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RESEARCH

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Computed tomography predictors of gastroesophageal varices in cirrhotic patients: the added value of portosystemic collaterals

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Abstract

Background Detection of 'spontaneous' portosystemic collateral veins (PSCV) serves as an important tool in diagnosing portal hypertension (PTHN) and predicting prognosis. Multidetector computed tomography (MDCT) imaging is noninvasive and allows accurate assessment of variceal site and size. So, this study was conducted to assess the role of MDCT in predicting, detecting and grading gastroesophageal varices in correlation with endoscopy in cirrhotic patients in relation to other portosystemic collaterals.

Methods Analytical cross-sectional prospective study was conducted on 100 cirrhotic patients. All patients were subjected to history taking, upper gastrointestinal endoscopic assessment, and triphasic CT or contrast-enhanced CT assessment of abdomen and pelvis.

Results Patients who had esophageal varices in MDCT show a statistically significant difference ($p=0.016$) with its endoscopic grading. There was good agreement between endoscopy and MDCT in diagnosing grade of esophageal varices as $k=0.882$. The presence of ascites, splenic size, and esophageal vein diameter serve as clinically significant predictors of esophageal varices. Splenic size showed a significant difference according to endoscopic grades of EV (esophageal varices) as $p=0.031$ as patients with no varices had splenic size of (15.9 ± 1.4) cm, patients with grade I had a mean splenic size of (15.2 ± 8.7) cm, patients with grade II had mean splenic size of (16.9 ± 1.8) cm and patients with grade III had mean splenic size of (18 ± 4.2) cm, while other veins diameters showed increase with advanced grades of EV but with statistically insignificant differences as $p>0.05$.

Conclusions Multidetector CT features of the presence of PSCVs, splenic size, and ascites are accurate predictors of PTHN in either EVs presence or absence. MDCT can be an excellent alternative for patients who are contraindicated for endoscopy. Moreover, it can be potential screening tool for early detection of esophageal varices in very early stage of chronic liver disease and in the early care of patient with varices. MDCT remains the most applicable noninvasive diagnostic tool for patients with portosystemic collaterals.

Keywords Cirrhosis, Computed tomography, Multidetector, Portosystemic shunt, Esophageal and gastric varices

Background

One of the main effects of liver cirrhosis is portal hypertension (PHTN), which is portosystemic resistance and increased blood flow through the portal venous system combine to cause it [1]. A large network of portosystemic collateral vessels is created when this high-pressure hepatopetal flow is diverted through alternate channels

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into the low-pressure systemic veins called portosystemic collateral veins (PSCV).

The identification of these "spontaneous" portosystemic collateral veins is a crucial step for diagnosis and prognosis of PHTN [2–5].

Accordance with current recommendations, an upper endoscopy should be used to stratify patients' risk of variceal bleeding. Endoscopy and mild sedation can come with expenses and dangers, especially for individuals with cirrhosis. However, risk stratification should take into account risks, rewards, and costs in addition to identifying high-risk people [6].

Esophagogastroduodenoscopy is now the preferred procedure for determining the existence and size of varices (EGD). The requirement for intravenous sedation and the comparatively expensive cost of EGD are its drawbacks [7].

The study of the liver using multidetector computed tomography (MDCT) angiography has grown in effectiveness. By illustrating these tortuous veins pathways, a portal-phase acquisition added to three-dimensional vascular reconstructions might improve the surgeon's view of potentially troublesome varices. This information is crucial for both large surgeries like liver transplants and more routine ones where unanticipated varix might cause serious bleeding [8].

Only one study has made a correlation between MDCT results and the paraumbilical vein [9], while other studies have used the radiological index model to predict PHTN, hemorrhage [10]. The majority of previous studies assess the value of MDCT in evaluation of esophageal varices and correlate the results with the endoscopic findings.

This study was aiming to discuss the role of MDCT in the assessment of gastroesophageal varices in correlation with upper GI endoscopy grading in cirrhotic patients, and other MDCT predictors in the light of other portosystemic collaterals.

Methods

Patients

An analytical cross-sectional prospective cohort study was conducted on 100 cirrhotic patients, who were sampled randomly over a period of two years from August 2019 to August 2021. The age of the patients ranged from 15 to 75 years with a mean age of 60.6 ± 10.6 years. In this study, 72% of the patients were males. The patients were confirmed to have chronic liver disease with liver cirrhosis based on previous ultrasound assessments and laboratory investigations that were reviewed by the referring internal medicine specialist in our institution or the referral institution. These patients were attending the CT unit in our institution to undergo triphasic CT or contrast-enhanced CT assessment of the abdomen and pelvis, as well as upper endoscopy assessment. Informed consent was taken from all patients or caregivers before taking any data or doing any investigations. The research was approved by the Faculty of Medicine, Suez Canal University Health Research Ethics Board (number 4312). It follows The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Inclusion criteria

(1) Patients with evidence of portal hypertension and liver cirrhosis (clinical, laboratory and previous imaging either by ultrasound or CT assessment) [7], (2) upper GI endoscopy performed within 20 days after CT assessment, either in case of routine screening or surveillance or prompted by a clinical question of gastrointestinal bleeding based on history.

Exclusion criteria

(1) Contraindications to contrast: renal impairment (not on dialysis), (2) hypersensitivity to the intravascular contrast agent, (3) a previous history of upper GI endoscopy with intervention, (band ligation or sclerotherapy), (4) pregnancy, (5) patients with previous transjugular intrahepatic portosystemic shunt (TIPS).

Methods

All patients were subjected to the followings:

History taking

A full clinical assessment should be performed, including recording the patient's age, sex, family history, and clinical presentation (symptoms and signs suggests chronic liver disease) [11]. For patients diagnosed with portal hypertension, the history should also include any history of Schistosoma infection and anti-Schistosoma treatment, as well as a history of viral hepatitis, which may be a potential cause of PHTN). The reasons for performing upper GI endoscopy and MDCT assessment should also be documented.

Upper GI endoscopy

All patients underwent an endoscopy of the upper GIT by an endoscopic specialist (has minimum 5 years of experience) within 20 days of MDCT at our institution The median interval between performing CT and endoscopy is about 1 week (4 to 10 days interquartile range).

These patients were identified by cross-referencing records for the stated period from the radiology information system, which contains the database of all triphasic liver CT studies, with the hospital information system, which contains the database of all upper endoscopies.

The grading system used for esophageal varices grading based on some combination of visual assessment of column size and tortuosity, color, degree of luminal protrusion, and confluence is called the Paquet grading system [12].

Each endoscopist, at his or her description, graded any varices either descriptively from small to giant or on a scale ranging from I to IV. For this study, each case will be grouped into one of four grades:

In addition, the presence of mucosal red signs (i.e., red wale, hemocystic, or cherry red spots) on endoscopy [9].

MDCT examination

CT imaging was performed using 16 slice scanner, Activion 16 model TSX-031A-2012 with standard accessories (Toshiba Medical Systems).

Patient preparation Patients were asked for fasting for 6 to 8 h and asked to continue adequate simple water intake up to 3 h before the examination to ensure adequate hydration. Patients were told how to hold their breath during the examination when requested.

MDCT technique and image acquisition.

a. The patient had been made to lie supine. Scanning started from the carina down to the symphysis pubis in plain, portovenous and delayed phases and from the dome of the liver to the lower border of the liver in the arterial phase.
b. One scout was acquired in an anteroposterior view. The examination was planned on this scout from above the carina to ensure full coverage of the lower part of the esophagus until the symphysis pubis.
c. The pre-contrast series were taken at 10 mm thickness, at a slice pitch of 1.5, a gantry rotation period of 0.6 s, and a table speed of 15 mm/ rotation. The X-ray tube voltage was 120 kV, and the current was 240–280 mA.
d. An intravenous administration of iodine contrast media at a concentration of 350 mg/mL is carried out using an automatic injector. The volume of contrast media given (100–140 mL) depends on the patient's weight, and the flow rate is 3 mL/s. The acquisition of arterial dominant-phase images is done 18 s after injection, using a collimation of 1.25 mm, a pitch of 0.6, a voltage of 120 kVp, and a current of 240–280 mA. Then, portal dominant-phase images were acquired at 60 s (collimation 2.5 mm; pitch 0.6; voltage 120 kVp; current 240–280 mA) and delayed-phase images were also taken of the entire liver at 200 s (collimation 2.5 mm; pitch 0.6; voltage 120 kVp; current 240–280 mA) [10].
e. In the case of contrast-enhanced CT assessment of the abdomen and pelvis, the acquisition was done as before in scout, plain, and portovenous phases without performing arterial or delayed phases of triphasic assessment.

Post-processing It was performed using a pre-installed post-processing application/ software. Three-dimensional (3D), multiplanar reconstruction (MPR), and maximum intensity projection (MIP) post-processed images were performed, and a vascular map demonstrating the different collateral pathways was created in each patient.

