim 2017	56	5	3	36	0.95 [0.86, 0.99]	0.88 [0.74, 0.96]
Jain 2025	55	4	23	8	0.71 [0.59, 0.80]	0.67 [0.35, 0.90]
Jalsh 2023	70	1	7	16	0.91 [0.82, 0.96]	0.94 [0.71, 1.00]
Kamisawa 2024	103	5	13	20	0.89 [0.82, 0.94]	0.80 [0.59, 0.93]
Kauge 2024	34	2	0	14	1.00 [0.90, 1.00]	0.88 [0.62, 0.98]
Lucchina 2018	16	8	5	14	0.76 [0.33, 0.92]	0.64 [0.41, 0.83]
Mdir 2024	45	17	7	43	0.87 [0.74, 0.94]	0.72 [0.59, 0.83]
Muñez-Codoceo 2019	31	5	3	17	0.90 [0.73, 0.98]	0.77 [0.55, 0.92]
Nagal 2021	28	41	6	19	0.93 [0.68, 0.93]	0.32 [0.20, 0.45]
Nagai 2021	27	22	3	45	0.90 [0.73, 0.98]	0.82 [0.33, 0.78]
Panteer 2024	59	2	15	45	0.80 [0.69, 0.88]	0.96 [0.85, 0.99]
Paocharem 2018	25	3	9	1	0.74 [0.56, 0.87]	0.25 [0.01, 0.81]
Park 2016	165	43	29	162	0.85 [0.79, 0.91]	0.79 [0.73, 0.84]
Shehna 2024	51	17	4	93	0.93 [0.82, 0.98]	0.85 [0.76, 0.91]
Sinha 2022	51	8	9	32	0.85 [0.73, 0.93]	0.80 [0.64, 0.91]
Waari 2022	57	13	12	14	0.95 [0.33, 1.93]	0.53 [0.32, 0.71]
Wada 2025	37	22	5	21	0.88 [0.74, 0.96]	0.49 [0.33, 0.65]
Wang 2017	32	70	3	39	0.91 [0.77, 0.98]	0.36 [0.27, 0.46]
	25	8	1	8	0.96 [0.80, 1.00]	0.50 [0.25, 0.75]





B

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Abdelghany 2021	47	26	16	61	0.75 [0.62, 0.85]	0.70 [0.59, 0.79]
Bakuol 2025	75	136	9	120	0.89 [0.81, 0.95]	0.47 [0.41, 0.53]
Buechter 2016	17	34	2	60	0.89 [0.67, 0.99]	0.64 [0.53, 0.73]
Colecchia 2018	55	109	1	85	0.98 [0.88, 1.00]	0.44 [0.37, 0.51]
Dabour 2022	6	5	1	38	0.86 [0.42, 1.00]	0.88 [0.75, 0.96]
Dawdar 2019	22	2	8	28	0.73 [0.54, 0.88]	0.93 [0.78, 0.99]
Elshimy 2024	27	20	3	70	0.90 [0.73, 0.98]	0.78 [0.68, 0.86]
Feh Oji 2021	36	19	5	41	0.88 [0.74, 0.96]	0.68 [0.55, 0.80]
Gaspar 2023	34	42	0	133	1.00 [0.90, 1.00]	0.76 [0.69, 0.82]
GüMt#232; 2020	30	16	0	86	1.00 [0.88, 1.00]	0.84 [0.76, 0.91]
Hashim 2017	34	9	6	51	0.85 [0.70, 0.94]	0.85 [0.73, 0.93]
Hirooka 2021	58	51	5	87	0.92 [0.82, 0.97]	0.63 [0.54, 0.71]
Joseph 2022	26	16	0	18	1.00 [0.87, 1.00]	0.53 [0.35, 0.70]
Kumisawa 2024	44	33	10	54	0.81 [0.69, 0.97]	0.62 [0.53, 0.72]
Lesmana 2024	20	28	3	51	0.87 [0.66, 0.97]	0.65 [0.53, 0.75]
Lu 2023	22	2	18	59	0.84 [0.75, 0.90]	0.97 [0.89, 1.00]
Mdir 2024	31	18	1	19	0.93 [0.86, 1.00]	0.51 [0.34, 0.68]
Nababan 2024	22	40	1	49	0.96 [0.78, 1.00]	0.55 [0.44, 0.66]
Nasser 2024	5	15	7	19	0.87 [0.74, 0.94]	0.56 [0.38, 0.73]
Panteer 2024	39	1	1	9	0.95 [0.75, 1.00]	0.90 [0.55, 1.00]
Pakash 2025	31	33	2	50	0.91 [0.76, 0.98]	0.90 [0.77, 0.97]
Sutmissaan 2025	31	13	8	36	0.84 [0.68, 0.93]	0.60 [0.49, 0.71]
Sumisasaan 2025	35	18	6	36	0.91 [0.83, 0.95]	0.67 [0.53, 0.79]
Tiwari 2022	32	6	1	42	0.87 [0.74, 0.95]	0.87 [0.74, 0.95]
Wang 2019	39	14	2	89	0.90 [0.79, 0.96]	0.86 [0.78, 0.92]
Wang 2020	67	94	3	127	0.96 [0.88, 0.99]	0.68 [0.59, 0.77]
Wang 2025	18	12	0	5	1.00 [0.81, 1.00]	0.29 [0.10, 0.56]
Zeng 2024	37	41	4	91	0.90 [0.77, 0.97]	0.69 [0.60, 0.77]



