Diagn Interv Radiol 2024; DOI: 10.4274/dir.2024.242723

ABDOMINAL IMAGING

ORIGINAL ARTICLE



# Computed tomography for the diagnosis of gastroesophageal varices and risk assessment in patients with cirrhosis: a systematic review and meta-analysis

Jinkui Li[1]
Yuanhui Zhu[2]
Jinrong Ni[3]
Lili Wang[1]
Junqiang Lei[1]

[1]The First Hospital of Lanzhou University; Intelligent Imaging Medical Engineering Research Center of Gansu Province, Department of Radiology; Accurate Image Collaborative Innovation International Science and Technology Cooperation Base of Gansu Province, Lanzhou, China

[2]Gansu Provincial Hospital, Department of Radiology, Lanzhou, China

[3]The First Hospital of Lanzhou University, Department of Cardiovascular Surgery, Lanzhou, China

**PURPOSE**

This meta-analysis aimed to evaluate the diagnostic accuracy of computed tomography (CT) for detecting gastroesophageal varices (GEVs) and identify high-risk GEVs in patients with cirrhosis.

**METHODS**

A comprehensive search of databases identified 28 studies reporting on CT-based diagnosis for GEVs confirmed via endoscopy. Meta-analyses were conducted to calculate pooled sensitivity (SEN) and pooled specificity (SPE), positive likelihood ratio (PLR) and negative likelihood ratio (NLR), diagnostic odds ratio (DOR), and the area under the curve (AUC).

**RESULTS**

Based on the number of patients (or varices), the pooled SEN, SPE, PLR, NLR, DOR, and AUC of CT-based diagnosis were estimated at 0.91 (0.92), 0.81 (0.45), 4.82 (1.67), 0.11 (0.17), 42.47 (10.26), and 0.93 (0.94), respectively, for any GEV and at 0.89 (0.89), 0.90 (0.79), 8.86 (4.28), 0.12 (0.14), 75.71 (30.19), and 0.95 (0.85), respectively, for high-risk GEVs. Subgroup analyses indicated that CT had a higher diagnostic accuracy for esophageal varices compared with gastric varices (AUC: 0.93 vs. 0.89, $P < 0.05$), and the 64-slice CT yielded superior SEN compared with 16-slice and <16-slice CT (AUC: 0.97 vs. 0.92 and 0.82, respectively, $P < 0.05$). Prospective studies demonstrated higher diagnostic accuracy than retrospective studies (AUC: 0.95 vs. 0.90, $P < 0.05$). Regarding variceal size, a cut-off of 3 mm and 5 mm discriminated between low- and high-risk individuals, respectively, with high diagnostic accuracy (AUC: 0.992 vs. 0.997, $P > 0.05$).

**CONCLUSION**

CT demonstrates promising diagnostic accuracy for identifying gastroesophageal varices and distinguishing high-risk GEVs in patients with cirrhosis. Further research to validate optimal variceal size cut-offs is warranted to enhance clinical utility.

**CLINICAL SIGNIFICANCE**

Such a high diagnostic accuracy of CT scans for predicting varices is clinically meaningful for patients with cirrhosis accompanied by portal hypertension. If high-risk varices are identified at CT scans, early intervention would be helpful to reduce the risk of variceal bleeding.

**KEYWORDS**

Computed tomography, gastroesophageal varices, gastric varices, esophageal varices, cirrhosis, meta-analysis

**Corresponding author:** Junqiang Lei

**E-mail:** leijq2011@126.com

Received 20 February 2024; revision requested 02 April 2024; accepted 16 April 2024.

Epub: 20.05.2024

Publication date: 06.11.2024

DOI: 10.4274/dir.2024.242723

Bleeding of gastroesophageal varices (GEVs) is a serious complication of portal hypertension (PH) in cirrhosis.[1] Gastric varices (GVs) and esophageal varices (EVs) can occur concurrently or separately. EVs are more important for the collateral circulation of PH than GVs and occur in 20%–40% and approximately 70% of compensated and decompensated patients with cirrhosis, respectively.[2] Esophagogastroduodenoscopy (EGD) is current-

You may cite this article as: Li J, Zhu Y, Ni J, Wang L, Lei J. Computed tomography for the diagnosis of gastroesophageal varices and risk assessment in patients with cirrhosis: a systematic review and meta-analysis. *Diagn Interv Radiol*. 2024;30(6):335-350.

ly the standard approach for assessment of GEVs when diagnosing cirrhosis.[3] Presence of advanced liver disease (Child Pugh's score B or C), large varices (>5 mm), or varices with the red color (RC) sign specify patients with a high hemorrhage risk.[4,5] The progression from small to large varices is detected in approximately 10% of patients with cirrhosis per year.[6] In this context, it is of great significance to detect GEVs and predict variceal bleeding in time. EGD screening is recommended for patients with cirrhosis with small varices and patients without any varices every 1–2 and 2–3 years, respectively.[7,8] However, as a screening method, EGD is limited due to its invasive nature and poor acceptance by patients.[9] Additionally, it is obvious that a significant part of patients undergoing EGD screening, particularly those with compensated cirrhosis, have no varices or only small EVs. Furthermore, EGD fails to evaluate the entire spectrum of extraparietal GEVs and may miss some GVs.[10,11]

These drawbacks have driven the ongoing studies to identify alternative, non-invasive techniques for repeat variceal detection.

The Baveno VI guidelines recommend that patients with alcoholic or viral cirrhosis, liver stiffness <20 kPa and a platelet count >150 G/L should avoid EGD screening, which is a highly sensitive approach with limited specificity for the detection of GEVs.[12] Computed tomography (CT) or magnetic resonance imaging of portosystemic collateral vessels has been shown to have a sensitivity of 95% and specificity of 36% in predicting high-risk EVs in patients who do not meet the Baveno VI criteria.[13] Unlike EGD, contrast-enhanced CT can clearly show the portal vein system and collateral circulation,[14] including in patients with periesophageal and perigastric fundal varices. Furthermore, CT is useful in assessing the risk of GEV bleeding.[15]

**Main points**

- Computed tomography (CT) demonstrates promising diagnostic accuracy for identifying gastroesophageal varices (GEVs) and distinguishing high-risk GEVs in patients with cirrhosis.
- CT with a >16-slice scanner showed a significantly better performance than the <16-slice CT.
- Varices of <3 mm and >5 mm may discriminate against low-risk and high-risk patients, respectively.
- Approximately 84.29% of patients prefer CT instead of endoscopy in screening for varices.

Herein, the study authors conduct a systematic review and meta-analysis to evaluate the diagnostic efficacy of CT for GEVs and analyze its predictive value for high-risk varices in patients with cirrhosis.

## Methods

The present study is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement and the published recommendations. The detailed protocol is accessible in PROSPERO (CRD42020220384). Ethics information and informed consent forms were not required, as systematic reviews typically involve synthesizing and summarizing existing literature rather than directly engaging in human or animal experiments.

### Literature search

To retrieve eligible studies on CT-based diagnosis of EV and/or GV, a systematic literature search in the PubMed, Embase, Cochrane Library, and Web of Science databases was performed from inception to November 30, 2023. The search was conducted based on the following search terms: "gastroesophageal varices," "gastric varices," "esophageal varices," "varices," "CT," and "computed tomography." The search strategy was determined after multiple pre-searches and combined free words with Medical Subject Headings terms for each database. No language or article-type restriction was applied. The references of the included studies and other systematic reviews and meta-analyses were also reviewed to obtain a comprehensive list of relevant studies.

### Eligibility criteria

The inclusion criteria were as follows: (1) the patients were diagnosed with cirrhosis; (2) the diagnostic examination was contrast-enhanced CT; (3) EGD was performed to confirm the presence and/or grade of esophageal and/or GVs; (4) the data provided was sufficient to conduct a 2 × 2 table to assess the diagnostic sensitivity and specificity of CT for the varices; and (5) >20 patients were evaluated for reliable assessment.

The exclusion criteria were as follows: (1) patients without cirrhosis; (2) patients who were not evaluated via endoscopy or CT; (3) duplicates; (4) review articles; (5) case reports; and (6) conference papers, letters, and abstracts.

### Study selection, data extraction, and quality assessment

The titles and abstracts of the search results were screened for eligibility by two independent readers (Y. Zhu and L. Wang with 3 years and 12 years of experience in abdominal imaging, respectively) according to the pre-enacted inclusion and exclusion criteria, and full texts meeting the inclusion criteria were retrieved. The following data were extracted according to the predefined data form: the first author's name, the study design (prospective or retrospective), publication year, country, sample size, age, gender, etiology of cirrhosis, Child–Pugh class, time interval between the CT and EGD, number of patients who underwent EGD, location of varices (EVs and/or GVs), prevalence of any-sized and/or high-risk varices, definitions of high-risk varices on CT and EGD, cut-off values (the maximal short-axis diameter of the largest varix), and CT imaging parameters (slice). The true-positive (TP), false-positive (FP), true-negative (TN), and false-negative (FN) values were also extracted directly or calculated. It should be recognized that all the data per study were extracted if the study involved several CT techniques or observers, and serial numbers to this study were given. Finally, two readers independently performed QUADAS-2 criteria[16] assessments. Results were cross-checked at every step, and a consensus was reached in the case of discrepancy.

### Statistical analysis

Analyses were performed using the STATA 15.0 (StataCorp, College Station, TX) and Revman 5.4 (The Cochrane Collaboration, 2020) software. However, in the case of <4 articles, MetaDiSc 1.4 was used for analysis, and $I^2$ statistics were used to analyze heterogeneity of the included studies.[17] Significant heterogeny was indicated by $I^2 > 50\%$ or $P < 0.10$.