Image analysis A single senior radiologist (Reader 1) at the center where the patients were treated, who had 10 years of experience in hepatobiliary and pancreatic diseases, evaluated all the CT examinations. In order to avoid recall bias and assess intra-observer variability, the same radiologist (Reader 1) re-evaluated all radiological examinations 8 months after the initial interpretation. Additionally, In order to determine inter-observer variability, a second radiologist (Reader 2) with 8 years of experience in liver imaging, who was employed at the same university hospital as (Reader 1), reviewed all CT examinations. (Reader 2) evaluated the scans separately and blindly, with the aim of obtaining inter-observer agreement.

The followings were assessed Abdominal organs (liver: size, signs of chronic liver disease, hepatic focal lesion (HFL)—Spleen: size and focal lesion), portal, splenic, superior mesenteric, and inferior mesenteric veins diameter, ascitic collection and Portosystemic collaterals: Common collateral pathways: [Esophageal, paraesophageal and (peri) esophageal, Gastric, paragastric and (peri) gastric, Pararectal and (peri)rectal, Recanalized paraumbilical vein and abdominal wall collaterals, Splenorenal and gastro-spleno-renal, Retroperitoneal collaterals], ectopic collaterals, atypical (uncommon) collateral pathways. Portosystemic collaterals were assessed and graded according to the grading of portosystemic collaterals by MDCT as in Table 1 [13].

Statistical analysis

The collected data were organized, tabulated, and statistically analyzed using the statistical package for social science (SPSS), version 24 (SPSS Inc. USA), running on an IBM-compatible computer. Quantitative data were represented as mean and standard deviation (SD). Test of normality Shapiro–Wilks test was used to examine the distribution of data. Comparisons between groups were

Table 1 Esophageal varices are graded by CT according to the followings:

Varices	The largest diameter of varices (mm)
Esophageal, paraesophageal, and gastric submucosal varices	
Grade	
0	< 2
1	2–2.9
2	3–6.9
3	≥ 7
4[a]	≥ 7
Gastric adventitial, splenic, mesenteric, retroperitoneal varices	
Grade	
0	< 3
1	3–4.9
2	5–9.9
3	≥ 10
4[a]	≥ 10

If the number of dilated 4[a] vessels on transverse images is more than 4, the grade of varices increases one step higher

Grade 4 was assigned when the number of grade 3 varices exceeded 4

made by student samples (t) test or Chi-square test for quantitative and qualitative data respectively. A p value less than or equal to 0.05 was considered statistically significant.

Results

This cross-sectional study included 100 cirrhotic patients, with a mean age of 60.6 ± 10.6 years, ranging from 15 to 75 years. The majority of the patients were males (72%).

The detection and measurement of varices were evaluated separately for both intra-observer and inter-observer agreements. The results showed that Reader 1 had an almost perfect intra-observer agreement ($K = 0.846$, $p \leq 0.001$) in detecting and measuring varices. The inter-observer agreement between two radiologists, Reader 1 and Reader 2, who had varying levels of experience but worked in the same hospital, was also excellent and significant ($K = 0.92$, $p \leq 0.001$), ($\kappa = 1$).

Out of the total patients, 86% were positive for HCV, while 14% were negative. Among the participants, 54% had esophageal varices (EV), while 46% did not. Among those with EV, 30% had grade I, 14% had grade II, and 10% had grade III.

Out of the total patients, 76% did not have ascites, while 24% had ascites. Among those with ascites, 2% had minimal ascites, 8% had mild ascites, 4% had moderate ascites, and 10% had marked ascites. Table 2 illustrates the range of splenic size, esophageal and paraesophageal varices as well as main portal and splenic veins in comparison with normal ranges.

Table 2 Results of MDCT assessment of the size of varices of the study patients ($N = 100$)

	Normal range	$N = 100$
Splenic size (cm)	9–13	16.7 ± 4.0
Esophageal varices (mm)	0	4.5 ± 2.1
Paraesophageal varices (mm)	0	5.01 ± 3.3
Main PV (mm)	10–13	14.5 ± 3.1
SV (mm)	7–10	11.8 ± 4.2

PV portal vein, *SV* splenic vein

The percentage of CT grades of common collateral veins among the examined patients. The most common varices were the hilar splenic varices of grade II, perisplenic varices of grade I, and retrogastric/adventitial varices of grade I, all were about 50% of cases. However, the least common varices to be found were the retroperitoneal varices, they were absent in about 94% of patients as described in Table 3.

The study evoked good agreement between endoscopy and MDCT in diagnosing the grade of esophageal varices as $k = 0.882$, as shown in Table 4.

Also, the group of patients with EV had a significantly higher association with the specific collaterals than the group of patients with no esophageal varices, collaterals like paraesophageal, submucosal, retrogastric, left gastric, hilar, perisplenic, mesenteric and coronary varices show as the p value was < 0.05 in as detailed in Table 5.

Although both endoscopy and MDCT showed that 46 cases did not have esophageal varices, multiple other hidden varices were found in those cases as revealed in Figs. 1, 2, 3 and 4.

Multidetector CT assessment revealed additional varices in the following locations: gastrorenal shunt (2 cases), lienorenal (2 cases) which were tortuous and had a diameter of 12 mm, pelvic-gastrorenal shunt G2-splenorenal shunt G4 (2 cases), periduodenal/gall bladder/choledochal varices (plexus of Saint) (2 cases), perirectal (2 cases) with one being mild, paraovarian (2 cases), right supradiaphragmatic, left hepatic shunt (2 cases), transverse colonic varices (2 cases), left supradiaphragmatic (4 cases) and left supradiaphragmatic/lateral lower abdominal wall varices (2 cases). It was observed that there was a statistically significant difference in value between the endoscopic grade of EV and ascites; however, no statistically significant difference in values was found with the other baseline data, as shown in Table 6.

Table 3 Results of MDCT triphasic assessment of common collateral varices

	CT grade				
	0	I	II	III	IV
Esophageal varices	38 (38%)	20 (20%)	30 (30%)	10 (10%)	2 (2%)
Paraesophageal varices	34 (34%)	14 (14%)	26 (26%)	8 (8%)	18 (18%)
Submucosal varices	72 (72%)	14 (14%)	12 (12%)	2 (2%)	0 (0%)
Retrogastric/adventitial varices	20 (20%)	50 (50%)	22 (22%)	4 (4%)	4 (4%)
Left gastric varices	10 (10%)	26 (26%)	36 (36%)	6 (6%)	22 (22%)
Hilar varices	6 (6%)	34 (34%)	50 (50%)	4 (4%)	6 (6%)
Perisplenic varices	20 (20%)	50 (50%)	22 (22%)	4 (4%)	4 (4%)
Retroperitoneal varices	94 (94%)	0 (0%)	0 (0%)	2 (2%)	4 (4%)
Periportal varices	88 (88%)	8 (8%)	4 (4%)	0 (0%)	0 (0%)
Mesenteric varices	22 (22%)	26 (26%)	50 (50%)	2 (2%)	0 (0%)

Table 4 Results of MDCT versus endoscopic assessment of EV of the study patients ($N=100$)

	Endoscopic grades				*K*
	0	I	II	III	
MDCT grades					
0	34	2	2	0	0.882
	73.9%	6.7%	14.3%	0.0%	
I	8	10	2	0	
	17.4%	33.3%	14.3%	0.0%	
II	4	18	8	0	
	8.7%	60.0%	57.1%	0.0%	
III	0	0	2	8	
	0.0%	0.0%	14.3%	80.0%	
IV	0	0	0	2	
	0.0%	0.0%	0.0%	20.0%	

Table 5 Results of MDCT assessment of porto systemic collaterals in EV of the study patients ($N=100$)

	Total $n=100$	No EV $n=46$	EV $n=54$	*p* value
Paraesophageal varices	66 (66%)	12 (12%)	54 (54%)	< 0.001*
Submucosal varices	28 (28%)	7 (7%)	21 (21%)	< 0.001*
Retrogastric/adventitial varices	80 (80%)	26 (26%)	54 (54%)	< 0.001*
Left gastric varices	90 (90%)	36 (36%)	54 (54%)	0.026*
Hilar varices	94 (94%)	40 (40%)	54 (54%)	0.033*
Perisplenic varices	80 (80%)	30 (30%)	50 (50%)	< 0.001*
Retroperitoneal varices	6 (10%)	2 (2%)	4 (4%)	0.982
Periportal varices	12 (92%)	6 (6%)	6 (6%)	1.00
Mesenteric varices	78 (98%)	24 (24%)	54 (54%)	< 0.001*
Coronary varices	60 (60%)	22 (22%)	38 (38%)	0.047*
Lienorenal shunt	48 (48%)	20 (60%)	28 (60%)	0.620
PUV	18 (18%)	8 (8%)	10 (10%)	0.982
Right ant abdominal wall collateral	6 (6%)	2 (2%)	4 (4%)	0.982
Paraumbilical and right abdominal wall collaterals	18 (18%)	8 (8%)	10 (10%)	0.620

[a] The Chi-square test was used

PUV paraumbilical varices

*Statistically significant as $p<0.05$

Regarding the comparison between the endoscopic grade of esophageal varices and splenic size, portal vein, splenic vein, esophageal and paraesophageal varices diameters, as follows: the splenic size showed a significant difference in grades of EV. On the other hand, great vein diameter showed an increase with advanced grades of EV but with statistically insignificant differences. Esophageal varices are the only vein that showed a statistically significant difference with the esophageal varices endoscopic grade, which is a logical relationship between the endoscopic and the MDCT assessment results as shown in Table 7.