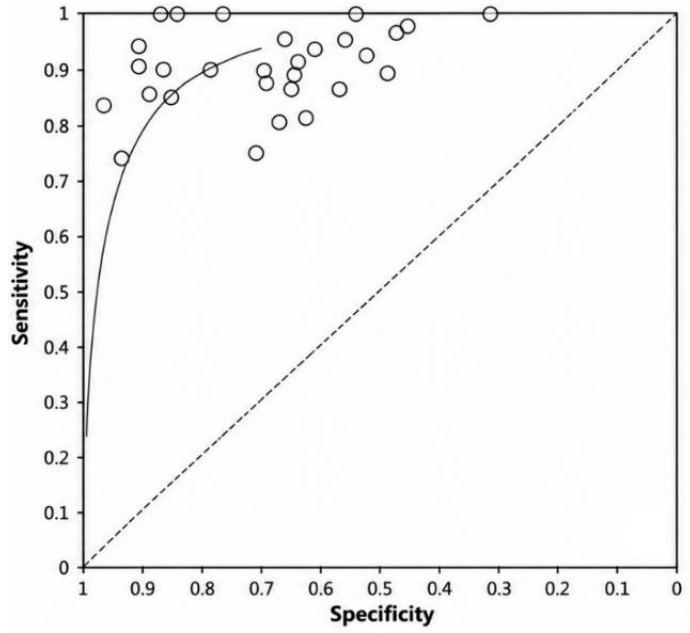


Figure 3. Forest plots and summary receiver operating characteristic (SROC) curves of spleen stiffness measurement (SSM) for the detection of (A) esophageal varices and (B) high-risk esophageal varices (HREV).

Subgroup analysis by elastography modality

Subgroup analysis explored diagnostic performance according to elastography technique. Sensitivity remained high across modalities, whereas specificity showed greater variation. Two-dimensional shear wave elastography (2D-SWE) produced the highest overall estimates for detecting esophageal varices. Sensitivity reached 0.88 (95%CI: 0.83–0.92), while specificity was 0.83 (95%CI: 0.67–0.92). The diagnostic odds ratio was 34.85. The positive likelihood ratio was 5.06, and the negative likelihood ratio was 0.15 (**Table 6**). TE at 100 Hz showed similarly strong performance. Sensitivity was 0.88 (95%CI: 0.82–0.93), whereas specificity was 0.81 (95%CI: 0.71–0.88). The diagnostic odds ratio was 32.73. Other modalities showed different diagnostic capabilities. TE at 50 Hz and pSWE produced lower specificity, at approximately 0.65 for both modalities. However, sensitivity remained high for detecting any esophageal varices (**Table 6**).