If there is no heterogeneity or if the heterogeneity is low, a fixed effects model should be chosen. A random effects model allows for high heterogeneity, and a sensitivity analysis or subgroup analysis should then be carried out. The pooled sensitivity (SEN), pooled specificity (SPE), positive predictive values and negative predictive values, positive likelihood ratio (PLR) and negative likelihood ratio (NLR), and diagnostic odds ratio (DOR) with a 95% confidence interval (CI) were calculated based on the number of TPs, FPs, FNs, and TNs, respectively. Following

this, the summary receiver operating characteristic and its corresponding area under the curve (AUC) were calculated. If there was significant heterogeneity, subgroup analysis was carried out to identify the sources of heterogeneity. In addition, in the case of >9 studies, the authors assessed for any publication bias by applying Deeks et al.[18] plot test. Statistical significance was indicated by $P < 0.05$.

# Results

## Literature search and study selection

This systematic review included 28 publications, involving 2,879 participants.[10,19-45] The PRISMA flow chart of the literature screening is shown in Figure 1.

## Study design and properties

The extractive data of the included studies are summarized in Table 1. The 28 selected articles were published between 2007 and 2023. In 27 of these papers, data were presented based on the number of patients,[10,19-44] and the data in the remaining article (a retrospective report evaluating EVs in 104 participants) were presented based on the number of varices.[45] Among the patient-based studies, which assessed for varices of any size, 11 (40.7%) were retrospective,[20,22-24,27,29,30,32,33,37,42] 12 (44.4%) were prospective,[10,19,26,28,31,34,35,38-41,44] and 4 (14.9%) were undefined;[21,25,36,43] 24 (88.9%) assessed for EVs[10,19-35,38-41,43,44,] and 6 (22.2%)[10,32,35,36,37,42] assessed for both EVs and GVs, including 3 for GVs only.[10,32,35] The prevalence of EVs and GVs were 33.6%–98% and 10.5%–28.3%, respectively. Two studies included only patients with hepatocellular carcinoma.[33,34] The remaining studies enrolled patients with various etiological factors, such as viral hepatitis, alcohol abuse, and cryptogenic cirrhosis.

Among the eligible studies, 18 assessed for high-risk varices.[20-24,27,29-35,36,39,41,43,45] The detailed characteristics of these studies are shown in Supplementary Table 1. A total of 16 articles (88.9%) assessed for high-risk EVs,[20-24,27,29-35,36,39,41,43,45] 1 assessed for high-risk GVs,[32] and 1 assessed for high-risk GEVs.[35] The prevalence of high-risk EVs and GVs was 15.4%–75% and 16.5%, respectively. The varix size cut-off of high-risk varices on CT was 2 mm,[21,22,33,34,45] 3 mm,[30,41] 3.9 mm,[24] 4 mm,[20,23] and 5 mm,[31,32,35,36] respectively. Finally, 3 studies did not specify the cut-off on CT.[27,29,39]

Additionally, 3 studies[31,40,42] reported that the varix size on CT was significantly correlated with the presence and severity of the RC sign. A cut-off of 4 or 5 mm was used to predict the RC sign.

A total of 5 studies[10,38-41] concerned preferences of the patients for CT versus EGD. Most (84.3%) patients preferred undergoing a CT scan instead of EGD for varix screening.

## Quality assessment

The results of the quality evaluation of the eligible articles are shown in Supplementary Figure 1. Most studies were identified as low-risk in terms of risk of bias and applicability concerns, and all of the studies met >4 terms of the 7 total domains. The most common domain of unclear risk was the reference standard regarding the blinding of EGD interpretation to the CT imaging.

## Diagnostic accuracy of computed tomography for gastroesophageal varices

The results of the meta-analyses are summarized in Table 2. Significant heterogeneity was observed in all the analyses ($P < 0.05$ and $I^2 > 50\%$).

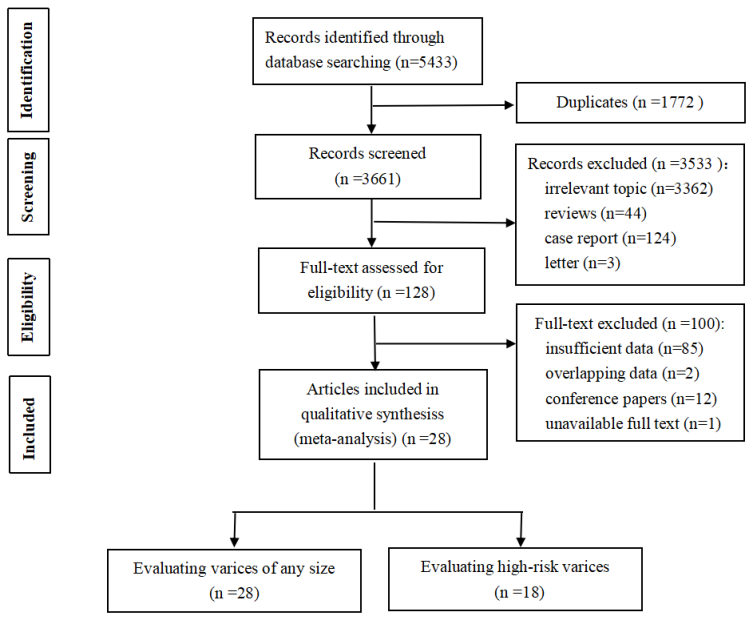



**Figure 1.** The study screening process.

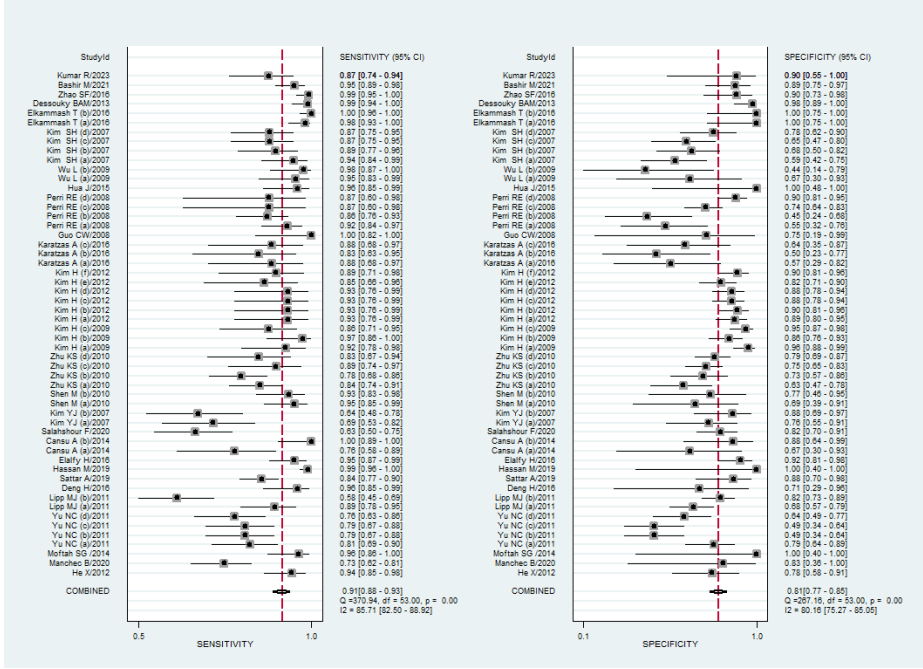



**Figure 2.** Coupled Forest plots of sensitivity and specificity for diagnosing gastroesophageal varices with CT.

*CT, computed tomography.*

**Table 1.** Characteristics of computed tomography for diagnosing gastroesophageal varices

| Study/journal/year | Study design | Country | Sample | M/ F | Mean age (y) | Etiology | Child–Pugh score |
|---|---|---|---|---|---|---|---|
| He et al.[19], Chin J Radiol (China), 2012 | P | China | 92 | 73/19 | 51 (34–80) | Viral 78, alcohol 12, pancreatic 1, cholestatic 1 | A 33, B 44, C 15 |
| Manchec et al.[20], AJR Am J Roentgenol, 2020 | R | US | 97 | 64/33 | 54.4 | HBV 2, HCV 35, alcohol 46, NASH 18 | A 36, B 50, C 11 |
| Moftah et al.[21], Egypt J Radiol Nucl Med, 2014 | / | Egypt | 54 | 40/14 | 56.8 (38–75) | / | / |
| Yu et al.[22], AJR Am J Roentgenol, 2011 | R | US | 109 | 60/49 | 55.9 (19–82) | HBV 7, HCV 51, alcohol 19, cryptogenic or others 32 | / |
| Lipp et al.[23], Dig Dis Sci, 2011 | R | US | 195 | / | 55.2 | / | / |
| Deng et al.[24], J Evid Based Med, 2017 | R | China | 52 | 33/19 | 55.4 | HBV 13, HCV 2, HBV and HCV 1, alcohol 16, alcohol and HBV 5, others 15 | A 25, B 21, C 6 |
| Sattar et al.[25], Med Forum, 2019 | / | Pakistan | 172 | 96/76 | 45.01 (35–60) | / | / |
| Hassan et al.[26], Cureus, 2019 | P | Pakistan | 196 | 106/90 | 55.8 (11–82) | HBV 13, HCV 79, others 104 | / |
| Elalfy et al.[27], World J Hepatol, 2016 | R | Egypt | 124 | 26/98 | 56.5 | HCV 124 | A 78, B 46, C 0 |
| Cansu et al.[28], Eur J Radiol, 2014 | P | Turkey | 42 | 29/13 | 56.2 | HBV 19, HCV 10, HBV and HCV 1, alcohol 2, others 10 | A16, B 13, C 13 |
| | | | 50 | 27/23 | 56.8 | HBV 20, HCV 15, HBV and HCV 2, alcohol 2, others 11 | A 26, B 18, C 6 |
| Salahshour et al.[29], Abdom Radiol (NY), 2020 | R | Iran | 124 | 76/48 | 50.38 (21–73) | HBV 30, HCV 7, alcohol 5, AIH 12, cryptogenic or others 70 | / |
| Kim et al.[30], AJR Am J Roentgenol, 2007 | R | US | 67 | 39/28 | 56.2 (33–77) | HBV 15, HCV 24, HBV and HCV 6, alcohol 15, cryptogenic or others 7 | A 16, B 25, C 26 |
| Shen et al.[31], Zhonghua Yi Xue Za Zhi, 2010 | P | China | 69 | 56/13 | 53 (23–76) | HBV 60, HCV 4, alcohol and HBV 3, alcohol 2 | A 44, B 22, C 3 |
| Zhu et al.[32], J Clin Gastroenterol, 2010 | R | China | 127 | 96/31 | 45.2 (30–75) | HBV 95, HCV 6, alcohol 13, cryptogenic or others 13 | A 48, B 47, C 32 |
| Kim et al.[33], Dig Dis Sci, 2009 | R | South Korea | 110 | 81/29 | 61 (27–80) | HBV 67, HCV 32, HBV and HCV 2, alcohol 7, unknown 2 | A 70, B 29, C 11 |
| Kim et al.[34], World J Gastroenterol, 2012 | P | South Korea | 100 | 79/21 | 58.4 (35–82) | HBV 76, HCV 14, alcohol 5, unknown 5 | A 89, B 10, C 1 |
| Karatzas et al.[35], Ann Gastroenterol, 2016 | P | Greece | 38 | 30/8 | 63 (48–81) | Viral 13, alcohol 18, others 7 | A 21, B 11, C 6 |
| Perri et al.[10], Hepatology, 2008 | P | US | 101 | 64/37 | 57.5 | Viral 22, alcohol 19, cholestatic 18, NASH 15, others 27 | A 45, B 40, C 16 |
| Guo et al.[36], Chin J Med Imaging Technol, 2008 | / | China | 27 | 14/13 | 48.6 (28–71) | HBV 23, HCV 2, alcohol 2 | A10, B 12, C 5 |