The regression model revealed that the presence of ascites, splenic size, and esophageal vein size detected by MDCT are direct significant predictors for EV (p value < 0.001) as shown in Table 8.

Also, it was reported that there was a significant direct correlation between splenic vein diameter and splenic size as shown in Fig. 5.

Additionally, the study aimed to investigate other MDCT predictors in relation to portosystemic collaterals, shown in Fig. 6.

Even, both endoscopy and MDCT did not reveal esophageal varices in 46 patients, clinically significant varices may remain undetected as shown in Figs. 7 and

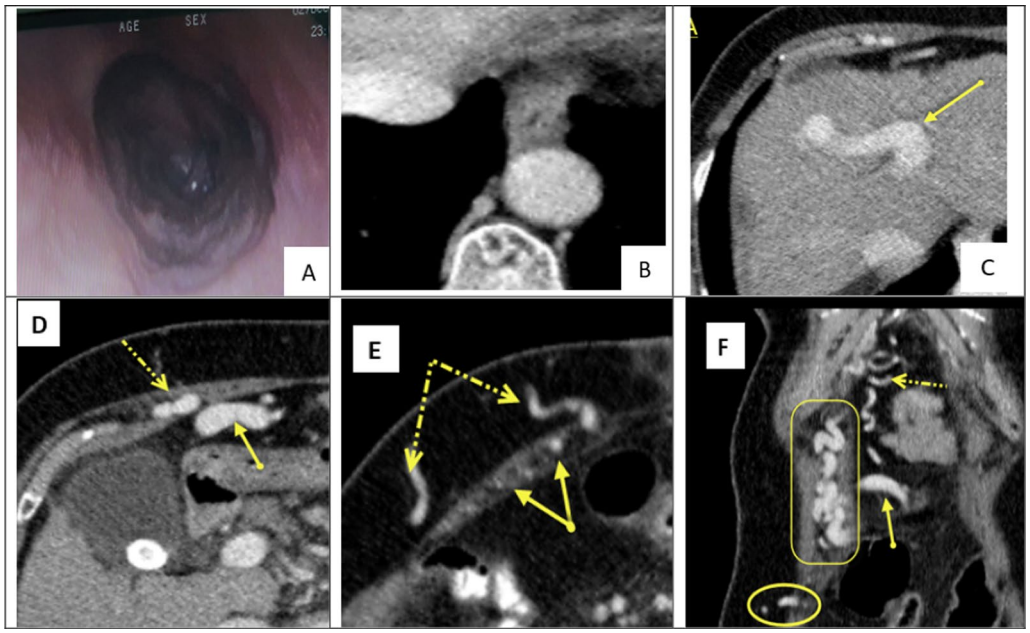

Fig. 1 A 66-year-old male patient with chronic liver disease. To evaluate the patient's hepatofugal flow, a triphasic MDCT scan was performed in addition to US scanning. Upper GI endoscopy was also performed to screen for esophageal varices. **A** Upper gastrointestinal (GI) endoscopy and **B** axial computed tomography (CT) both demonstrated the absence of esophageal varices. Also, axial CT revealed; **C**, **D** left hepatic shunt (solid arrow), right rectus intramuscular varices (dashed arrow), **E** right rectus intramuscular varices (solid arrow), as well as subcutaneous varices (dashed arrow). **F** Coronal CT demonstrated a right hepatic shunt (solid arrow), a paraumbilical vein (dashed arrow), right rectus intramuscular varices (rectangular region), and subcutaneous varices (round region)

8. These varices may have advanced grades that are beyond the detection capabilities of endoscopy.

As shown in Fig. 9, the patient's endoscopy indicated the presence of grade I and II cords of esophageal varices. However, MDCT scans showed the presence of paraesophageal varices, dilated tortuous splenic vein, and perisplenic varices. Additionally, we identified other dilated PSCV and shunts, such as the left and right hepatic shunts, which combine to form the paraumbilical vein. The left shunt also penetrates the right rectus abdominis muscle, resulting in intramuscular varices.

Discussion

The study of the collateral network has many important implications in clinical practice. From a therapeutic point of view, the presence of portosystemic collaterals is a specific feature of clinically significant PHTN, which might become an indication to start treatment with nonselective beta-blockers in compensated patients [14].

The risk of variceal bleeding can be lowered for big esophageal varices from 50 to 15%, according to several studies; hence, early detection of gastroesophageal varices before the commencement of the first bleed is strongly advised [15].

(See figure on next page.)

Fig. 2 A 53-year-old female patient complaining of chronic liver disease and HFL. Upper GI endoscopy was done for variceal scanning and triphasic MDCT scan was done for HFL scanning. **A** Upper gastrointestinal (GI) endoscopy demonstrates two cords of esophageal varices grade II (solid arrows). Axial (CT) shows the following; **B** two esophageal varices of grade II (solid arrow), **C** paraesophageal varices grade I (arrows), **D** dilated, tortuous splenic vein (arrow), **E** Hilar perisplenic collaterals. **F** Anterior pole perisplenic collaterals. **G** Coronal CT shows splenomegaly (splenic LS diameter = 22 cm. Axial CT shows the following; **H**, **I** dilated and tortuous right hepatic shunt (solid arrow), a left hepatic shunt (dashed arrow), and right rectus abdominus muscle penetrated with dilated, tortuous varices (oval area), **J**, **K** right hepatic shunt (solid arrow), paraumbilical vein (dashed arrow), and right intrarectal muscle varices (oval region). **L** Coronal CT demonstrates right intra-rectus muscle varices (solid arrow), and a paraumbilical vein (dashed arrow). **M** Axial CT shows an enhanced hepatic focal lesion noted in the arterial phase

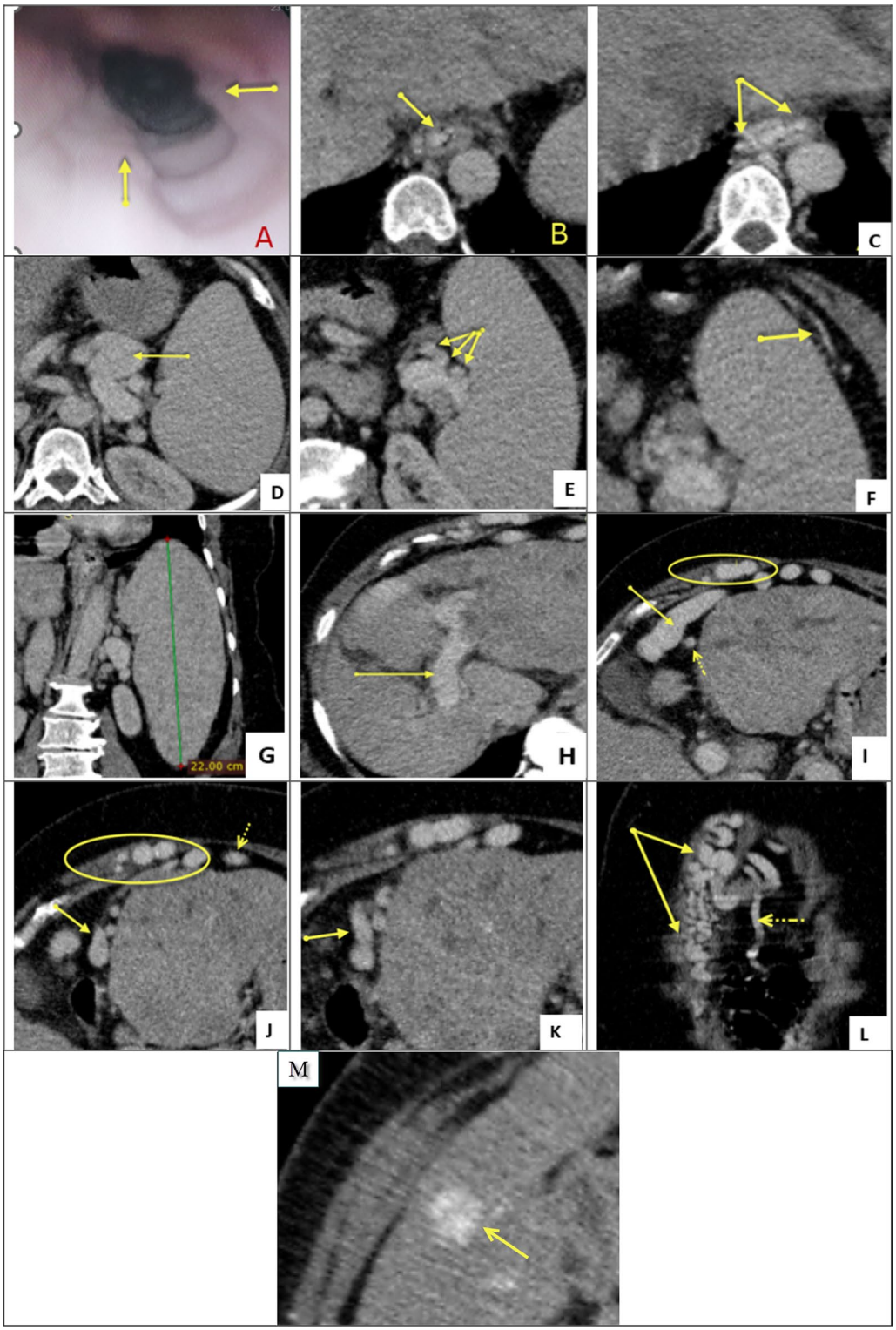

Fig. 2 (See legend on previous page.)