When the outcome shifted to HREV, all modalities continued to demonstrate high sensitivity. TE at 100 Hz appeared to provide the most consistent performance, with a sensitivity of 0.92 (95%CI: 0.88–0.95) and a specificity of 0.72 (95%CI: 0.63–0.80). The diagnostic odds ratio was 29.22, and the negative likelihood ratio was the lowest among the modalities, at approximately 0.11. Two-dimensional SWE also demonstrated good diagnostic accuracy, with a sensitivity of 0.89 (95%CI: 0.84–0.93) and a specificity of 0.69 (95%CI: 0.50–0.79). In contrast, TE at 50 Hz again showed reduced specificity, at approximately 0.60 (95%CI: 0.47–0.71), although sensitivity remained high. Complete numerical estimates are summarized in **Table 7**.

Table 6. Pooled diagnostic accuracy according to elastography modality for any esophageal varices (bivariate random-effects model)

SSM modality	Sensitivity (95%CI)	Specificity (95%CI)	DOR (95%CI)	LR+ (95%CI)	LR− (95%CI)
TE 100 Hz	0.88 (0.82–0.93)	0.81 (0.71–0.88)	32.73 (6.04–59.42)	4.65 (2.45–6.85)	0.14 (0.08–0.21)
TE 50 Hz	0.85 (0.72–0.92)	0.65 (0.48–0.79)	10.65 (3.53–32.09)	2.45 (1.20–3.70)	0.23 (0.06–0.40)
pSWE	0.89 (0.82–0.94)	0.65 (0.56–0.73)	15.34 (5.81–24.87)	2.57 (1.96–3.18)	0.17 (0.08–0.25)
2D-SWE	0.88 (0.83–0.92)	0.83 (0.67–0.92)	34.85 (4.35–65.36)	5.06 (1.52–8.60)	0.15 (0.09–0.20)

2D-SWE: two-dimensional shear wave elastography; 95%CI: 95% confidence interval; DOR: diagnostic odds ratio; LR+: positive likelihood ratio; LR−: negative likelihood ratio; pSWE: point shear wave elastography; TE: transient elastography

Table 7. Pooled diagnostic accuracy by elastography modality for high-risk esophageal varices (bivariate random-effects model)

SSM modality	Sensitivity (95%CI)	Specificity (95%CI)	DOR (95%CI)	LR+ (95%CI)	LR− (95%CI)
TE 100 Hz	0.92 (0.88–0.95)	0.72 (0.63–0.80)	29.22 (14.82–43.61)	3.32 (2.33–4.30)	0.11 (0.07–0.16)
TE 50 Hz	0.86 (0.68–0.94)	0.60 (0.47–0.71)	8.91 (2.58–30.77)	2.14 (1.49–2.79)	0.24 (0.04–0.44)
2D-SWE	0.89 (0.84–0.93)	0.69 (0.50–0.79)	19.19 (7.59–30.79)	2.91 (1.89–3.94)	0.15 (0.09–0.22)

2D-SWE: two-dimensional shear wave elastography; DOR: diagnostic odds ratio; LR+: positive likelihood ratio; LR−: negative likelihood ratio; TE: transient elastography

Comparison across modalities

Bayesian pairwise comparisons revealed no statistically significant differences between elastography modalities. Absolute differences in sensitivity and specificity were small, and the 95% posterior intervals crossed zero. For instance, the comparison of 2D-SWE and pSWE for any esophageal varices, as summarized in **Table 8**, revealed a sensitivity difference of −0.01 and a specificity difference of 0.17, with corresponding ratios of 0.99 and 1.27, respectively. Similarly, the differences in sensitivity (less than −0.01) and specificity (0.01) between 2D-SWE and TE at 100 Hz were minimal. These results indicate that the overall diagnostic performance of SSM may be minimally affected by the choice of elastography modality.

Comparable outcomes were observed in the remaining pairwise comparisons for any esophageal varices as presented in **Table 8**. The sensitivity and specificity differences between 2D-SWE and TE at 50 Hz were 0.05 and 0.20, respectively, while the corresponding differences between pSWE and TE at 50 Hz were 0.05 and 0.03. The differences in sensitivity and specificity between TE at 100 Hz and TE at 50 Hz were 0.05 and 0.19, respectively. The posterior intervals for these estimates included zero, suggesting that the observed numerical differences did not provide clear evidence of superior diagnostic performance for one modality over another.

