

RESEARCH

Open Access



# Assessment of variceal bleeding in cirrhotic patients: accuracy of multi-detector computed tomography

Marwa Samy<sup>1</sup>, Doaa Gamal<sup>1</sup>, Mostafa H. M. Othman<sup>1</sup> and Shimaa Abdalla Ahmed<sup>2\*</sup> 

## Abstract

**Background:** Esophageal variceal hemorrhage (EVH) has been shown to be a leading cause of mortality in patients with portal hypertension. Our purpose was to assess the utility of multi-detector computed tomography (MDCT) features in the assessment of esophageal varices (EVs) and esophageal variceal hemorrhage (EVH). This prospective study included 85 cirrhotic patients who underwent MDCT and Upper Gastrointestinal Tract (UGIT) endoscopy within 2 weeks. Four radiologists evaluated the presence of EVs and the presence and size of different collaterals. Multivariable logistic regression analysis was calculated to investigate the significant predictors influencing EV and EVH.

**Results:** Findings of EV with MDCT were the best predictor of EV or EVH. The presence (and/or size) of following collaterals had significant association with both EV and EVH: paraesophageal ( $p < 0.001$ ,  $< 0.001$ ), short gastric ( $p = 0.024$ ,  $0.010$ ), gastric varicosities ( $p < 0.001$ ,  $< 0.001$ ), coronary ( $p < 0.001$ ,  $< 0.001$ ), and main coronary vein (MCV) ( $p < 0.001$ ,  $= 0.011$ ). We proposed an imaging-based model (presence of coronary collaterals, main coronary vein size  $> 3.5$  mm, presence of short gastric collaterals, presence of gastric varicosities, size  $> 1.5$  mm) with 97% sensitivity, 91% specificity, and 94% accuracy to predict EVs. We suggested another model (presence of paraesophageal collaterals, presence of short gastric vein (SGC), SGC size  $> 2.5$  mm, main coronary vein size  $> 3.5$  mm, gastric varicosities size  $> 1.5$  mm, size of EVs  $> 4$  mm, and Child C score) to predict EVH with 98% sensitivity, 81% specificity, and 89.5% accuracy. Inter-observer agreement was high in the detection of EVs (W. Kappa = 0.71–0.88).

**Conclusion:** MDCT is an effective modality in the diagnosis of EVs. At MDCT, the presence and/or size of various collaterals including para-esophageal, short gastric, coronary collaterals, and gastric varicosities are accurate predictors for either EVs existence or EVH. We suggested two computed tomography imaging-based models with high reproducibility and acceptable accuracy for the prediction of EV and EVH. With cirrhotic patients, we recommend that radiologists report collaterals in their daily practice.

**Keywords:** Liver cirrhosis, Portography, Multidetector computed tomography, Esophageal and gastric varices

## Background

The incidence, prevalence, and mortality from liver cirrhosis increased in the last decades and had a considerable impact on health care systems [1–3]. Liver cirrhosis was often associated with a series of

complications including esophageal varices (EVs). In cirrhotic patients, the prevalence of EVs has been reported as high as 80–90%. EVs have high bleeding risk with a rate of 10–30% per year. Esophageal variceal hemorrhage (EVH) has been shown to be a leading cause of mortality in those patients [4–6].

Upper gastrointestinal tract (UGIT) endoscopy is the gold standard for the diagnosis of EVs [5]. However, it is an invasive procedure, relatively expensive, poorly tolerated by patients and has potential complications

\*Correspondence: shimaabdalla@aun.edu.eg

<sup>2</sup> Department of Diagnostic Radiology, South Egypt Cancer Institute, Assiut University, Assiut, Egypt

Full list of author information is available at the end of the article

(including perforation and reaction to sedation) [4, 6]. The American Association for the study of liver diseases (AASLD) recommends screening UGIT for detecting EVs when the diagnosis of cirrhosis is made. When an early diagnosis of high-risk EVs is made, patients should receive prophylactic medication (B-blockers) or minimally invasive preventive therapy (EV ligation or sclerotherapy) [7, 8] to decrease further complications of EVs.