**Table 1.** Continued

| CT scanner | CT technique | Patients underwent EGD | Time interval | Patient acceptance | Varice location | Prevalence of varices (%) | TP | FP | FN | TN |
|---|---|---|---|---|---|---|---|---|---|---|
| 64-slice | MSCT portography | 92 | Within 4 w | / | GEVs | 70.65% | 61 | 6 | 4 | 21 |
| / | / | 97 | Within 3 m | / | EVs | 94.80% | 66 | 1 | 25 | 5 |
| 4 or 8-slice | MDCT | 54 | / | / | EVs | 92.59% | 48 | 0 | 2 | 4 |
| 16 or 64-slice | MDCT with standard 5 mm and thin-section MPR | 109 | Within 10 w | / | EVs | 56.88% | 50 | 10 | 12 | 37 |
| | | | | | | | 49 | 24 | 13 | 23 |
| | | | | | | | 49 | 24 | 13 | 23 |
| | | | | | | | 47 | 17 | 15 | 30 |
| 4 or 16 or 64-slice | MDCT | 137 | Within 3 m | / | EVs | 44.52% | 54 | 24 | 7 | 52 |
| | | 165 | | | | 43.03% | 41 | 17 | 30 | 77 |
| / | / | 52 | Within 4 w | / | EVs | 86.54% | 43 | 2 | 2 | 5 |
| 16-slice | MDCT | 172 | / | / | EVs | 84.88% | 123 | 3 | 23 | 23 |
| 64-slice | MDCT | 196 | Within 20 d | / | EVs | 97.95% | 190 | 0 | 2 | 4 |
| 16-slice | MDCT | 124 | / | / | EVs | 59.68% | 70 | 4 | 4 | 46 |
| 16-slice | MDCT with effervescent powder | 42 | Within 4 w | / | EVs | 78.57% | 25 | 3 | 8 | 6 |
| 16-slice | MDCT without effervescent powder | 50 | Within 4 w | / | EVs | 66% | 33 | 2 | 0 | 15 |
| 16 or 64-slice | MDCT | 124 | Within 6 m | / | EVs | 50.81% | 40 | 11 | 23 | 50 |
| single or 4 slice | Single-detector helical CT or MDCT | 67 | Within 4 w | / | EVs | 62.69% | 29 | 6 | 13 | 19 |
| | | | | | | | 27 | 3 | 15 | 22 |
| 320-slice | MDCT | 69 | Within 1 w | / | EVs | 81.16% | 53 | 4 | 3 | 9 |
| | | | | | | | 52 | 3 | 4 | 10 |
| 4-slice | MDCT | 127 | Within 4 w | / | EVs | 67.72% | 72 | 15 | 14 | 26 |
| | | | | | | | 67 | 11 | 19 | 30 |
| | | | | | GVs | 28.34% | 32 | 23 | 4 | 68 |
| | | | | | | | 30 | 19 | 6 | 72 |
| 16-slice | MDCT | 110 | Within 4 w | / | EVs | 33.64% | 34 | 3 | 3 | 70 |
| | | | | | | | 36 | 10 | 1 | 63 |
| | | | | | | | 32 | 4 | 5 | 69 |
| 64-slice | MDCT with and without MPR | 100 | Within 4 h | / | EVs | 50.00% | 25 | 8 | 2 | 65 |
| | | | | | | | 25 | 7 | 2 | 66 |
| | | | | | | | 25 | 9 | 2 | 64 |
| | | | | | | | 25 | 9 | 2 | 64 |
| | | | | | | | 23 | 13 | 4 | 60 |
| | | | | | | | 24 | 7 | 3 | 66 |
| 16-slice | MDCT | 38 | Within 1 m | / | GEVs | 63.16% | 21 | 6 | 3 | 8 |
| | | | | | | | 20 | 7 | 4 | 7 |
| | | | | | | | 21 | 5 | 3 | 9 |
| | | | | | EVs | 60.53% | 20 | 7 | 3 | 8 |
| | | | | | | | 19 | 8 | 4 | 7 |
| | | | | | | | 20 | 6 | 3 | 9 |
| | | | | | GVs | 10.53% | 3 | 4 | 1 | 30 |
| | | | | | | | 3 | 4 | 1 | 30 |
| | | | | | | | 3 | 4 | 1 | 30 |
| 4 slice or higher | MDCT | 101 | Within 5 d | 88% CT, 6% EGD, 6% no preference | EVs | 78.22% | 73 | 10 | 6 | 12 |
| | | | | | | | 68 | 12 | 11 | 10 |
| | | | | | GVs | 14.85% | 13 | 22 | 2 | 64 |
| | | | | | | | 13 | 9 | 2 | 77 |
| 64-slice | MSCT portography | 23 | / | / | GEVs | 82.61% | 19 | 1 | 0 | 3 |

**Table 1.** Continued

| Study/journal/year | Study design | Country | Sample | M/ F | Mean age (y) | Etiology | Child– Pugh score |
|---|---|---|---|---|---|---|---|
| Hua et al.[37], J Dig Dis, 2015 | R | China | 90 | 57/33 | 54.4 (31–75) | HBV 49, HCV 3, alcohol 8, AIH 5, others 25 | A 36, B 34, C 20 |
| Wu et al.[38], Chin J Gastroenterol, 2009 | P | China | 50 | 30/20 | 57.7 (31–78) | HBV 38, HBV, and HCV 1, AIH 1, others 10 | A 13, B 31, C 6 |
| Kim et al.[39], Radiology, 2007 | P | China | 90 | 65/25 | 54.8 (21–77) | HBV 66, HCV 19, Alcohol 2, cryptogenic 3 | A 73, B 17, C 0 |
| Elkammash et al.[40], Egypt J Radiol Nucl Med, 2016 | P | Egypt | 112 | 77/45 | 51.4 (38–72) | HBV 52, HCV 49, bilharziasis 11 | / |
| Dessouky and Abdel Aal[41], Arab J Gastroenterol, 2013 | P | Egypt | 137 | 73/64 | 58.7 (45–77) | HBV 27, HCV 93, HBV and HCV 14, steatohepatitis 3 | A 75, B 42, C 20 |
| Zhao et al.[42], Chin J Gastroenterol, 2016 | R | China | 143 | 96/47 | 52.39 (23–78) | HBV 101, HCV 5, alcohol 16, cryptogenic or others 21 | A 54, B 48, C 41 |
| Bashir et al.[43], P J M H S, 2021 | / | Rawalpidi | 145 | / | 35–80 | / | / |
| Kumar et al.[44], Pol J Radiol, 2023 | P | India | 62l | / | 62 | / | / |
| Kim et al.[45], J Gastroenterol Hepatol, 2009* | R | South Korea | 104 | 77/27 | 59 (27–80) | HBV 75, HCV 13, alcohol 7, cryptogenic 9 | A 43, B 32, C 29 |

*Data presented based on number of varices. R, retrospective; P, prospective; HBV, hepatitis B virus; HCV, hepatitis C virus; AIH, autoimmune hepatitis; PSC, primary sclerosing cholangitis; NASH, non-alcoholic steatohepatitis; MDCT, multi-detector computed tomography; MPR, multiplanar reconstruction; MSCT, multi-slice spiral computed tomography; EVs, esophageal varices; GVs, gastric varices; GEVs, gastroesophageal varices; TP, true-positive; FP, false-positive; TN, true-negative; FN, false-negative.

**Based on the number of patients:** In 27 studies,[10,19-44] which contained 54 sets of data regarding GEVs of any size, the pooled SEN and SPE were 0.91 and 0.81, respectively (Figure 2), with an AUC of 0.93 (Supplementary Figure 2). There were 35 sets of data from 17 studies[20-24,27,29-35,36,39,41,43] that assessed for high-risk GEVs. The pooled SEN and SPE were 0.90 and 0.90, respectively (Figure 3), with an AUC of 0.96 (Supplementary Figure 3). The pooled SPE and PLR for high-risk varices were significantly higher than those for varices of any size ($P = 0.001$ and 0.020, respectively).

**Based on the number of varices:** There was only 1 study[45] with 3 sets of data. The pooled SEN, SPE and AUC for varices of any size (and high-risk EVs) were 0.92 (0.89), 0.45 (0.85), and 0.94 (0.95), respectively.

## Patient-based subgroup analysis of gastroesophageal varices of any size

To identify the sources of heterogeneity, the authors performed subgroup analysis according to the location of varices, study design, and CT scanners used.