Table 8. Direct comparison among elastography modalities for any esophageal varices (Bayesian analysis)

Comparison	Parameter	Median estimation	95% posterior interval
2D-SWE vs pSWE	Difference in sensitivity	−0.01	−0.14 to 0.11
	Difference in specificity	0.17	−0.05 to 0.39
	Sensitivity ratio	0.99	0.84 to 1.14
	Specificity ratio	1.27	0.93 to 1.84
2D-SWE vs TE 100 Hz	Difference in sensitivity	−0.01	−0.13 to 0.08
	Difference in specificity	0.01	−0.17 to 0.14
	Sensitivity ratio	1.00	0.85 to 1.10
	Specificity ratio	1.01	0.79 to 1.19
2D-SWE vs TE 50 Hz	Difference in sensitivity	0.05	−0.12 to 0.28
	Difference in specificity	0.20	−0.09 to 0.53
	Sensitivity ratio	1.05	0.87 to 1.43
	Specificity ratio	1.33	0.89 to 2.72
pSWE vs TE 100 Hz	Difference in sensitivity	0.01	−0.09 to 0.09
	Difference in specificity	−0.17	−0.38 to 0.02
	Sensitivity ratio	1.01	0.89 to 1.11
	Specificity ratio	0.79	0.54 to 1.02
pSWE vs TE 50 Hz	Difference in sensitivity	0.05	−0.09 to 0.27
	Difference in specificity	0.03	−0.30 to 0.39
	Sensitivity ratio	1.07	0.90 to 1.45
	Specificity ratio	1.05	0.63 to 2.10
TE 100 Hz vs TE 50 Hz	Difference in sensitivity	0.05	−0.07 to 0.27
	Difference in specificity	0.19	−0.06 to 0.51
	Sensitivity ratio	1.06	0.92 to 1.43
	Specificity ratio	1.32	0.93 to 2.73

2D-SWE: two-dimensional shear wave elastography; pSWE: point shear wave elastography; TE: transient elastography

A comparable pattern was observed in the supplementary Bayesian analysis for HREV presented in **Table 9**. The differences in sensitivity and specificity between 2D-SWE and TE at 100 Hz were −0.02 and −0.03, respectively, and 0.06 and 0.10 for 2D-SWE and TE at 50 Hz, respectively. The sensitivity and specificity differences between TE at 100 Hz and TE at 50 Hz were 0.08 and 0.13, respectively. Again, the posterior intervals included zero for all comparisons. Collectively, these results support the consistency of SSM diagnostic performance across different elastography technologies and suggest that the observed discrepancies are unlikely to indicate a clinically significant advantage of one modality over another.

Table 9. Comparison among elastography modalities for high-risk esophageal varices (Bayesian analysis)

Comparison	Parameter	Median estimation	95% posterior interval
2D-SWE vs TE 100 Hz	Difference in sensitivity	−0.02	−0.09 to 0.03
	Difference in specificity	−0.03	−0.18 to 0.12
	Sensitivity ratio	0.98	0.90 to 1.04
	Specificity ratio	0.96	0.76 to 1.19
2D-SWE vs TE 50 Hz	Difference in sensitivity	0.06	−0.07 to 0.29
	Difference in specificity	0.10	−0.17 to 0.39
	Sensitivity ratio	1.07	0.92 to 1.48
	Specificity ratio	1.16	0.78 to 2.21
TE 100 Hz vs TE 50 Hz	Difference in sensitivity	0.08	−0.04 to 0.30
	Difference in specificity	0.13	−0.13 to 0.41
	Sensitivity ratio	1.09	0.96 to 1.50
	Specificity ratio	1.21	0.84 to 2.31

2D-SWE: two-dimensional shear wave elastography; TE: transient elastography

Discussion

This meta-analysis shows that SSM is a reliable diagnostic tool to evaluate esophageal varices in people with chronic liver disease, especially for those with HREV. Sensitivity remained consistently high across analyses, whereas the negative likelihood ratio was relatively low. A low negative likelihood ratio suggests that SSM may function well as a rule-out tool when screening for high-risk varices. This could lead to a reduction in unwarranted endoscopic procedures.