Early detection of EVs and prediction of EVH have been more noted due to increased morbidity and mortality rate and debilitating consequences on the healthcare system [9, 10]. Several studies have investigated the use of inexpensive, noninvasive, and accurate alternatives for UGIT endoscopy [11–20]. Several modalities have been investigated as an alternative for UGIT endoscopy including liver and spleen stiffness measurement [11–13], ultrasound parameters [14, 15], serum markers [16, 17], MDCT [18–20], and MRI [20]. Several studies assessed the predictive parameters for EVH in cirrhotic patients due to higher mortality compared to other causes of upper GIT bleeding [21, 22].

Given that previous studies have a retrospective design, addressed some limited collaterals, and the confounding effect of systemic and visceral veins has not been investigated, we designed this prospective study to assess MDCT variables associated with EVs and EVH as a potential surrogate for UGIT endoscopy. Also, we aimed to introduce an accurate predictive model for the early detection of EVs and EVH.

## Methods

This prospective study was conducted between May 2017 and Aug 2020. Consecutive patients with liver cirrhosis and portal hypertension who underwent MDCT and UGIT endoscopy within 2 weeks were included. Patients were referred from inpatients of the hepatology department Assiut university and diagnosed based on the medical history, clinical features, laboratory findings, imaging, and/or and liver biopsy.

Exclusion criteria were: (a) Patients with a history of endoscopic variceal ligation (b) patients with a long time interval between MDCT and UGIT endoscopy > 2 weeks, and (c) history of liver tumors. Eighty-five patients met the inclusion criteria. The medical ethical committee of our hospital approved this prospective study (IRB: 17100414), and written informed consent was obtained from all participants in the study.

### CT technique

#### Image acquisition

CT data were obtained using a 64-slice CT scanner (Somatom Definition AS, Siemens Medical, Forchheim, Germany). All patients received a dose of 150 mL

of intravenous contrast material (iopromide; Ultravist 300, Schering). It was injected using an automatic injector (Medrad Stellant injector, Indianola PA, USA), with a rate of 3.0 mL/s. MDCT of the abdomen was performed including the non-contrast phase (to demonstrate calcification and compare the pattern of enhancement), the hepatic arterial phase (20–30 s), the portal venous phase (50–60 s; delayed 5–8 s for cirrhosis patients), and the balance phase (120–180 s). The imaging parameters were: section thickness 2–3 mm; beam collimation 0.6–2 mm; tube voltage 120 Peak kilovoltage (kVp), tube current 150–250 Milliampere-seconds (mAs), and gantry rotation time 0.5–0.75 s.

Images were transferred to Siemens workstation, and multiplanar reformation (MPR) images were obtained for further evaluation and analysis.

### Image analysis

All CT examinations were independently analyzed by four radiologists with 9, 11, 13, and 15 years of experience in abdominal imaging. Readers were blinded to the endoscopy results. The following features were evaluated: (1) EV was reported if there are enhancing dots and linear structures seen within the esophageal wall or protruding into the esophageal lumen [6]. (2) The size of EV was measured as the maximum diameter of EVs at the axial images, then it was classified into three categories (1st category < 2 mm, 2nd category 2–4 mm, and 3rd category > 4 mm), (3) diameters of the main portal vein (MPV), intrahepatic right portal vein (IHRPV), intrahepatic left portal vein (IHLPV), splenic vein (SV), left gastric vein (LGV), and main coronary vein (MCV) were measured. The diameter of MPV was measured at the middle point of the portal vein and 2 cm before the point where SPV entered the portal vein, respectively. The diameter of LGV was measured at the widest point within the 2-cm-range before the point where LGV entered the portal vein, while the diameters of IHLPV and IHRPV were measured at the points that were 1.0–1.5 cm away from MPV. Para-umbilical vein (PUV) drains from the left PV and communicates with the subcutaneous veins at the anterior abdominal wall. (4) existence and size of the following collaterals: (a) para esophageal collaterals: seen around the distal thoracic esophagus, (b) coronary collaterals: it drains the lesser gastric curvature to PV or SV near the PV confluence, (c) short gastric collaterals: it drains from the gastric fundus to the SV, (d) para-umbilical collaterals, (e) perisplenic collaterals: seen around the spleen, (f) splenorenal collaterals: connection between SV and the left renal vein, and (g) varices of the gastric fundus, (h) omental collaterals: seen at the greater omentum, (5) Size of the spleen (splenomegaly was defined as the spleen size > 130 mm), (6) Presence of ascites. Three

measurements were obtained for each item, and average measurement was used for statistical analysis.