## Location of the varices

**EVs:** There were 47 sets of data from 24 studies[10,20-35,38-41,43,44] that assessed for EVs of any size, and 32 sets of data from 15 studies[20-24,27,29-31,33,34,36,37,41,43] that assessed for high-risk EVs (Table 2). The pooled SPE and PLR for high-risk EVs were significantly higher than those for EVs of any size ($P = 0.010$ and 0.034, respectively). However, no statistically significant difference in SEN, NLR, DOR or AUC was found between high-risk EVs and EVs of any size (all $P > 0.05$). According to the corresponding $I^2$ (82.5%–100%), there was substantial heterogeneity in the EV subgroup among the studies. Then, a subgroup analysis was carried out for EVs (Supplementary Table 2).

**GVs:** There were 7 data sets from 3 studies[10,32,35] concerning the presence of GVs of any size (Table 2). There was no statistically significant heterogeneity in the GV subgroup among these studies. Since only 1 study[32] reported on high-risk GVs, a pooled analysis could not be performed.

## Study design

**Prospective vs. retrospective:** There were 29 and 21 sets of data from 12 prospective[10,19,26,28,31,34,35,38-41,44] and 11 retrospective[20,22-24,27,29,30,32,33,37,42] studies, respectively (Table 3). Between the prospective studies

**Table 1.** Continued

| CT scanner | CT technique | Patients underwent EGD | Time interval | Patient acceptance | Varice location | Prevalence of varices (%) | TP | FP | FN | TN |
|---|---|---|---|---|---|---|---|---|---|---|
| / | MSCT | 50 | / | / | GEVs | 90% | 43 | 0 | 2 | 5 |
| 16-slice | MSCT | 50 | Within 4 w | 74% CT, 1% EGD, 24% no preference | EVs | 82% | 39 | 3 | 2 | 6 |
| | | | | | | | 40 | 5 | 1 | 4 |
| 16-slice | CT esophagograms | 90 | Within 4 h | 66.67% CT, 14.44% EGD, 18.89% no preference | EVs | 58.89% | 50 | 15 | 3 | 22 |
| | | | | | | | 47 | 12 | 6 | 25 |
| | | | | | | | 46 | 13 | 7 | 24 |
| | | | | | | | 46 | 8 | 7 | 29 |
| 64-slice | MDCT | 112 | Within 2 w | 83% CT, 7.1% EGD, 9.9% no preference | EVs | 88.39% | 97 | 0 | 2 | 13 |
| | | | | | | | 99 | 0 | 0 | 13 |
| 16-slice | MDCT | 137 | Within 24 h | 98% CT, 2% EGD | EVs | 65.69% | 89 | 1 | 1 | 46 |
| 64-slice | MDCT | 143 | Within 1 w | / | GEVs | 80.42% | 112 | 3 | 1 | 27 |
| / | MDCT | 145 | / | / | EVs | 74.5% | 102 | 4 | 6 | 33 |
| 128-slice | MDCT | 62 | Within 2 d | / | EVs | 37.30% | 45 | 1 | 7 | 9 |
| 16 or 64-slice | MDCT | 104 | Within 4 w | / | EVs | 90.38% | 180 | 9 | 8 | 11 |
| | | | | | | | 169 | 9 | 19 | 11 |
| | | | | | | | 172 | 15 | 16 | 5 |

*Data presented based on number of varices. R, retrospective; P, prospective; HBV, hepatitis B virus; HCV, hepatitis C virus; AIH, autoimmune hepatitis; PSC, primary sclerosing cholangitis; NASH, non-alcoholic steatohepatitis; MDCT, multi-detector computed tomography; MPR, multiplanar reconstruction; MSCT, multi-slice spiral computed tomography; EVs, esophageal varices; GVs, gastric varices; GEVs, gastroesophageal varices; TP, true-positive; FP, false-positive; TN, true-negative; FN, false-negative.

**Table 2.** Overall diagnostic accuracy of studies researching gastroesophageal varices

| Study characteristic | No. of article/ set/patient | SEN (95% CI) | SPE (95% CI) | PLR (95% CI) | NLR (95% CI) | DOR (95% CI) | AUC (95% CI) |
|---|---|---|---|---|---|---|---|
| **Patient-based** | | | | | | | |
| Any sized GEVs | 27/54/5217 | 0.91 (0.88–0.93) | 0.81 (0.77–0.85) | 4.82 (3.84–6.03) | 0.11 (0.08–0.15) | 42.47 (26.61–67.77) | 0.93 (0.90–0.95) |
| High-risk GEVs | 17/35/3526 | 0.90 (0.85–0.93) | 0.90 (0.86–0.93) | 8.85 (6.25–12.70) | 0.12 (0.08–0.17) | 75.10 (41.44–136.11) | 0.96 (0.93–0.97) |
| *P* value | / | 0.682 | 0.001 | 0.020 | 0.728 | 0.215 | 0.069 |
| Any sized EVs | 24/47/4596 | 0.91 (0.87–0.93) | 0.81 (0.76–0.85) | 4.75 (3.67–6.15) | 0.12 (0.08–0.16) | 41.00 (24.17–69.55) | 0.93 (0.90–0.95) |
| High-risk EVs | 15/32/3234 | 0.90 (0.85–0.93) | 0.89 (0.85–0.93) | 8.36 (5.82–12.01) | 0.11 (0.08–0.17) | 73.75 (39.62–137.30) | 0.95 (0.93–0.97) |
| *P* value | / | 0.682 | 0.010 | 0.034 | 0.739 | 0.233 | 0.224 |
| Any sized GVs | 3/7/570 | 0.85 (0.76–0.91) | 0.83 (0.77–0.87) | 4.88 (3.59–6.62) | 0.19 (0.12–0.30) | 26.03 (14.02–48.33) | 0.89 (0.86–0.92) |
| High-risk GVs* | 1/2/252 | 0.83 (0.69–0.93) | 0.97 (0.93–0.99) | 25.06 (11.95–52.54) | 0.17 (0.09–0.34) | 149.43 (48.87–456.86) | / |
| *P* value | / | 0.789 | <0.001 | <0.001 | 0.787 | 0.007 | / |
| **Varix-based** | | | | | | | |
| Any sized (EVs)* | 1/3/104 | 0.92 (0.90–0.94) | 0.45 (0.32–0.58) | 1.67 (1.07–2.61) | 0.17 (0.08–0.36) | 10.26 (3.38–31.17) | 0.9373 (0.1522) |
| High-risk (EVs)* | 1/3/104 | 0.89 (0.85–0.92) | 0.79 (0.74–0.84) | 4.28 (3.31–5.53) | 0.14 (0.09–0.22) | 30.19 (17.42–52.33) | 0.8483 (0.0532) |
| *P* value | / | 0.145 | <0.001 | <0.001 | 0.664 | 0.088 | 0.581 |

*Data calculated using Meta-Disc 1.4. GEVs, gastroesophageal varices; EVs, esophageal varices; GVs, gastric varices; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; DOR, diagnostic odds ratio; AUC, area under the curve; 95% CIs, corresponding 95% confidence interval.

and the retrospective studies, statistically significant differences were found in the pooled SEN, NLR, and AUC (0.93 vs. 0.85; 0.08 vs. 0.18; and 0.95 vs. 0.90, respectively; $P$ = 0.007, 0.015, and 0.002, respectively), but no statistically significant difference in SPE or PLR was found ($P$ = 0.883 and 0.598, respectively).

### Computed tomography scanner

**<16-slice vs. 16-slice vs. 64-slice:** There were 7, 17, and 12 sets of data from 3,[21,30,32] 8,[25,27,28,33,35,38,39,41] and 6[19,26,34,36,40,42] studies that assessed for varices by using the <16-slice, 16-slice, and 64-slice CT scans, respectively (Table 3). Among the three subgroups, the 64-slice CT yielded the highest SEN, whereas the 16-slice CT and 64-slice CT yielded a similarly high SPE and AUC, which were higher than those of the <16-slice CT (all $P$ < 0.05).

### Patient-based subgroup analysis of the high-risk esophageal varices

The results of the subgroup analyses for high-risk EVs are summarized in Table 4. A study that used a cut-off of 3.9 mm[24] was classified into the 4 mm subgroup. The SEN from a cut-off of 2 mm was close to that from a cut-off of 3 mm (0.92 vs. 0.97, $P = 0.107$) and higher than that from a cut-off of 4 or 5 mm ($P$ < 0.001). Likewise, the SPE from a cut-off of 3 mm was close to that from a cut-off of 5 mm (0.91 vs. 0.93, $P$ = 0.491) and higher than that from a cut-off of 2 mm ($P$ = 0.001 and <0.001, respectively). Cut-offs of 3 and 5 mm shared the approximate AUC (0.992 vs. 0.997, $P$ = 0.657), which was higher than for cut-offs of 2 and 4 mm ($P$ = 0.004 and 0.006, respectively).

### Publication bias

Deek's funnel plot (Supplementary Figure 4) revealed no evidence of significant publication bias ($P$ = 0.410).