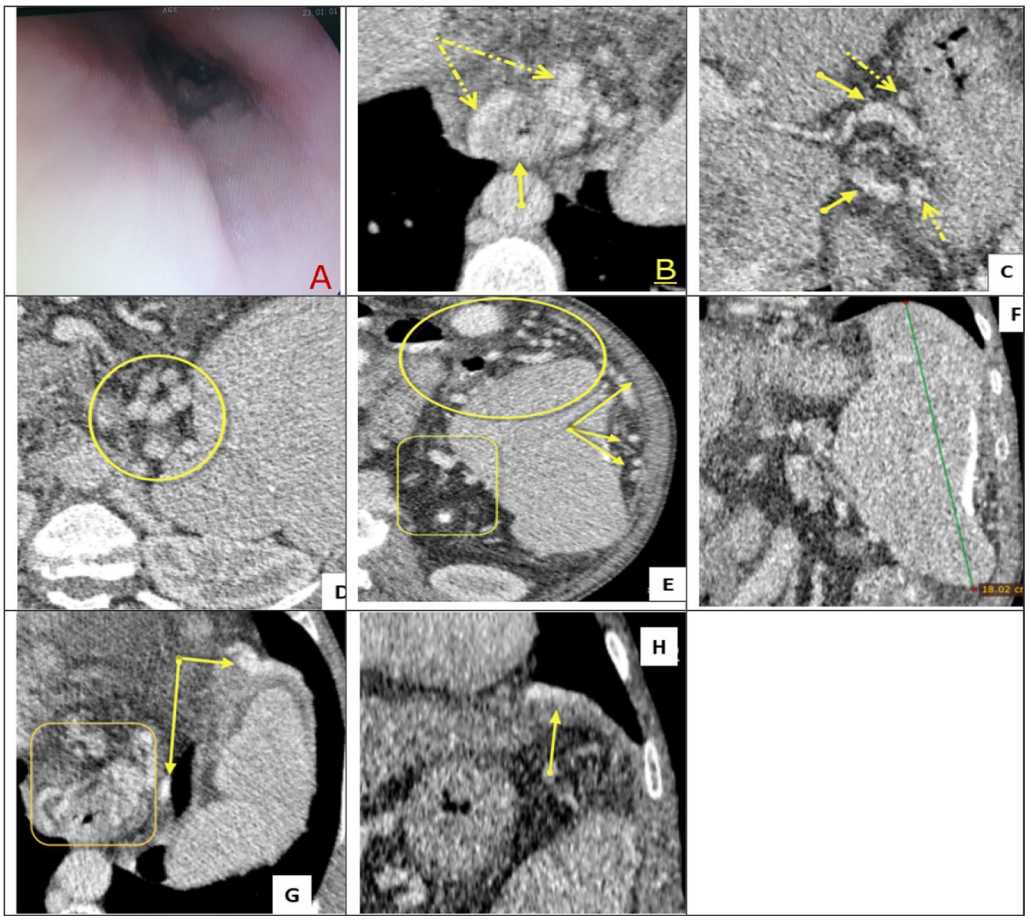

Fig. 3 A 66-year-old male patient complained of chronic liver disease complicated by esophageal varices on follow-up with upper GI endoscopy. **A** Upper GI endoscopy shows obliterated esophageal varices. Axial CT shows; **B** no esophageal (obliterated) varices (solid arrow) but large tortuous paraesophageal varices (dashed arrows), **C** dilated tortuous left gastric (coronary) varices (solid arrow) and perigastric (adventitial) varices (dashed arrow), **D** perisplenic (hilar) collaterals (round region), **E** perisplenic collaterals with anterior border (round region), lateral border (solid arrows), and hilar (rectangular region). Coronal CT shows; **F** enlarged LS diameter of the spleen 18 cm. **G** Axial CT shows left supradiaphragmatic varices (solid arrows) and paraesophageal varices (rectangular region). **H** Coronal CT shows left supradiaphragmatic varices (solid arrow)

The objective of this study was to explore the utility of MDCT in evaluating gastroesophageal varices in cirrhotic patients and to examine the correlation between MDCT grading and upper GI endoscopy grading of esophageal and gastric varices. Additionally, the study aimed to investigate other MDCT predictors in relation to portosystemic collaterals.

Among the selected population, 86% of the examined individuals were positive for HCV, while the remaining 14% received negative test results. Regarding ascites status, 76% of the patients were ascites-free, while 2% had minimal ascites, 8% had mild ascites, 4% had moderate ascites, and 10% had marked ascites. Accordingly, hepatitis C is a significant contributor to liver cirrhosis, which is consistent with the Dessouky et al. [16] study's finding that hepatitis C was the most frequent cause of liver cirrhosis (68%).

The level of agreement between Reader 1 and Reader 2, two experienced radiologists with 10 and 8 years of experience respectively, was almost perfect ($K=0.92$, $p \leq 0.001$), indicating a high level of inter-observer agreement. Intra-observer agreement was also strong, as ($K=0.846$, $p \leq 0.001$), demonstrating the proposed CT protocol's excellent results in detecting and measuring esophageal varices.

During our investigation, we found a high level of agreement between endoscopy and MDCT in grading esophageal varices, with $k=0.882$. Our study showed