### Upper GIT endoscopy

All endoscopies were performed by two expert gastroenterologists with 11, 8 years of experience in upper GIT endoscopy. Endoscopic grading of EV was reported as following: EV extended beyond the mucosal level (grade I), EV protruded up to 1/3 luminal diameter, separated by normal mucosa, and not flattened by insufflation (grade II), EV projected by ½ of the luminal diameter, not flattened by insufflation (grade III) [23]. The presence of a red sign was also reported according to the Japanese description [24]. The low-risk group was defined as (no EV and grade I EV without red sign), and then compared with the high-risk group (Grade II, III, and grade I + red sign or Child–Pugh class C) [25]. The mean time between CT and endoscopy was  $2 \pm 0.5$  weeks (median, 1.2 weeks).

EVH had to be proven by upper GI endoscopy. Upper GIT bleeding due to esophagitis, Mallory-Weiss syndrome, and ulcers were not considered as EVH.

### Statistical analysis

Descriptive statistics: Means, standard deviations, medians, interquartile ranges (IQR), frequencies, and percentages were calculated. Test of significances: Chi-square test was used to compare the difference in the distribution of frequencies among different groups. Student *t*-test/Mann–Whitney *U* test was used to test the mean/median differences in continuous variables between groups (parametric and non-parametric). Multivariable logistic regression analysis was conducted to investigate the significant predictors influencing EVH (Odds Ratio—OR 95% confidence interval 95% CI and *p* value). ROC curve was depicted to test the diagnostic performance of the different correlates of EVH, analyzed as the area under the curve (AUC), standard error (SE), and 95% CI. Validity statistics (sensitivity, specificity, positive and negative predictive value, and Youden's *J*) were calculated. Fleiss' kappa was calculated to assess the reliability of agreement between raters. Kappa characteristics of each observer were compared with the median of the other observers. Significant test results were considered when the *p* value was  $< 0.05$ .

Statistical analyses were performed using the Statistical Package for Social Sciences (IBM-SPSS/PC/VER 24). *p* value  $< 0.05$  was considered statistically significant.

### Results

Table 1 shows the baseline data of patients with or without EV or EVH. A total of 85 patients were involved in this study. The mean age was  $53.82 \pm 8.9$  years. Of them,

30 (35.3%) were females, and 55 (64.7%) were males. Etiologies of liver cirrhosis were: 61 (71.8%) HCV, 15 (17.6%) HBV, 4 (0.05%) Budd–Chiari syndrome, 3 (0.04%) cryptogenic, and 2 (0.02%) others.

Out of 85 patients, EVs were confirmed by endoscopy in 78 (91.8%) [33 (38.8%) grade I, 25 (29.4%) grade II, and 20 (23.5%) grade III]. Forty-two (49.4%) patients experienced EVH.

According to upper GIT endoscopy, EVs were classified into low and high-risk categories. Thirty-eight (44.7%) had low-risk EVs [7 (8.2% had no EV, 31 (36.5%) had grade I without red sign], and 47 (55.3%) had high-risk EVs [2 (2.4%) grade I with red sign, 25 (29.4%) grade II, and 20 (23.5%) grade III].

At MDCT, high-risk EVs were detected in 39 (45.9%). Of them, 8 had low-risk EVs (3 no EV and 5 grade I without red sign). Of 47 high-risk EVs at endoscopy, 6 were not detected by CT (of which 4 were grade II and 2 were grade III). CT had sensitivity 81.1% (95% CI 80.40–83.22), specificity 89% (82.62–90.64), PPV 87% (80.54–88.12), NPV 83.5% (80.32–86.38), and accuracy 85% (79.81–85) in predicting EVs.

Regarding EVs, data analysis of CT revealed significant associations between endoscopic confirmed EVs and the presence of visible EVs, paraesophageal collaterals, short gastric collaterals, gastric varicosities, coronary collaterals (*p* values  $< 0.001$ ,  $< 0.001$ ,  $= 0.024$ ,  $< 0.001$ , and  $< 0.001$ , respectively), and the size of gastric varicosities, MCV (*p* values  $= 0.004$ , and  $< 0.001$ , respectively) (Table 1).