## Discussion

In this study, the authors confirmed the feasibility of CT in diagnosing GEVs, including high-risk varices, in patients with cirrhosis. The data were analyzed according to each patient and lesion, the relationship between the GEV size and RC sign was assessed, and the patient's acceptance of CT and EGD was

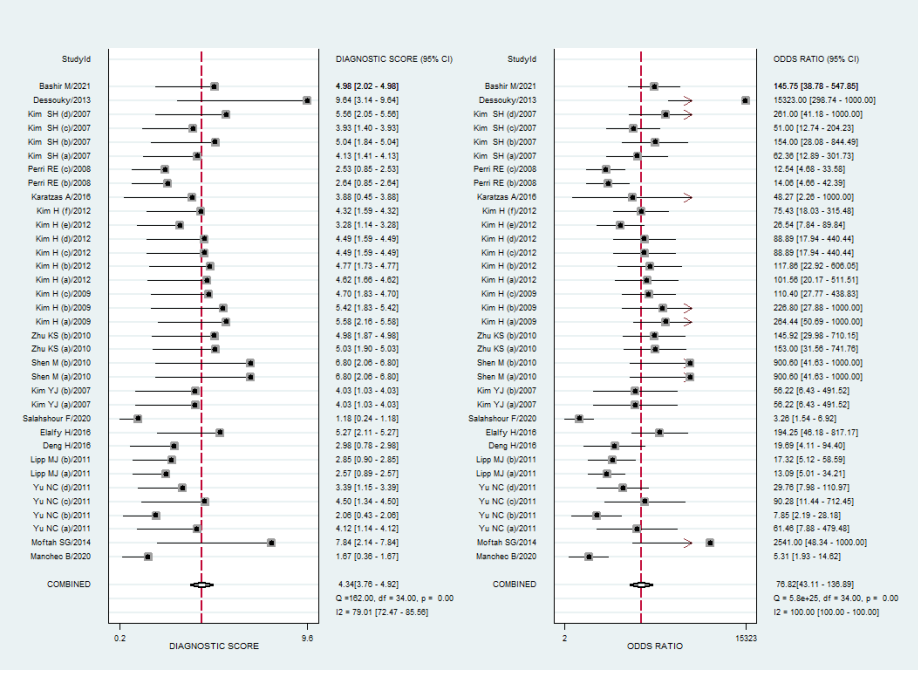



**Figure 3.** Coupled Forest plots of sensitivity and specificity for predicting high-risk varices with CT.

*CT, computed tomography.*

**Table 3.** Subgroup results of meta-analyses regarding any sized gastroesophageal varices based on number of patients

| Study subgroups | No. of article/ set/patient | SEN (95% CI) | SPE (95% CI) | PLR (95% CI) | NLR (95% CI) | DOR (95% CI) | AUC (95% CI) |
|---|---|---|---|---|---|---|---|
| **Location of varices** | | | | | | | |
| Any sized EVs | 24/47/4596 | 0.91 (0.87–0.93) | 0.81 (0.75–0.85) | 4.75 (3.67–6.15) | 0.12 (0.08–0.16) | 41.00 (24.17–69.55) | 0.93 (0.90–0.95) |
| Any sized GVs | 3/7/570 | 0.85 (0.76–0.91) | 0.83 (0.77–0.87) | 4.88 (3.59–6.62) | 0.19 (0.12–0.30) | 26.03 (14.02–48.33) | 0.89 (0.86–0.92) |
| $P$ value | / | 0.164 | 0.585 | 0.896 | 0.117 | 0.302 | 0.046 |
| **Study design** | | | | | | | |
| Retrospective | 11/21/2300 | 0.85 (0.79–0.90) | 0.80 (0.73–0.86) | 4.32 (3.08–6.06) | 0.18 (0.12–0.27) | 23.56 (12.00–46.23) | 0.90 (0.87–0.92) |
| Prospective | 12/29/2519 | 0.93 (0.91–0.95) | 0.81 (0.74–0.87) | 4.93 (3.51–6.93) | 0.08 (0.06–0.12) | 60.52 (31.18–117.44) | 0.95 (0.93–0.97) |
| $P$ value | / | 0.007 | 0.883 | 0.598 | 0.015 | 0.118 | 0.002 |
| **Computed tomography scanner** | | | | | | | |
| <16 detector | 3/7/696 | 0.82 (0.73–0.88) | 0.76 (0.71–0.81) | 3.39 (2.77–4.17) | 0.24 (0.16–0.36) | 14.10 (8.41–23.64) | 0.81 (0.77–0.84) |
| 16 detector | 8/17/129 | 0.92 (0.88–0.94) | 0.80 (0.70–0.88) | 4.64 (2.97–7.25) | 0.10 (0.07–0.16) | 44.64 (20.44–97.50) | 0.94 (0.92–0.96) |
| 64 detector | 6/12/1278 | 0.97 (0.93–0.98) | 0.89 (0.85–0.93) | 9.09 (6.45–12.82) | 0.04 (0.02–0.08) | 239.76 (99.27–579.06) | 0.95 (0.93–0.97) |
| $P_{<16 \text{ vs.} 16}$ | / | 0.023 | 0.446 | 0.21 | 0.003 | 0.016 | <0.001 |
| $P_{<16 \text{ vs.} 64}$ | / | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| $P_{16 \text{ vs.} 64}$ | / | 0.014 | 0.089 | 0.019 | 0.026 | 0.005 | 0.488 |

GEVs, gastroesophageal varices; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; DOR, diagnostic odds ratio; AUC, area under the curve; 95% CIs, corresponding 95% confidence interval.

**Table 4.** Subgroup results of meta-analyses regarding high-risk esophageal varices based on number of patients

| Study subgroups | No. of article/ set/patient | SEN (95% CI) | SPE (95% CI) | PLR (95% CI) | NLR (95% CI) | DOR (95% CI) | AUC (95% CI) |
|---|---|---|---|---|---|---|---|
| **Study design** | | | | | | | |
| Retrospective | 9/17/1732 | 0.89 (0.81–0.93) | 0.87 (0.78–0.92) | 6.67 (3.96–4.76) | 0.13 (0.08–0.22) | 50.68 (22.08–116.31) | 0.94 (0.92–0.96) |
| Prospective | 4/13/1299 | 0.90 (0.82–0.95) | 0.90 (0.87–0.93) | 4.95 (3.48–7.05) | 0.11 (0.06–0.20) | 82.17 (35.20–191.81) | 0.95 (0.93–0.97) |
| *P* value | / | 0.828 | 0.455 | 0.109 | 0.677 | 0.425 | 0.488 |
| **Cut-off of high-risk in computed tomography** | | | | | | | |
| ≥2 mm | 4/14/1420 | 0.92 (0.89–0.94) | 0.83 (0.81–0.86) | 6.63 (4.26–10.31) | 0.11 (0.08–0.16) | 70.24 (39.22–125.81) | 0.9599 (0.0089)* |
| ≥3 mm | 2/3/271 | 0.97 (0.89–1.00) | 0.91 (0.87–0.95) | 11.11 (2.17–56.78) | 0.07 (0.02–0.23) | 227.33 (13.44–3846.11) | 0.9919 (0.0066)* |
| ≥4 mm | 3/4/451 | 0.72 (0.64–0.78) | 0.87 (0.82–0.91) | 3.93 (1.57–9.82) | 0.39 (0.22–0.68) | 11.13 (6.21–19.96) | 0.8270 (0.0301)* |
| ≥5 mm | 2/4/340 | 0.78 (0.71–0.84) | 0.93 (0.88–0.96) | 9.98 (3.23–30.83) | 0.20 (0.08–0.48) | 59.06 (9.67–360.73) | 0.9974 (0.0105)* |
| $P_{\geq 2\text{ mm vs. }\geq 3\text{ mm}}$ | / | 0.107 | 0.001 | 0.550 | 0.485 | 0.425 | 0.004 |
| $P_{\geq 2\text{ mm vs. }\geq 4\text{ mm}}$ | / | <0.001 | 0.125 | 0.314 | <0.001 | <0.001 | <0.001 |
| $P_{\geq 2\text{ mm vs. }\geq 5\text{ mm}}$ | / | <0.001 | <0.001 | 0.508 | 0.223 | 0.858 | 0.006 |
| $P_{\geq 3\text{ mm vs. }\geq 4\text{ mm}}$ | / | <0.001 | 0.196 | 0.277 | 0.012 | 0.041 | <0.001 |
| $P_{\geq 3\text{ mm vs. }\geq 5\text{ mm}}$ | / | <0.001 | 0.491 | 0.916 | 0.174 | 0.431 | 0.657 |
| $P_{\geq 4\text{ mm vs. }\geq 5\text{ mm}}$ | / | 0.227 | 0.054 | 0.209 | 0.216 | 0.085 | <0.001 |

*Data calculated using Meta-Disc 1.4. EVs, esophageal varices; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; DOR, diagnostic odds ratio; AUC, area under the curve; 95% CIs, corresponding 95% confidence interval.

evaluated. The diagnosis of high-risk GEVs showed higher specificity than that of any-sized GEVs, without compromising the sensitivity. The sensitivity of CT is currently not sufficient to replace EGD as the first screening approach for GEVs in these patients. Additionally, given the high accuracy and better patient acceptance, CT may be used in cases where patients refuse to or are unable to undergo EGD. Furthermore, several subgroup analyses of GEVs were also conducted according to the location of varices, study design, and CT scanner.

The authors observed a better diagnostic performance of CT in detecting GEVs than that observed by a previous meta-analysis.[46] Based on the location of varices, the AUC of CT for EVs was found to be significantly higher than that for GVs, which was inconsistent with the previous study.[46] This discrepancy might be due to the different sample sizes or inclusion/exclusion criteria of the studies. Additionally, more recent studies, which used CT with >16 slices to detect varices and mostly evaluated EVs, were included. The present subgroup-analysis results also confirmed that the >16-slice CT showed a significantly better performance for diagnosing varices of any size than the <16-slice CT, and the 64-slice CT yielded the highest sensitivity. With recent advancements in multi-detector CT, CT with >16 detectors provide isotropic or near isotropic data sets that enable multi-planner details, and consequently, GEVs can be easily evaluated. In addition, prospective studies demonstrated higher diagnostic accuracy compared with retrospective studies, which is likely attributable to their stringent inclusion criteria, standardized data collection protocols, fostering of homogeneity in study populations, and enhanced control over confounding variables.