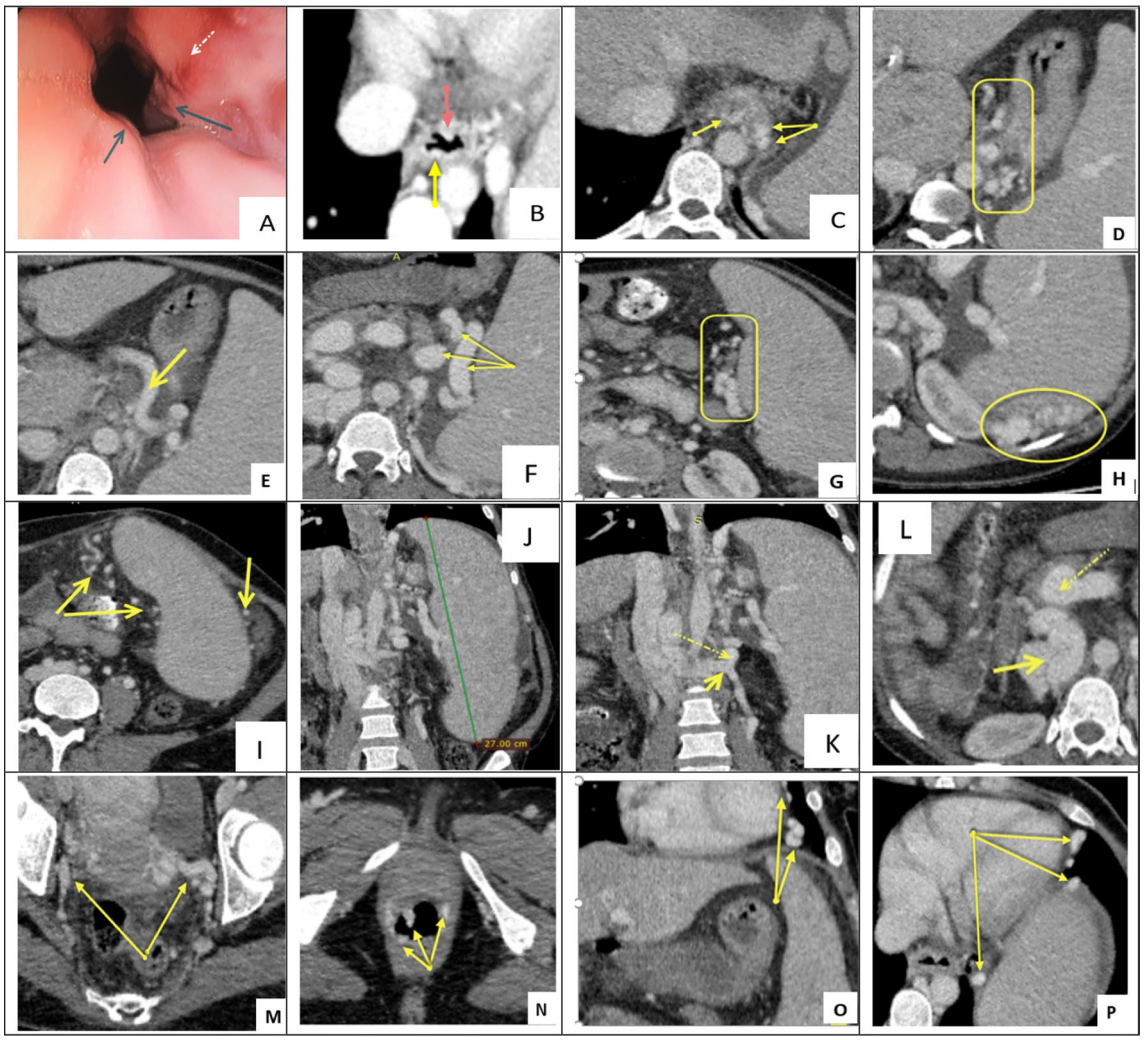

Fig. 4 A 42-year-old female patient with chronic liver disease and esophageal varices; **A** Upper GI endoscopy shows 2 cords of grade 2 (arrows) with a red cherry spot (dashed arrow). Axial CT shows the following; **B** esophageal varices; upper arrow for grade II and lower arrow for grade I, **C** paraesophageal varices (solid arrows), **D** retrogastric (adventitial) varices, (rectangular region), **E** left gastric (coronary) vein (solid arrow), **F** dilated tortuous splenic vein (solid arrows), **G** Hilar splenic varices (rectangular region), **H** perisplenic (posterior border) varices, **I** Perisplenic collaterals in a lower pole. Coronal CT displays the following; **J** Large splenic LS diameter measuring 27 cm, **K** A lienorenal shunt (dashed arrow) and left renal vein (solid arrow). Axial CT shows, **L** Retroperitoneal (right pararenal) (solid arrow) and portal vein (dashed arrow) varices, **M** Paraovarian and pelvic varices (solid arrows), **N** perirectal varices (solid arrows). **O**, **P** Left supradiaphragmatic varices are visible in a coronal CT (**O**) and axial CT (**P**)

that MDCT in detection of EV were 100% sensitivity, 82.6% specificity, 87.1% accuracy, PPV and NPV were 100% and 92%, respectively. These findings are consistent with another study by ElKammash et al. [17], which reported that multidetector CT has high levels of sensitivity, specificity, accuracy, and positive and negative predictive values. For radiologist A, the sensitivity, specificity, accuracy, PPV, and NPV were 94.8%, 98.5%, 97.8%, 94.8%, and 98.5%, respectively, while for radiologist B, the values were 99.4%, 99.6%, 99.6%, 99.3%, and 99.7%, respectively.

Additionally, we observed good agreement in identifying and grading esophageal varices between upper GIT endoscopy and other methods. Our investigation also revealed that multidetector CT performed well with a sensitivity of 85% and specificity of 75%, consistent with the findings reported by Perri et al. [18].

Table 6 Baseline data of the study patients according to endoscopic grades ($N=100$)

	Endoscopy grades				*p* value
	0 $n=46$	I $n=30$	II $n=14$	III $n=10$	
Age (years)	63.6 ± 6.4	56.7 ± 10.1	57.9 ± 9.9	64.3 ± 8.8	0.165[a]
Gender (*n*, %)					
Female	21 (44.4%)	5 (25%)	2 (2%)	0 (0%)	0.810[b]
Male	25 (55.6%)	25 (75%)	12 (12%)	10 (100%)	
Presence of HCV	36 (72.2%)	26 (88%)	14 (100%)	10 (100%)	0.230[b]
Presence of ascites	0 (0%)	4 (12%)	10 (100%)	10 (100%)	0.029*[b]

HCV Hepatitis C virus

[a] ANOVA test used

[b] The Chi-square test was used

*Statistically significant as $p<0.05$

According to the study by Dessouky et al. [16], upper GIT endoscopy has an overall sensitivity of 99% and specificity of 98% for CT.

When predicting the EV in endoscopy by MDCT interpretation, Salahshour et al. [19] found 63.49% sensitivity, 81.97% specificity, and 72.58% accuracy.

Many studies agreed with ours that CT scanning is a dependable method for identifying large esophageal varices, with a specificity ranging from 90 to 100% and a sensitivity ranging from 84 to 100% [20, 21], despite a moderate degree of variability between observers. Additionally, CT has demonstrated effectiveness in the detection of gastric varices [22].

To the best of our knowledge, a limited number of previous studies had comprehensively investigated the influences of the presence or size of different collaterals, as well as the size of different effective varices in the presence of EVs.

Table 8 Regression model of MDCT and clinical findings for predicting the EV ($N=100$)

	Exp (B)	95% CI	*p* value
Ascites	1.89	1.1–2.9	**0.02**
Splenic size	4.36	2.3–7.9	**< 0.001**
Esophageal varices size	7.42	3.2–19.23	**< 0.001**

Statistically significant as $p < 0.05$ values are shown in bold

Different types of collateral varices are developed in cirrhotic individuals with PHTN. These varices redirect blood flow, which lowers portal pressure, but they ultimately result in increased blood flow, which may not lower the risk of bleeding. The link between the incidence of EVs and the existence and magnitude of varices and collaterals, particularly on the PUV, has been the subject of continuous discussion [23].

The study of the collateral network has numerous critical implications in clinical practice. From a therapeutic standpoint, the presence of PSCV is a distinctive feature of clinically significant PHTN, which could be an indication to commence treatment with nonselective beta-blockers in compensated patients [14]. Additionally, there is mounting evidence supporting embolization's role in preventing variceal rebleeding [24], reducing portal pressure [25], treating gastric varices [26], or other PHTN related complications [27, 28]. From a prognostic perspective, the presence and characteristics of shunts predicts the development of decompensation, including ascites and variceal bleeding, as well as survival in cirrhotic patients, making them highly informative in the context of liver transplantation [29–31]. Furthermore, the combination of PSCV presence with other portal hypertension features in a simple score can be a helpful tool for clinicians in daily clinical practice.

Table 7 Comparison of MDCT results with endoscopic results of the study patients ($N=100$)

	Endoscopy grades				*p* value
	0 $n=46$	I $n=30$	II $n=14$	III $n=10$	
Splenic size (cm)	15.9 ± 1.4	15.2 ± 8.7	16.9 ± 1.8	18 ± 4.2	0.031*[a]
Portal vein (mm)	14.1 ± 2.6	14.6 ± 4.1	15.1 ± 3.5	15.7 ± 2.5	0.904[a]
Splenic Vein (mm)	11 ± 2.6	12.1 ± 4.7	12.7 ± 4.2	12.9 ± 5.5	0.841[a]
Esophageal varices (mm)	3.1 ± 0.9	3.9 ± 1.2	5.9 ± 1.2	6.1 ± 3.7	0.016*[a]
Paraesophageal varices (mm)	63.6 ± 6.4	3.5 ± 1.6	6 ± 2.1	7.2 ± 2.2	0.253[a]

[a] ANOVA test was used

*Statistically significant as $p<0.05$

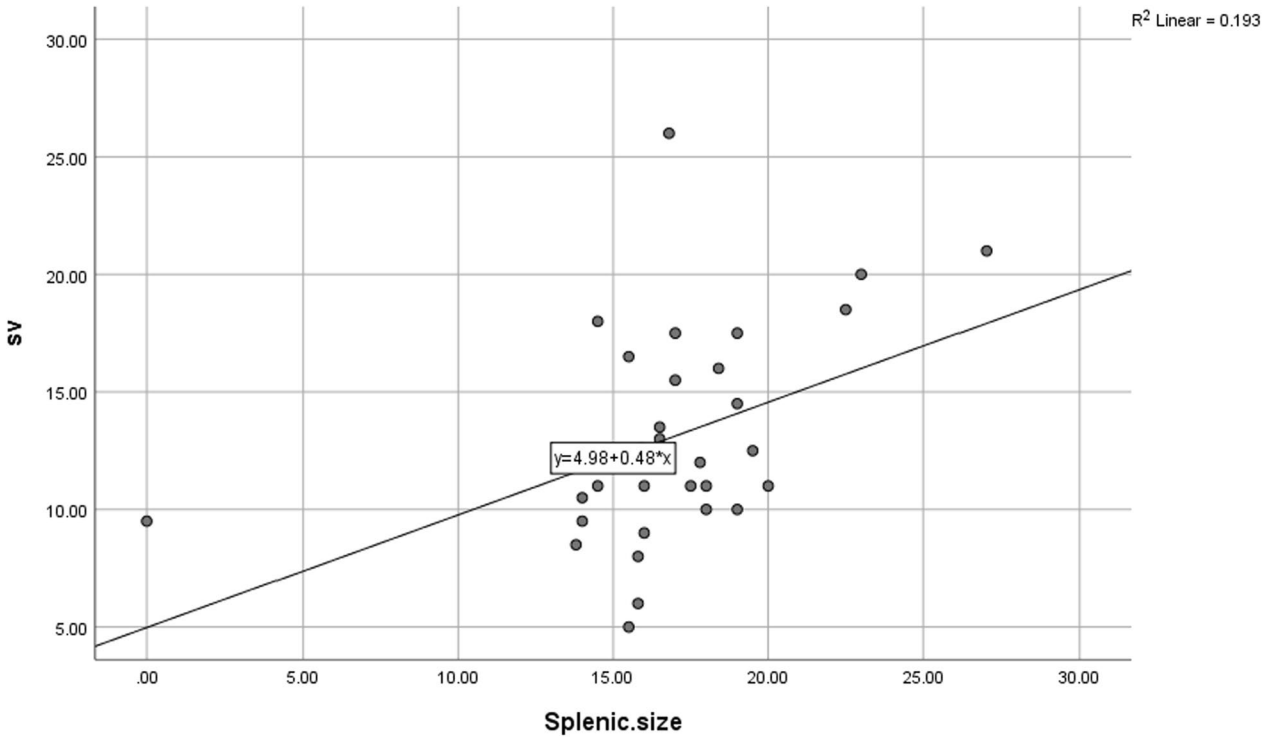

Fig. 5 Correlation between SV and splenic size

A prior investigation by Calame et al. [32] demonstrated the paraumbilical vein's (PUV) protective impact on EVs and found that a larger PUV is substantially related with a decreased incidence of EV hemorrhage. While this was going on, Kondo et al. [33] revealed contrary findings and the beneficial effects of PUV on EVs.