On binary logistic regression analysis (Table 2), the following factors were found to be independently associated with EVs: the presence of short gastric, coronary collaterals (OR 1.128–6.808, 3.827–23.447,  $p = 0.026$ ,  $< 0.001$ , respectively), the presence and size of gastric varicosities (OR 6.291–63.783,  $p < 0.001$ ), and MCV size (OR 1.464–3.180,  $p < 0.001$ ). The Logistic regression model had 97% (92–99) sensitivity, 91% (87–98) specificity, 91% (88–96) PPV, 97% (90–99) NPV, and 94% (87–96) accuracy in the prediction of EVs. Based on the ROC curve and Youden's *J* index, we suggested 3.5 mm, and 1.5 mm cutoff values for the size of MCV, and gastric varicosities (Table 3).

Regarding EVH, CT variables that were significantly associated with EV had also a significant association with EVH (the presence of para-esophageal collaterals, short gastric collaterals, gastric varicosities, coronary collaterals, and the size of gastric varicosities, and MCV). Additionally, the size of EVs  $> 4$  mm, and Child C score category had significant correlation with EVH ( $p = 0.001$ ,  $< 0.001$ , and  $< 0.001$ , respectively) (Table 1).

The binary logistic regression analysis (Table 2) showed that some of the variables remained significant in the model as followings: the presence of para-esophageal collaterals, short gastric collaterals, and size of

**Table 1** Comparison of baseline data of patients with or without EV or EVH

Variable	n (%) / Mean ± SD	EV		p value	EVH		p value
		No (n = 35)	Yes (n = 50)		No (n = 43)	Yes (n = 42)	
		Median (IQR)			Median (IQR)		
Age/years	53.82 ± 8.9	55.57 ± 9.4	52.60 ± 8.5	= 0.133*	55.30 ± 8.8	52.31 ± 8.9	= 0.124*
Sex							
Female	30 (35.3%)	13 (37.1%)	17 (34%)	= 0.756**	16 (37.2%)	14 (33.3%)	= 0.709**
Male	55 (64.7%)	22 (62.9%)	33 (66%)		27 (62.8%)	28 (66.7%)	
EVs at CT							
Existence	50 (58.8%)	0 (0%)	50 (100%)	< 0.001**	19 (44.2%)	31 (73.8%)	= 0.131**
Size							
< 2 mm	16 (32%)	19 (54.3)	16 (32)	= 0.112**	20 (46.5%)	2 (4.8%)	= 0.098***
2–4 mm	11 (22%)	9 (25.7)	10 (20)	= 0.233**	22 (51.2)	18 (42.9)	= 0.832***
> 4 mm	23 (46%)	7 (20)	24 (48)	= 0.098**	1 (2.3)	22 (52.4)	= 0.001***
Para-esophageal collateral							
Existence	42 (49.4%)	0 (0%)	42 (84%)	< 0.001**	4 (9.3%)	38 (90.5%)	< 0.001**
Size	5.40 ± 1.4	0 (0)	6 (2)	NA	7.2 (4)	6 (3)	= 0.468***
Short gastric collateral							
Existence	51 (60%)	16 (45.7%)	35 (70%)	= 0.024**	20 (46.5%)	31 (73.8%)	= 0.010**
Size	3.51 ± 0.8	4 (3)	3 (1.5)	= 0.457***	3.6 (3)	3.2 (1)	= 0.946***
Peri-splenic collateral							
Existence	19 (22.4%)	13 (30.2%)	6 (14.3%)	= 0.118**	15 (24.2%)	4 (17.4%)	= 0.504**
Size	4.12 ± 0.9	3 (1.9)	3.2 (1.6)	= 0.101***	3.2 (2)	3.3 (1)	= 0.984***
Lino-renal collateral							
Existence	61 (71.8%)	24 (68.6%)	37 (74%)	= 0.584**	29 (76.4%)	32 (76.2%)	= 0.370**
Size	6.03 ± 1.7	7.5 (4)	7 (2)	= 0.988***	7 (3)	7 (2)	= 0.942***
Omental collateral							
Existence	34 (40%)	16 (37.2%)	18 (42.9%)	= 0.595**	24 (38.7%)	10 (43.5%)	= 0.690**
Size	3.11 ± 0.9	4.4 (0.9)	4.3 (1.5)	= 0.112***	4.8 (1)	3.8 (1)	= 0.148***
Para-umbilical collateral							
Existence	46 (54.1%)	21 (60%)	25 (50%)	= 0.363**	24 (55.8%)	22 (52.4%)	= 0.751**
Size	5.58 ± 1.3	3.5 (3)	5 (3.5)	= 0.121***	3.6 (2)	4.8 (3)	= 0.134***
IVC							
AP	21.98 ± 4.1	20 (6)	20 (5.5)	= 0.479***	20 (4)	23 (5.5)	= 0.260***
Width	28.80 ± 7.8	30 (10)	30 (5)	= 0.923***	28 (10)	30 (6)	= 0.681***
MCV	3.72 ± 2.7	2 (1)	4.7 (1)	< 0.001**	3 (1)	4 (2)	= 0.011**
LGV	2.10 ± 1.9	0.62 (0.3)	0.66 (0.5)	= 0.389***	0.62 (0.8)	0.66 (0.9)	= 0.356***
RPV	2.75 ± 2.1	1.21 (0.5)	1.33 (0.9)	= 0.158***	1.22 (1.7)	1.31 (0.3)	= 0.568***
LPV	3.06 ± 2.8	1.38 (1.4)	1.31 (1.5)	= 0.211***	1.35 (1.6)	1.30 (1.5)	= 0.274***
MPV	16.71 ± 1.8	14.7 (0.2)	15.82 (0.3)	= 0.133***	14.56 (0.2)	15.75 (0.2)	< 0.121***
SPV	3.04 ± 3.0	1.42 (1.3)	1.46 (0.3)	= 0.785***	1.44 (1.2)	1.45 (0.3)	= 0.775***
Child score category							
Child A	21 (24.7%)	18 (51.4%)	3 (6%)		21 (48.8%)	0 (0%)	
Child B	29 (34.1%)	1 (2.9%)	28 (56%)		3 (7%)	26 (61.9%)	
Child C	35 (41.2%)	19 (44.2%)	16 (38.1%)	= 0.213**	30 (48.4%)	5 (21.6%)	< 0.001**
IMV size	4.26 ± 1.7	4 (2.5)	4 (2.8)	= 0.791***	4 (2)	4.3 (3)	= 0.149***
SMV Size	12.57 ± 3.3	12 (6)	11.5 (6)	= 0.530***	11 (6)	12 (6)	= 0.603***
PUV size	10.19 ± 2.6	10 (3.7)	9 (2.8)	= 0.288***	10 (4)	9 (3)	= 0.420***
Splenic size	138.78 ± 43.7	150 (40)	142.5 (55)	= 0.516***	145 (55)	147.5 (46)	= 0.826***
Ascites (+)	34 (40%)	17 (48.6%)	17 (34%)	= 0.177**	17 (39.5%)	17 (40.5%)	= 0.929**
Gastric varicosities							