Another point of interest appears when comparing elastography methods. Diagnostic performance did not differ substantially across modalities. Statistical comparisons did not reveal a substantial difference between the groups, despite the presence of numerical differences. A previous study reported consistent findings across different techniques, showing comparable diagnostic performance between TE and SWE when evaluating liver stiffness for fibrosis staging [9]. The findings indicated that the overall diagnostic efficacy was consistent across various elastography instruments. Portal hypertension leads to splenic congestion, expansion of splenic pulp, increased splenic blood flow, and structural remodeling of splenic tissue [15]. These mechanical changes directly increased spleen stiffness. Unlike liver stiffness, which may fluctuate with inflammation, cholestasis, or congestion, splenic stiffness reflects hemodynamic consequences of portal pressure more directly [15,59]. The spleen serves as a barometer of portal hypertension. Because clinically significant portal hypertension drives the development of esophageal varices, the relationship between portal pressure and spleen stiffness becomes biologically plausible. Changes in SSM therefore track the progression of portal hypertension itself rather than the underlying liver disease alone. This may help explain the consistent diagnostic performance observed across cirrhosis etiologies in the included studies. Viral, alcohol-related, and mixed etiologies may show similar patterns because the underlying mechanism remains the same [60].

This study adds several insights to the existing literature. First, SSM is examined primarily as a marker of portal hypertension–related complications rather than as a complement to liver stiffness measurements or serum indices [61]. This perspective brings the assessment of spleen stiffness closer to the pathophysiological factors underlying the development of esophageal varices. Second, the results were categorized according to the detection of esophageal varices and HREV. This distinction is clinically important because strategies for preventing variceal bleeding are ultimately guided by the identification of HREV, which is the focus of current screening recommendations. The analysis also included subgroup analysis across techniques of elastography and Bayesian pairwise comparisons between techniques. In previous meta-analyses, systematic exploration of direct comparisons has been limited [11]. Overall, the findings suggest that clinicians do not necessarily need to rely on one specific elastography technique to assess spleen stiffness. However, several important factors should be considered when interpreting these findings, including differences in patient selection, severity of cirrhosis, elastography technique, and SSM cut-off values. Third, heterogeneity was observed across studies, most likely due to differences in patient selection, cirrhosis severity, and SSM cut-off values. Some studies also lacked important clinical variables that could affect portal hypertension and endoscopic findings, such as beta-blocker therapy and the degree of cirrhosis compensation [60-62]. In screening for portal hypertension and related complications, the findings suggest that non-invasive measurement of splenic stiffness may be useful for identifying patients with a very low likelihood of having HREV.

There are several limitations to this study. The included studies showed significant heterogeneity, particularly in the estimations of specificity. This could have been caused by differences in diagnostic cut-off values, esophageal varices prevalence, study designs, and population characteristics. However, a random-effects model was used to address this heterogeneity. Furthermore, since the ideal cut-off may differ depending on the clinical goal and disease spectrum of the population under study, the lack of a generally applicable SSM cut-off number restricts the capacity to define a single diagnostic threshold. Robust comparisons were also hindered by the small number of studies in some subgroups, such as the FIB-4 study for HREV. Additionally, the diagnostic accuracy estimates may have been impacted by variations in outcome definitions and reference standards among primary studies, as well as a lack of reporting

of possible clinical confounders like beta-blocker use and decompensation status, which could not be evaluated separately in this meta-analysis.

Conclusion

This systematic review and meta-analysis indicate that evaluating splenic rigidity demonstrates potential diagnostic precision in the identification of esophageal varices among individuals suffering from chronic liver conditions, with the most consistent performance observed for HREV. Overall, SSM showed intermediate specificity and high sensitivity, indicating that it may be used as a non-invasive HREV rule-out method. The findings support the potential utility of SSM as part of a non-invasive assessment strategy for esophageal varices, but differences among elastography modalities may lead to variability in diagnostic performance. Before widespread clinical implementation, further prospective validation of study-specific SSM cut-off values and integration into standardized clinical algorithms are required.

Ethics approval

Not required.

Acknowledgments

None.

Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

We hereby confirm that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

How to cite

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