In our study, we found no significant association between EVs and PUV size**.** Along the same line, several previous studies reported no significant association between EVs and PUV patency or size [34].

According to our research, splenic size significantly increased as EV grade climbed. Previous research has demonstrated larger spleen size and volume in individuals with EVs, which is consistent with our findings [35].

Even, both endoscopy and MDCT did not reveal esophageal varices in 46 patients or in cases of obliterated EV. However, it is important to note that even after endoscopic obliteration of EV, clinically significant varices may remain undetected. These varices may have advanced grades that are beyond the detection capabilities of endoscopy.

Several more concealed varices were discovered in those cases as follows: 12 percent had paraesophageal varices, 7 percent had submucosal gastric varices, 26 percent had retrogastric (adventitial) varices, 36 percent had left gastric varices, 40 percent had hilar (splenic) varices, 30 percent had perisplenic varices, 2 percent had retroperitoneal varices, 6 percent had periportal varices, 24 percent had mesenteric varices, 22 percent had coronary varices.

The predictive role of MDCT in relation to the presence and absence of esophageal varices, which could be detected with both endoscopy and MDCT. In our study, the group of patients with esophageal varices had a significantly higher association with specific portosystemic collaterals than the group of patients without esophageal varices. These collaterals include paraesophageal, submucosal, retrogastric, left gastric, mesenteric, and coronary, hilar, and perisplenic varices, as the p value was < 0.05. Therefore, esophageal varices could be a good predictor of the presence of other clinically significant portosystemic collaterals.

Calame et al. [32] research suggested that PUV size, ascites, and spleen size could be used as a predictive model for EVs. The study investigated various traits, such as PUV size and existence, expanded and tortuous left stomach vein, spleen size, ascites, and others. On the other hand, Yang et al. [36] found that perigastric and

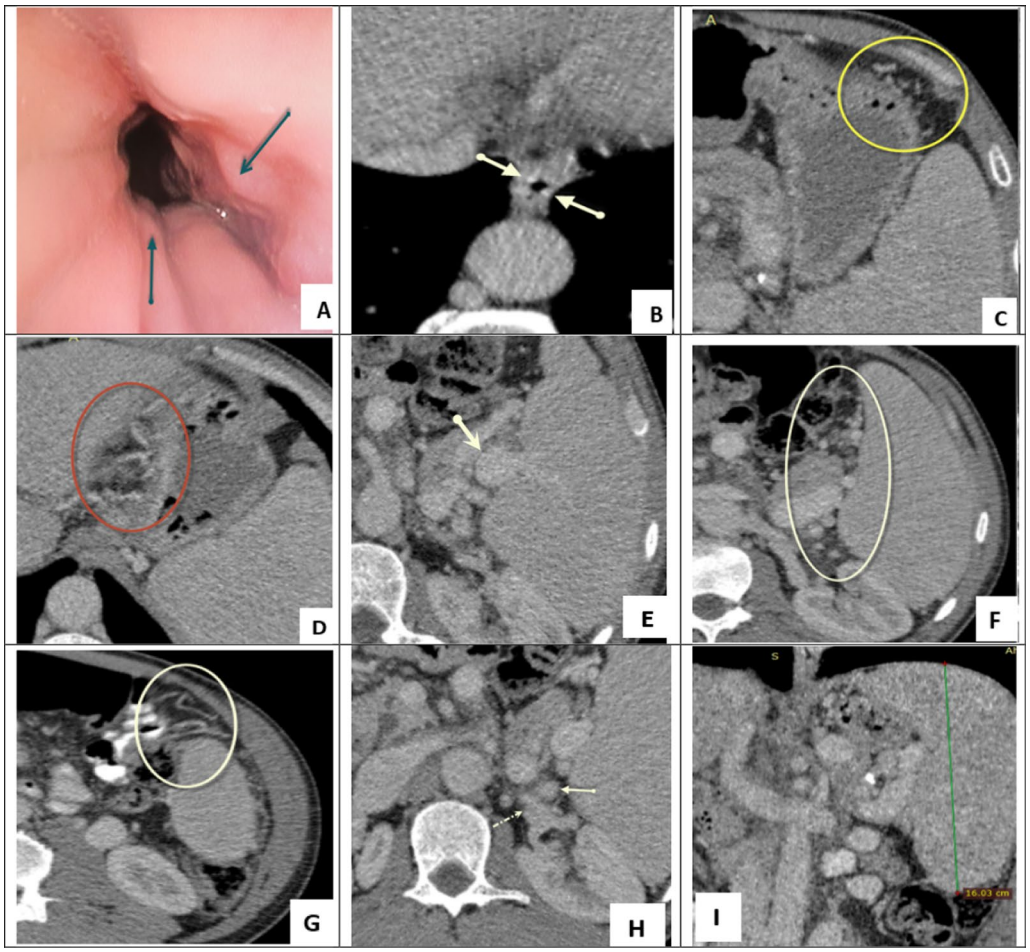

Fig. 6 A 55-year-old male patient with chronic liver disease and esophageal varices: **A** Upper GI endoscopy reveals 2 cords grade I (solid arrows). Axial CT shows the following; **B** 2 cords grade I (solid arrows), **C**, **D** Retrogastric (adventitial varices), **E** dilated and tortuous splenic vein (solid arrow), **F** hilar splenic varices (oval region). **G** Lower pole perisplenic varices (oval region). **H** Lienorenal shunt (solid arrow), left renal vein (dashed arrow). **I** Coronal CT demonstrates mild enlargement of the LS diameter of the spleen to 16 cm

paraesophageal varices were the most reliable indicators of the presence of EVs. Salahashour et al. [19] discovered that high-risk EVs were significantly associated with the presence of short gastric collateral veins (present and size > 2.5 mm) and major coronary vein size > 3.5 mm in MDCT studies of cirrhotic individuals.

However, we found that the presence of ascites, splenic size, and esophageal vein size are direct significant predictors for EV.

Based on our study, we were able to identify several varices, including abdominal wall varices and supradiaphragmatic varices, which have been reported as rare in some literature.

Specifically, we observed three cases of abdominal wall varices. In two cases, the patient's endoscopy indicated the presence of grade I and II cords of esophageal varices, while there were no varices seen in the other case**.** However, MDCT scans showed the presence of paraesophageal varices, dilated tortuous splenic vein, and perisplenic varices. Additionally, we identified other dilated PSCV and shunts, such as the left and right hepatic shunts, which combine to form the paraumbilical vein. The left shunt also penetrates the right rectus abdominis muscle, resulting in intramuscular varices.

It was discovered that there were six patients who had left supradiaphragmatic varices**.** Right supradiaphragmatic varices with left hepatic shunt were found in two cases, one of them as follows: Despite the negative matched result of upper GI endoscopy and MDCT scan of the absence of esophageal varices, the MDCT showed