In the subgroup analyses, CT yielded a higher specificity in identifying high-risk EVs than EVs of any size, which was similar to the previous report.[47] At present, there is no consensus regarding the diagnostic criteria for high-risk EVs on CT, and no systematic review or meta-analysis has used multiple thresholds to risk-stratify patients. Therefore, the authors of the present study attempted to perform subgroup analyses based on the cut-off values for high-risk EVs on CT. They identified an interesting result: a threshold of 3 mm provided the highest sensitivity and a high specificity, with a PLR of 11.11 and an NLR of 0.07 as substantial evidence to rule in or rule out a large varix, respectively. These results suggested that EGD is not necessary in individuals with small (<3 mm) or undetectable EVs via CT scan since they are unlikely to experience variceal bleeding, which is in line with a previous case–control study.[48] In contrast, a cut-off of 5 mm provided similar specificity and AUC, but lower sensitivity for large varices than that of a cut-off of 3 mm. Preventive medication with beta-blockers might be considered against possible bleeding in this setting. Only patients who have contraindications to beta-blockers and need endoscopic variceal ligation would require EGD. Consequently, EGD may be efficiently allocated to those who need it the most. However, given the small number of included studies in the subgroup, it would be best evaluated using prospective cohort studies to demonstrate the diagnostic and prognostic value of these different variceal sizes.

Bleeding events caused by GVs tend to be more severe than EV bleeds.[49] It is clinically meaningful to accurately identify patients at a high risk of GV bleeding. The authors identified that CT has a relatively high sensitivity and specificity in detecting GVs of any size, and a relatively high sensitivity and extremely high specificity in detecting large GVs. The size of GVs has been reported to be the most important risk factor for GV bleeding.[50] However, only 1 included study[32] was concerned with high-risk GVs with a diameter >5 mm. GVs are always located in deep submucosa or subserosa and the overlying mucosa is normal, meaning the endoscopic diagnosis of GVs is limited. Studies have found that CT is more sensitive than EGD in identifying GVs, detecting GVs missed by EGD.[10,11,42,51] The clinical implications of these results need to be verified using additional prospective cohorts in the future.

Although variceal size is a valuable predictor of bleeding, other important risk factors, such as the RC sign, cannot be observed in CT images.[52] Studies have revealed that the presence and severity of the RC sign are significantly correlated with CT variceal grade

or size.[15,31,40,41,53] Such a significant correlation may serve as a basis for a CT-based screening method. A diameter of 4 mm[15,41] or 5 mm[31] was used as the cut-off value to predict the RC sign, with a sensitivity of 97%–100%.

Although the present findings are significant, several limitations should be acknowledged. First, there was a variable time interval (from 4 hours to 6 months) between the EGD and CT assessments. Therefore, the interval progression or regression of GEVs cannot be entirely ruled out. Second, the definitions or cut-off values of high-risk varices were different among the analyzed studies. Thus, we could not determine a standard diagnostic cut-off size for CT assessment of GEVs. Third, contrast-enhanced CT has a risk of radiation and allergy. Nevertheless, CT is routinely used to evaluate the complications of cirrhosis and hepatocellular carcinoma, as well as concurrently assess for GEVs without adding extra cost and radiation exposure. Such a dual-screening strategy would further improve the cost-effectiveness of CT.

In conclusion, contrast-enhanced CT, especially with >16 slices, has a high diagnostic accuracy for GEVs and high-risk varices in patients with cirrhosis. Although EGD remains the gold standard for the diagnosis and risk stratification of GEVs, CT is a relatively more tolerable modality and may be an effective alternative in patients unwilling or contraindicated to undergo EGD.

### Conflict of interest disclosure

The authors declared no conflicts of interest.


### Funding

This work was supported by the science and technology development guiding plan project of Lanzhou (grant numbers: 2019-ZD-46).


## References


1. Marshall JP, Smith PD, Hoyumpa AM Jr. Gastric varices. Problem in diagnosis. *Am J Dig Dis.* 1977;22(11):947-955. [CrossRef]
2. Garcia-Tsao G, Bosch J. Management of varices and variceal hemorrhage in cirrhosis. *N Engl J Med.* 2010;362(9):823-832. Erratum in: N Engl J Med. 2011;364(5):490. [CrossRef]
3. Spiegel BM, Targownik L, Dulai GS, Karsan HA, Gralnek IM. Endoscopic screening for esophageal varices in cirrhosis: Is it ever cost effective? *Hepatology.* 2003;37(2):366-377. [CrossRef]
4. Garcia-Tsao G, Abraldes JG, Berzigotti A, Bosch J. Portal hypertensive bleeding in cirrhosis: risk stratification, diagnosis, and management: 2016 practice guidance by the American Association for the study of liver diseases. *Hepatology.* 2017;65(1):310-335. [CrossRef]
5. ASGE Standards of Practice Committee; Early DS, Lightdale JR, et al. Guidelines for sedation and anesthesia in GI endoscopy. *Gastrointest Endosc.* 2018;87(2):327-337. [CrossRef]
6. Zoli M, Merkel C, Magalotti D, et al. Natural history of cirrhotic patients with small esophageal varices: a prospective study. *Am J Gastroenterol.* 2000;95(2):503-508. [CrossRef]
7. Tripathi D, Stanley AJ, Hayes PC, et al. U.K. guidelines on the management of variceal haemorrhage in cirrhotic patients. *Gut.* 2015;64(11):1680-1704. [CrossRef]
8. de Franchis R; Baveno VI Faculty. Expanding consensus in portal hypertension: Report of the Baveno VI Consensus Workshop: Stratifying risk and individualizing care for portal hypertension. *J Hepatol.* 2015;63(3):743-752. [CrossRef]
9. Sharma VK, Nguyen CC, Crowell MD, Lieberman DA, de Garmo P, Fleischer DE. A national study of cardiopulmonary unplanned events after GI endoscopy. *Gastrointest Endosc.* 2007;66(1):27-34. [CrossRef]
10. Perri RE, Chiorean MV, Fidler JL, et al. A prospective evaluation of computerized tomographic (CT) scanning as a screening modality for esophageal varices. *Hepatology.* 2008;47(5):1587-1594. [CrossRef]
11. El-Assaly H, Metwally LIA, Azzam H, Seif Elnasr MI. A comparative study of multi-detector CT portography versus endoscopy in evaluation of gastro-esophageal varices in portal hypertension patients. *Egypt J Radiol Nucl Med.* 2020;51(1):2-10. [CrossRef]
12. Rosman M, Aneke-Nash C, Whitsett M, et al. The utility of radiographic evidence of portosystemic collateral vessels to improve the Baveno VI consensus recommendations in the non-invasive prediction of esophageal varices. *Gastroenterology.* 2019;156:1334. [CrossRef]
13. Sousa M, Fernandes S, Proença L, et al. The Baveno VI criteria for predicting esophageal varices: validation in real life practice. *Rev Esp Enferm Dig.* 2017;109(10):704-707. [CrossRef]
14. Januszewicz MM, Hałaburda-Rola M, Pruszyńska-Włodarczyk I, Czachór-Zielińska A, Rowiński O. Computed tomography evaluation of patent paraumbilical vein and its aneurysm in relation to other portosystemic collateral channels in patients with liver cirrhosis and portal hypertension. *Pol J Radiol.* 2019;84:112-117. [CrossRef]
15. Mifune H, Akaki S, Ida K, Sei T, Kanazawa S, Okada H. Evaluation of esophageal varices by multidetector-row CT: correlation with endoscopic 'red color sign'. *Acta Med Okayama.* 2007;61(5):247-254. [CrossRef]
16. Whiting PF, Rutjes AW, Westwood ME, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med.* 2011;155(8):529-536. [CrossRef]
17. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ.* 2003;327(7414):557-560. [CrossRef]
18. Deeks JJ, Macaskill P, Irwig L. The performance of tests of publication bias and other sample size effects in systematic reviews of diagnostic test accuracy was assessed. *J Clin Epidemiol.* 2005;58(9):882-893. [CrossRef]
19. He X, Huang Z, Long L, et al. Comparison of multi-slice spiral CT portography and endoscopy in the diagnosis of esophageal and gastric varices in liver cirrhosis. *Chin J Radiol (China).* 2012;46(12):1092-1095. [CrossRef]
20. Manchec B, Pham E, Noor M, et al. Contrast-Enhanced CT may identify high-risk esophageal varices in patients with cirrhosis. *AJR Am J Roentgenol.* 2020;215(3):617-623. [CrossRef]
21. Moftah SG, Kamal S, Hanna ATK. CT esophagography: non invasive screening and grading of esophageal varices in cirrhosis. *Egypt J Radiol Nucl Med.* 2014;45(2):263-270. [CrossRef]
22. Yu NC, Margolis D, Hsu M, Raman SS, Lu DS. Detection and grading of esophageal varices on liver CT: comparison of standard and thin-section multiplanar reconstructions in diagnostic accuracy. *AJR Am J Roentgenol.* 2011;197(3):643-649. [CrossRef]
23. Lipp MJ, Broder A, Hudesman D, et al. Detection of esophageal varices using CT and MRI. *Dig Dis Sci.* 2011;56(9):2696-2700. [CrossRef]
24. Deng H, Qi X, Zhang Y, Peng Y, Li J, Guo X. Diagnostic accuracy of contrast-enhanced computed tomography for esophageal varices in liver cirrhosis: a retrospective observational study. *J Evid Based Med.* 2017;10(1):46-52. [CrossRef]
25. Sattar A, Anjum S, Rana S, Hamid N. Diagnostic accuracy of multidetector computed tomography (MDCT) in evaluation of varices in cirrhotic patients. *Med Forum.* 2019;30(9):7-9. [CrossRef]
26. Hassan M, Husen Y, Abbasi SU, Hussain Z. Diagnostic accuracy of multidetector computed tomography in detection of esophageal varices. *Cureus.* 2019;11(1):e3933. [CrossRef]
27. Elalfy H, Elsherbiny W, Abdel Rahman A, et al. Diagnostic non-invasive model of large risky esophageal varices in cirrhotic hepatitis C virus patients. *World J Hepatol.* 2016;8(24):1028-1037. [CrossRef]
28. Cansu A, Ahmetoglu A, Kul S, et al. Diagnostic performance of using effervescent powder for detection and grading of esophageal varices by multi-detector computed tomography. *Eur J Radiol.* 2014;83(3):497-502. [CrossRef]