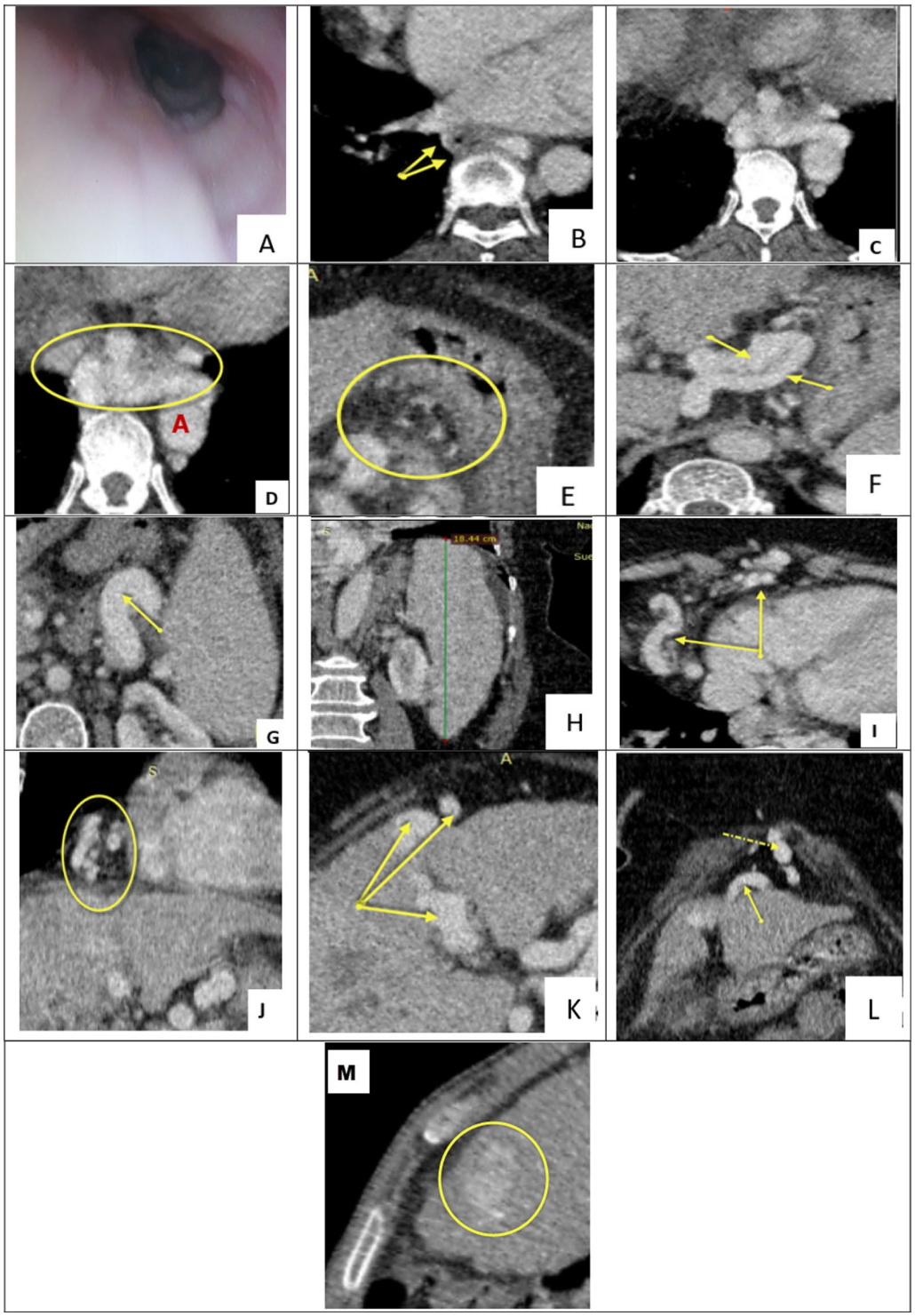

Fig. 7 A 60-year-old female patient with chronic liver disease and esophageal varices on follow-up after esophageal varices band ligation. Upper GI endoscopy was done for variceal scanning, and triphasic MDCT scan was done for HFL scanning. **A** Upper GI endoscopy shows obliterated varices. Axial CT shows the following; **B** no esophageal varices (solid arrow), **C**, **D** dilated paraesophageal varices grade IV (oval region); letter A denotes Aorta, **E** retrogastric (adventitial) varices (round region), **F**, **G** markedly dilated and tortuous both left gastric (coronary) varix (solid arrows)in **F**, and splenic vein in **G**, **H** heterogeneous enhancing lesion in the right lobe of the liver, suggestive of a HFL lesion. Both **I**, **J** show right dilated, tortuous cardiophrenic varices, where appeared in Axial CT in figure (**I**) (solid arrows), and in Coronal CT in figure (**J**) (oval region). **K** Axial CT shows left hepatic shunt (arrow), **L** Coronal CT shows left hepatic shunt (solid arrow), ascending left supradiaphragmatic varix piercing the left diaphragm to reach the chest (dashed arrow). **M** Axial CT shows enhanced hepatic focal lesion appeared in arterial phase (round region)

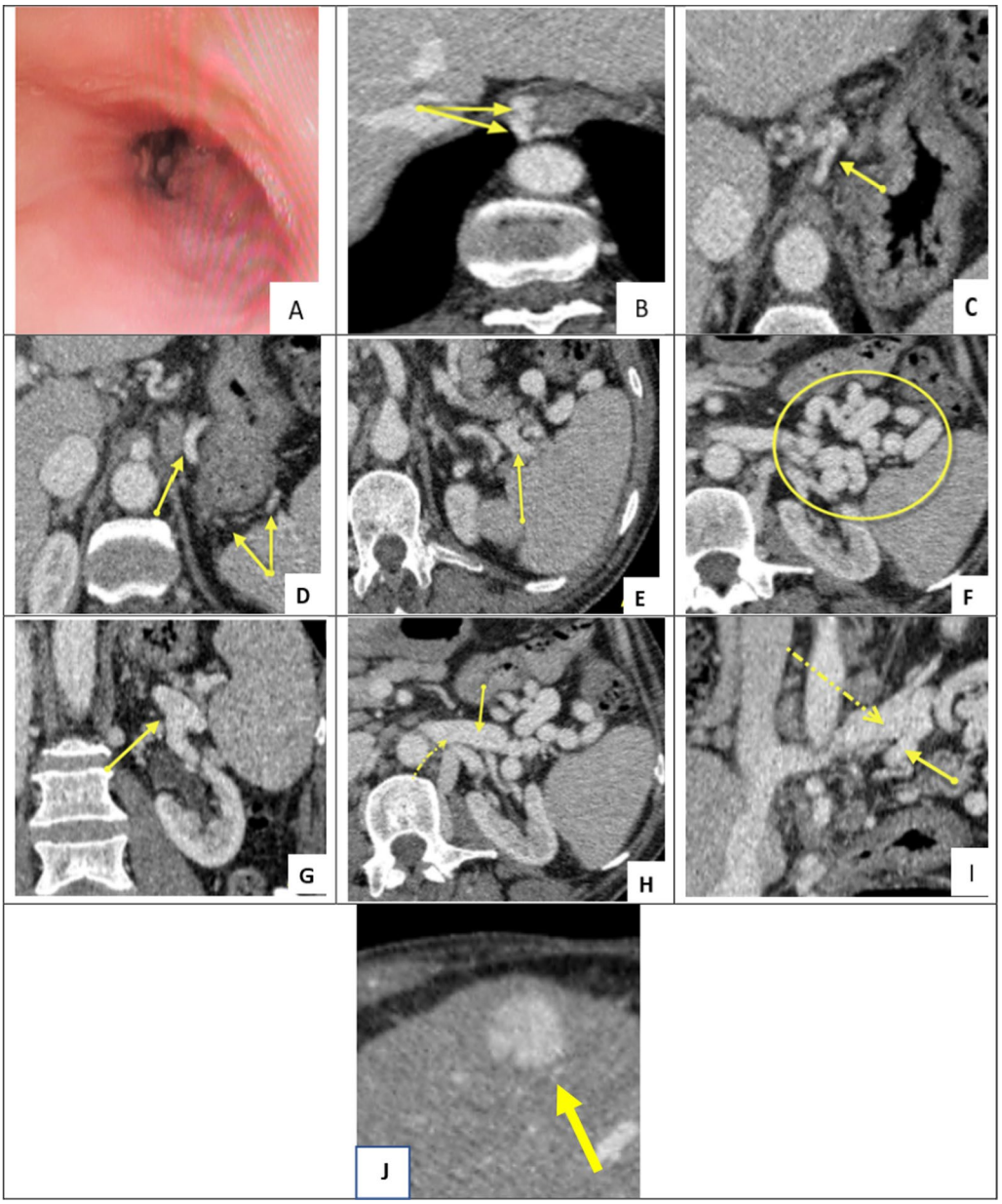

Fig. 8 A 69-year-old male patient performed Upper GI endoscopy and triphasic MDCT scanning for chronic liver disease and HFL to identify varices and HFL scanning. **A** Upper GI endoscopy shows no esophageal varices. Axial CT shows; **B** multiple paraesophageal varices (solid arrows), **C** left gastric (coronary) varix (solid arrow), **D** retrogastric (adventitial) varices (solid arrows), **E**, **F** normal splenic vein diameter (solid arrow), dilated and tortuous lienorenal shunt (round mark). **G** Coronal CT shows a lienorenal shunt (solid arrow). **H** Axial CT of the lienorenal shunt (solid arrow) and the left renal vein (dashed arrow). **I** Coronal CT shows a gastrorenal shunt (solid arrow) and the left renal vein (dashed arrow). **J** Axial CT shows a hepatic focal lesion with rapid enhancement in the arterial phase

advanced grade (IV) of paraesophageal varices, retrogastric, dilated, tortuous grade IV left gastric varix, dilated tortuous splenic vein, the markedly dilated splenic vein accompanied with enlarged LS of the splenic length measuring about 18.5 cm, dilated tortuous right cardiophrenic varices which is an afferent from the left hepatic shunt as the left hepatic shunt arises to the right supradiaphragmatic region to form the right supradiaphragmatic varix.

Currently, numerous studies [37–40] employ a cross-sectional design and concentrate on diagnosing PHTN or esophageal varices in individuals with cirrhosis. However,

only a limited number of studies have examined the predictive capacity of PHTN characteristics detected through CT scans [41, 42]. In our study, we not only assessed the role of MDCT in describing different types of PSCV, but also evaluated other predictors of ascites and splenic size. We found that these factors have a significant correlation with esophageal varices. Additionally, MDCT can identify other clinically significant varices, such as retroperitoneal, coronary, and cardiophrenic varices, which may not be detectable by other imaging modalities.