29. Salahshour F, Mehrabinejad MM, Rashidi Shahpasandi MH, et al. Esophageal variceal hemorrhage: the role of MDCT characteristics in predicting the presence of varices and bleeding risk. *Abdom Radiol (NY).* 2020;45(8):2305-2314. [CrossRef]
30. Kim YJ, Raman SS, Yu NC, To'o KJ, Jutabha R, Lu DS. Esophageal varices in cirrhotic patients: evaluation with liver CT. *AJR Am J Roentgenol.* 2007;188(1):139-144. [CrossRef]
31. Shen M, Zhu KS, Meng XC, Zhang JS, Liu LY, Shan H. [Evaluation of esophageal varices and predicting the risk of esophageal varices bleeding with multi-detector CT in patients with portal hypertension]. *Zhonghua Yi Xue Za Zhi.* 2010;90(41):2911-2915. [CrossRef]
32. Zhu K, Meng X, Pang P, et al. Gastric varices in patients with portal hypertension: evaluation with multidetector row CT. *J Clin Gastroenterol.* 2010;44(5):108-115. [CrossRef]
33. Kim H, Choi D, Gwak GY, et al. High-risk esophageal varices in patients treated with locoregional therapies for hepatocellular carcinoma: evaluation with regular follow-up liver CT. *Dig Dis Sci.* 2009;54(10):2247-2252. [CrossRef]
34. Kim H, Choi D, Lee JH, et al. High-risk esophageal varices in patients treated with locoregional therapy for hepatocellular carcinoma: assessment with liver computed tomography. *World J Gastroenterol.* 2012;18(35):4905-4911. [CrossRef]
35. Karatzas A, Triantos C, Kalafateli M, et al. Multidetector computed tomography versus platelet/spleen diameter ratio as methods for the detection of gastroesophageal varices. *Ann Gastroenterol.* 2016;29(1):71-78. [CrossRef]
36. Guo CW, Quan XY, Fang CH, et al. Portography diagnotic value of collateral circulation of portal hypertension on 64-slice spiral CT. *Chin J Med Imaging Technol.* 2008;24(6):932-935. [CrossRef]
37. Hua J, Liu GQ, Bao H, et al. The role of liver stiffness measurement in the evaluation of liver function and esophageal varices in cirrhotic patients. *J Dig Dis.* 2015;16(2):98-103. [CrossRef]
38. Wu L, Fan Z, Gu H, Feng Q. Value of multislice spiral ct in detecting and grading of esophageal varices in cirrhotic patients. *Chin J Gastroenterol.* 2009;14(1):12-15. [CrossRef]
39. Kim SH, Kim YJ, Lee JM, et al. Esophageal varices in patients with cirrhosis: multidetector CT esophagography--comparison with endoscopy. *Radiology.* 2007;242(3):759-768. [CrossRef]
40. Elkammash T, Elfiky I, Zaiton F, Khorshed SE. Diagnostic performance of multidetector computed tomography in the evaluation of esophageal varices. *Egypt J Radiol Nucl Med.* 2016;47(1):43-51. [CrossRef]
41. Dessouky BA, Abdel Aal el SM. Multidetector CT oesophagography: an alternative screening method for endoscopic diagnosis of oesophageal varices and bleeding risk. *Arab J Gastroenterol.* 2013;14(3):99-108. [CrossRef]
42. Zhao S, Feng K, Qu Q, et al. Application of ct portography in esophagogastric varices in cirrhotic patients. *Chin J Gastroenterol.* 2016;21(10):615-619. [CrossRef]
43. Bashir M, Mughal HH, Mehmood F, Aftab MI, Ali M, Muhammad MD. Diagnostic accuracy of multi-detector computed tomography esophagography in grading of esophageal varices in cirrhotic patients. *P J M H S.* 2021;15(8):2175-2177. [CrossRef]
44. Kumar R, Nandolia KK, Sharma P, et al. Computed tomography virtual oesophagography for the grading of oesophageal varices in cirrhotic liver disease patients with upper gastrointestinal endoscopic examination as the gold standard: a diagnostic validation study. *Pol J Radiol.* 2023;88:187-193. [CrossRef]
45. Kim H, Choi D, Gwak GY, et al. Evaluation of esophageal varices on liver computed tomography: receiver operating characteristic analyses of the performance of radiologists and endoscopists. *J Gastroenterol Hepatol.* 2009;24(9):1534-1540. [CrossRef]
46. Deng H, Qi X, Guo X. Computed tomography for the diagnosis of varices in liver cirrhosis: a systematic review and meta-analysis of observational studies. *Postgrad Med.* 2017;129(3):318-328. [CrossRef]
47. Li Y, Li L, Weng HL, Liebe R, Ding HG. Computed tomography *vs* liver stiffness measurement and magnetic resonance imaging in evaluating esophageal varices in cirrhotic patients: A systematic review and meta-analysis. *World J Gastroenterol.* 2020;26(18):2247-2267. [CrossRef]
48. Somsouk M, To'o K, Ali M, et al. Esophageal varices on computed tomography and subsequent variceal hemorrhage. *Abdom Imaging.* 2014;39(2):251-256. [CrossRef]
49. Ryan BM, Stockbrugger RW, Ryan JM. A pathophysiologic, gastroenterologic, and radiologic approach to the management of gastric varices. *Gastroenterology.* 2004;126(4):1175-1189. [CrossRef]
50. Kim T, Shijo H, Kokawa H, et al. Risk factors for hemorrhage from gastric fundal varices. *Hepatology.* 1997;25:307-312. [CrossRef]
51. Suvak B, Kekilli M, Beyazıt Y, Okten S, Tanoglu A, Sasmaz N. Is computerised tomography better than fibreoptic gastroscopy for early detection of gastric varices. Is computerised tomography better than fibreoptic gastroscopy for early detection of gastric varices? *Prz Gastroenterol.* 2017;12(1):34-37. [CrossRef]
52. Yoshida H, Mamada Y, Taniai N, et al. Risk factors for bleeding esophagogastric varices. *J Nippon Med Sch*. 2013;80(4):252-259. [CrossRef]
53. Murachima N, Ikeda K, Kobayashi M, et al. Incidence of the appearance of the red color sign on esophageal varices and its predictive factors: long-term observations of 359 patients with cirrhosis. *J Gastroenterol*. 2001;36(6):368-374. [CrossRef]

**Supplementary Table 1.** Characteristics of CT to predict high-risk varices

| Study/journal/year | Study design | CT canner | Patients underwent EGD | Varices location | Prevalence of high-risk varices (%) | Cut-off of high-risk varices on EGD | Cut-off of high-risk varices on CT | TP | FP | FN | TN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Manchec et al.[20], AJR Am J Roentgenol, 2020 | R | / | 97 | EVs | 60.82% | Grade 3 or higher | ≥4 mm | 51 | 18 | 8 | 15 |
| Moftah et al.[21], Egypt J Radiol Nucl Med, 2014 | / | 4 or 8-slice | 54 | EVs | 29.63% | Grade 3 or 4, mucosal red signs, recommendation of endoscopic or medical prophylactic therapy | ≥2 mm | 16 | 0 | 0 | 38 |
| Yu et al.[22], AJR Am J Roentgenol, 2011 | R | 16 or 64-slice | 109 | EVs | 23.85% | Grade 3 or 4, variceal mucosal red signs or platelet plug | ≥2 mm | 25<br>23<br>25<br>23 | 24<br>41<br>18<br>17 | 1<br>3<br>1<br>3 | 59<br>42<br>65<br>66 |
| Lipp et al.[23], Dig Dis Sci, 2011 | R | 4 or 16 or 64-slice | 137<br>165 | EVs | 15.38% | ≥5 mm, or ≥3/4 of the normal esophageal lumen being obstructed | ≥4 mm | 18<br>12 | 11<br>4 | 12<br>22 | 96<br>127 |
| Deng et al.[24] J Evid Based Med, 2016 | R | / | 52 | EVs | 75% | Slight tortuous varices with RC signs; or snake-like varices with or without RC signs; or beady, nodular, or tumor-shaped varices with or without RC signs | ≥3.9 mm | 35 | 4 | 4 | 9 |
| Elalfy et al.[27], World J Hepatol, 2016 | R | 16-slice | 124 | EVs | 37.10% | medium/large varices | / | 42 | 4 | 4 | 74 |
| Salahshour et al.[29], Abdom Radiol (NY), 2020 | R | 16 or 64-slice | 124 | EVs | 40.32% | grade 2, 3, or grade 1 with red signs or Child-Pugh class C | / | 29 | 22 | 21 | 52 |
| Kim et al.[30], AJR Am J Roentgenol, 2007 | R | single or 4 slice | 67 | EVs | 17.91% | Protrude into the esophageal lumen and touch each other | ≥3 mm | 11<br>11 | 9<br>9 | 1<br>1 | 46<br>46 |
| Shen et al.[31], Zhonghua Yi Xue Za Zhi, 2010 | P | 320 slice | 69 | EVs | 59.42% | Grade 2 and 3 | ≥5 mm | 39<br>39 | 0<br>0 | 2<br>2 | 28<br>28 |
| Zhu et al.[32], J Clin Gastroenterol, 2010 | R | 4 slice | 127 | GVs | 16.54% | ≥5mm | ≥5 mm | 18<br>17 | 4<br>3 | 3<br>4 | 102<br>103 |