The suggested models for high-risk EVs can be clinically significant as radiologists are expected to report the presence and size of the mentioned collaterals (including coronary, short gastric, paraesophageal, and paraesophageal draining collateral) with significant correlation with high-risk EVs in their everyday practice, especially in cirrhotic patients not receiving prophylactic treatments. Therefore, to avoid further mortal complications, our two suggested models with acceptable accuracy can help clinicians provide high-risk patients with prophylactic measures.

Deng et al. [43] study concluded that MDCT in cirrhotic patients provided an opportunity for dual screening and evaluation strategy of two crucial pathological conditions, which are HCC and esophageal Varices, without any added cost, effort, time, or risk of radiation. Considering the high cost of performing multiple tests and the relative invasiveness of upper GI endoscopy, a single noninvasive surveillance tool for Varices may be important. These factors constitute a major advantage of MDCT over upper GI endoscopy.

During our study, we encountered several limitations that are important to note. Firstly, the cross-sectional design of the study may have led to selection bias, which could have impacted the accuracy and generalizability of our findings. Additionally, we had a relatively small sample size, which may have limited the statistical power of our study and reduced the precision of our estimates. Therefore, caution should be exercised when interpreting our results. Finally, our study highlights the need for larger multicenter investigations to confirm our findings and provide more robust evidence on this topic. By addressing these limitations and conducting more rigorous studies in the future, we can improve our understanding of the phenomenon under investigation and inform clinical practice and policy.

Conclusions

Multidetector CT features, including various collaterals such as paraesophageal, submucosal, retrogastric, left gastric, hilar, perisplenic, mesenteric, and coronary varices, can accurately predict the presence of esophageal varices and PHTN. MDCT can serve as a surrogate for upper GIT endoscopy in diagnosing and assessing EVs, especially in cirrhotic patients. Daily abdominal contrast-enhanced MDCT reports should address these collaterals. MDCT can also be used as an alternative diagnostic tool for patients contraindicated for endoscopy and for early screening of esophageal varices in chronic liver disease. It remains the most suitable

(See figure on next page.)

Fig. 9 A 53-year-old male patient with chronic liver disease underwent upper GI endoscopy and Triphasic MDCT scanning was done for HFL. **A** Upper GI endoscopy showed one esophageal varix grade II (dashed arrow) and three esophageal varices grade I (straight arrow). **B** Axial CT showed one esophageal varix grade II (dashed arrow) and three esophageal varices grade I (solid arrows). **C** Upper GI endoscopy showed hypertensive gastropathy. Axial CT showed the following; **D** submucosal varices grade I (round region), **E** dilated splenic vein (double-headed arrow) and perisplenic collaterals, **F** hilar perisplenic collaterals (marked region), **G** posterior border perisplenic collaterals (round region). Coronal CT shows the following; **H** Lower pole perisplenic collaterals (rectangular region), **I** enlarged LS diameter of the spleen 17.1 cm, **J** Lienorenal shunt (dashed arrow) and left renal vein (solid arrow).Axial CT demonstrates the following; **K** right internal oblique and transversus abdominal muscles pierced by varices (oval region), retroperitoneal varices passed from the right intramuscular varices anterior to the right quadratus lumborum muscle to enter posterior to the right psoas muscle (solid arrow), and subcutaneous lumbar varices (dashed arrow). **L** Right lateral rectus muscle pierced with intramuscular varices (oval region), right internal oblique and right transversus lumborum muscles pierced with intramuscular varices (rectangular region), right retroperitoneal varix (dashed arrow), and paraumbilical vein (solid arrow).Coronal CT shows the following; **M** right retroperitoneal varix passing anterior to the right quadratus lumborum muscle to pass posterior to the right psoas muscle (solid arrow), **N** posterior border perisplenic collateral veins (oval region), right and left intramuscular internal oblique and transversus abdominus varices, more prominent in the right side (rectangular region), right supradiaphragmatic varix (solid arrow), and left retroperitoneal varix (dashed arrows) passing anterior to the left quadratus lumborum and medially posterior to the left rectus abdominus muscle, **O** left supradiaphragmatic varix arising to the left supradiaphragmatic region (solid arrows). **P** Axial CT showed the left supradiaphragmatic varix passing above the left copula of the diaphragm. **Q** Sagittal CT showed the right intramuscular varices traversing through the lateral abdominal muscles (solid arrows). **R** Coronal CT showed the supradiaphragmatic posterior mediastinal varices (rectangular region). **S** Axial CT showed a hypovascular irregular HFL lesion in the arterial phase of the right hepatic lobe (oval region)

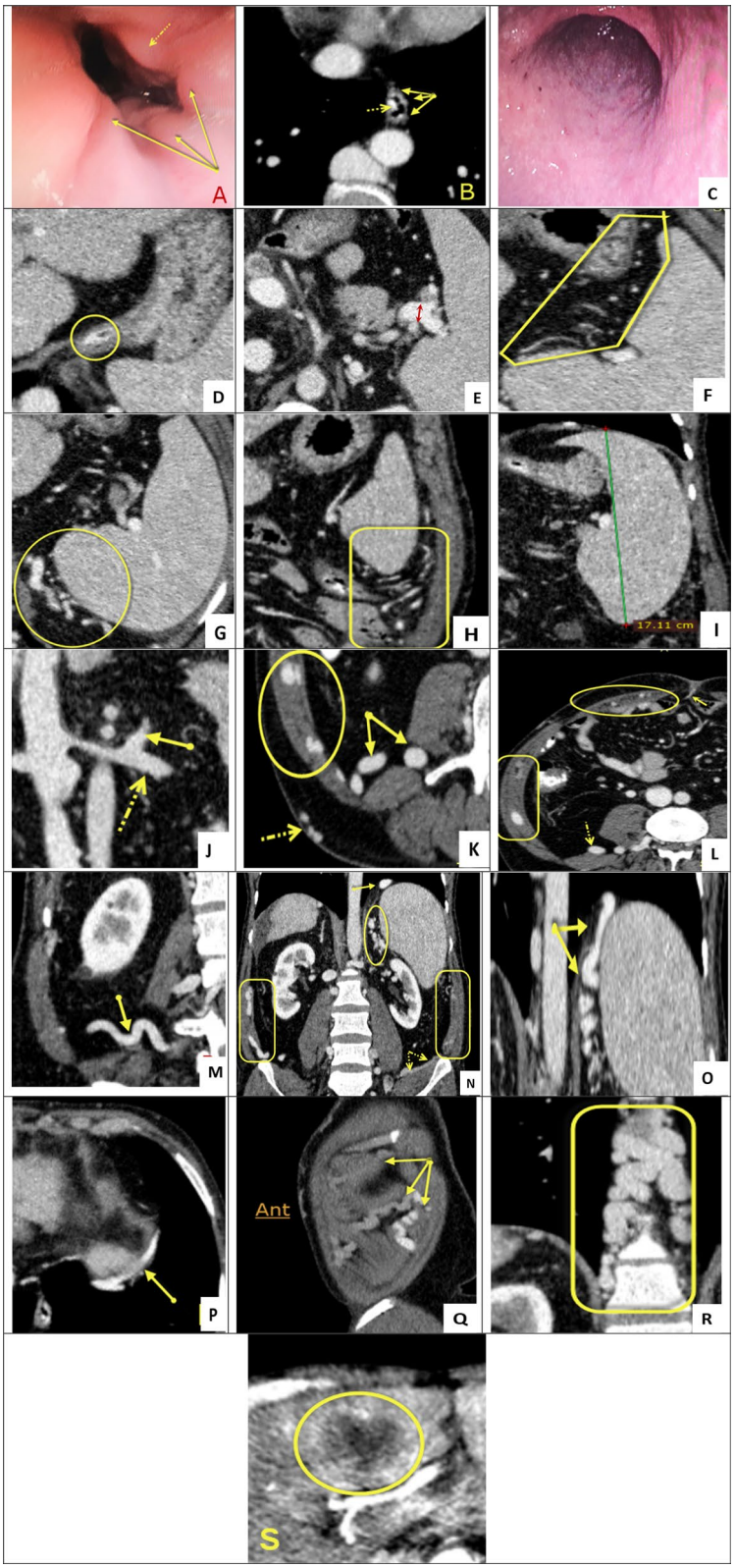

Fig. 9 (See legend on previous page.)

noninvasive diagnostic tool for patients with portosystemic collaterals.

Abbreviations

EV	Esophageal varices
PUV	Paraumbilical varices
MDCT	Multidetector computed tomography
PSCV	Portosystemic collateral veins
PTHN	Portal hypertension
HCV	Hepatitis C virus

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Author contributions
HR: Formulation of the study, preparation of methodology, data collection, analysis of the data, and writing the paper. All authors have read and approved the manuscript.

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Availability of data and materials
The dataset used and/or analyzed during the current study is available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
It was approved by the local institutional ethics committee (Committee of Scientific Research Ethics (CSRE), Suez Canal University, Egypt); written informed consent was obtained from all patients. The reference number is not applicable and/or not available.

Consent for publication
Consent for publication was obtained from the patients and controls.

Competing interests
The authors declare that they have no competing interests.

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