**Supplementary Table 1.** Continued

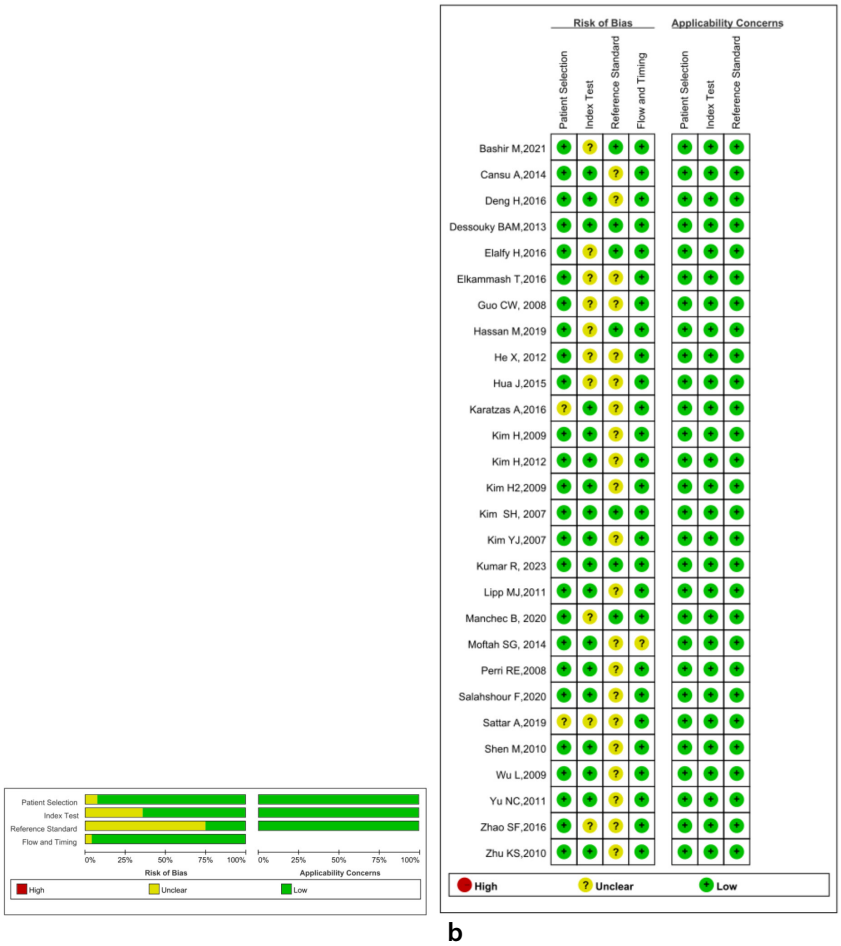
| Study/journal/year | Study design | CT canner | Patients underwent EGD | Varices location | Prevalence of high-risk varices (%) | Cut-off of high-risk varices on EGD | Cut-off of high-risk varices on CT | TP | FP | FN | TN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kim et al.[33], Dig Dis Sci, 2009 | R | 16-slice | 110 | EVs | 33.63% | Grade 2 and 3 | ≥2 mm | 34 | 3 | 3 | 70 |
| | | | | | | | | 36 | 10 | 1 | 63 |
| | | | | | | | | 32 | 4 | 5 | 69 |
| Kim et al.[34], World J Gastroenterol, 2012 | P | 64-slice | 100 | EVs | 27.00% | Grade 2 and 3 | ≥2 mm | 25 | 8 | 2 | 65 |
| | | | | | | | | 25 | 7 | 2 | 66 |
| | | | | | | | | 25 | 9 | 2 | 64 |
| | | | | | | | | 25 | 9 | 2 | 64 |
| | | | | | | | | 23 | 13 | 4 | 60 |
| | | | | | | | | 24 | 7 | 3 | 66 |
| Karatzas et al.[35], Ann Gastroenterol, 2016 | P | 16-slice | 38 | EVs + GVs | 10.52% | ≥5 mm | ≥5 mm | 4 | 5 | 0 | 29 |
| Perri et al.[10], Hepatology, 2008 | P | 4 slice or higher | 101 | EVs | 40.59% | ≥5 mm | ≥5 mm | 23 | 5 | 18 | 55 |
| | | | | | | | | 27 | 8 | 14 | 52 |
| Kim et al.[39], Radiology, 2007 | P | 16-slice | 90 | EVs | 33.33% | Grade 2 and 3 | / | 28 | 11 | 2 | 49 |
| | | | | | | | | 28 | 5 | 2 | 55 |
| | | | | | | | | 27 | 9 | 3 | 51 |
| | | | | | | | | 27 | 2 | 3 | 58 |
| Dessouky and Abdel Aal[41], Arab J Gastroenterol, 2013 | P | 16-slice | 137 | EVs | 27.74% | ≥ Grade 2 | ≥3 mm | 38 | 0 | 0 | 99 |
| Bashir et al.[43], P J M H S, 2021 | / | / | 145 | EVs | 74.5% | / | / | 102 | 4 | 6 | 33 |
| Kim et al.[45], J Gastroenterol Hepatol, 2009 * | R | 16 or 64-slice | 104 | EVs | 64.42% | Grade 2 and 3 | ≥2 mm | 123 | 15 | 9 | 61 |
| | | | | | | | | 113 | 17 | 19 | 59 |
| | | | | | | | | 115 | 15 | 17 | 61 |

*Data presented base on number of varices. R, retrospective; P, prospective; EGD, Esophagogastroduodenoscopy; EVs, esophageal varices; GVs, gastric varices; TP, true positive;FP, false-positive; TN, true-negative;FN, false-negative; Grade 2: Varices show beaded appearance; Grade 3: Varices run in oblique course and are tortuous with tumorlike appearance.

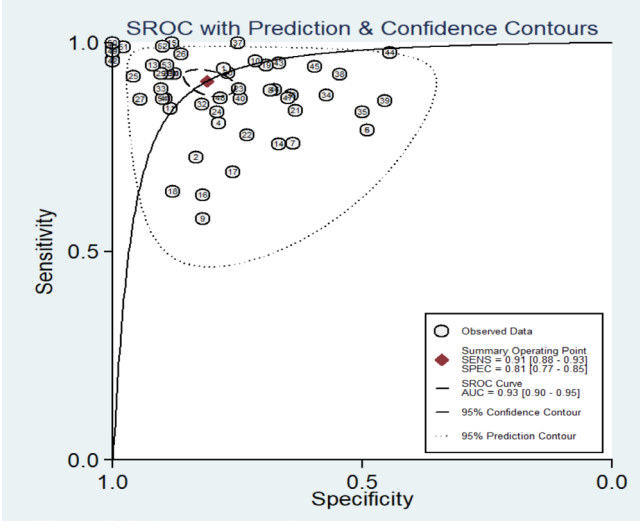
**Supplementary Table 2.** Subgroup results of meta-analyses regarding any sized EVs based on number of patients

| Study subgroups | No.of article/set/patient | SEN (95% CI) | SPE (95% CI) | PLR (95% CI) | NLR (95% CI) | DOR (95% CI) | AUC (95% CI) |
|---|---|---|---|---|---|---|---|
| **Study design** | | | | | | | |
| Retrospective | 9/17/1853 | 0.82 (0.75–0.87) | 0.79 (0.71–0.87) | 3.95 (2.72–5.73) | 0.23 (0.16–0.33) | 17.29 (8.96–33.33) | 0.88 (0.84–0.90) |
| Prospective | 11/26/2225 | 0.94 (0.91–0.96) | 0.81 (0.73–0.87) | 4.91 (3.34–7.23) | 0.08 (0.05–0.12) | 61.81 (29.22–130.76) | 0.95 (0.93–0.97) |
| *P* value | / | <0.001 | 0.715 | 0.444 | <0.001 | 0.095 | <0.001 |
| **CT scanner** | | | | | | | |
| <16 detector | 3/7/696 | 0.82 (0.73–0.88) | 0.76 (0.71–0.81) | 3.39 (2.77–4.17) | 0.24 (0.16–0.36) | 14.10 (8.41–23.64) | 0.81 (0.77–0.84) |
| 16 detector | 8/17/1429 | 0.92 (0.88–0.94) | 0.80 (0.70–0.88) | 4.64 (3.00–7.25) | 0.10 (0.07–0.16) | 44.64 (20.44–97.50) | 0.94 (0.92–0.96) |
| 64 detector | 3/9/1020 | 0.96 (0.91–0.98) | 0.91 (0.85–0.94) | 10.19 (6.31–16.44) | 0.05 (0.02–0.10) | 228.85 (75.50–693.65) | 0.96 (0.94–0.98) |
| $P <_{16\text{ vs.}16}$ | / | 0.023 | 0.446 | 0.206 | 0.003 | 0.016 | <0.001 |
| $P <_{16\text{ vs. }64}$ | / | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| $P_{16\text{ vs. }64}$ | / | 0.093 | 0.043 | 0.018 | 0.133 | 0.018 | 0.166 |

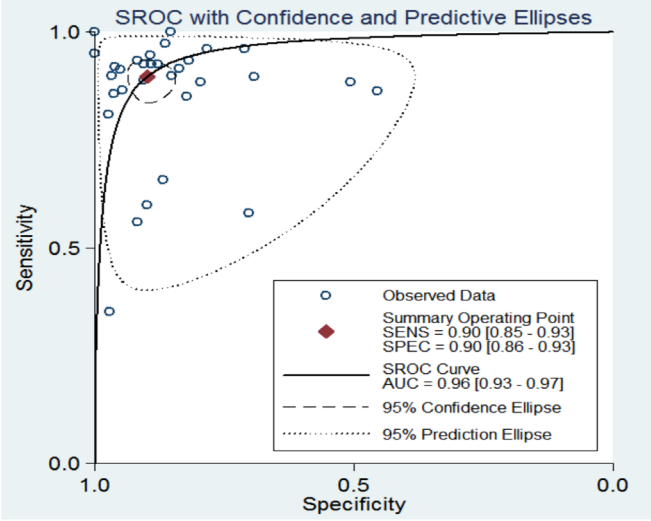
EVs, esophageal varices; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; DOR, diagnosis odds ratio; AUC, area under the curve; 95% CIs, corresponding 95% confidence interval.




**Supplementary Figure 1.** Risk bias and applicability concerns of QUDADS 2 assessment in summary (a) and graph (b).




**Supplementary Figure 2.** Summary receiver operating characteristics (SROC) curves of computed tomography (CT) for diagnosing gastroesophageal varices with CT.




**Supplementary Figure 3.** Summary receiver operating characteristics (SROC) curves of computed tomography (CT) for predicting high-risk varices with CT.


**Supplementary Figure 4.** Deeks' funnel plot for evaluation of publication bias of studies.