**Table 1** (continued)

Variable	n (%) / Mean ± SD	EV		p value	EVH		p value
		No (n = 35)	Yes (n = 50)		No (n = 43)	Yes (n = 42)	
		Median (IQR)			Median (IQR)		
Existence	34 (40%)	2 (5.7%)	32 (64%)	<0.001**	3 (7%)	31 (73.8%)	<0.001**
Size	2.22 ± 1.3	0.4 (0)	2.3 (1.5)	=0.004***	0.5 (0)	2.5 (1)	<0.001***
Coronary collateral (+)	38 (44.7%)	5 (14.3%)	33 (66%)	<0.001**	5 (11.6%)	33 (78.6%)	<0.001**

EV esophageal varices, EVH esophageal variceal hemorrhage, IVC inferior vena cava (AP anterior–posterior), LGV left gastric vein, RPV right portal vein, LPV left portal vein, MPV main portal vein, SPV splenic vein, IMV inferior mesenteric vein, SMV superior mesenteric vein, LRV left renal vein

\*Independent sample t-test was used to compare the means among groups

\*\*Chi-square test was used to compare the frequency among groups

\*\*\*Mann Whitney U-test was used to compare the medians among groups

**Table 2** Regression model of MDCT and clinical findings for predicting the EV and EVH

Variable	Odds ratio	95% CI	p value
<i>EV</i>			
Short gastric collateral (+)	2.771	1.128–6.808	=0.026
Main coronary vein size	2.157	1.464–3.180	<0.001
Gastric varicosities (+)	29.312	6.291–63.783	<0.001
Coronary collateral (+)	11.647	3.827–23.447	<0.001
<b>Accuracy</b>	<b>Sensitivity</b>	<b>Specificity</b>	<b>PPV</b>
94% (87–96)	97% (92–99)	91% (87–98)	91% (88–96)
<b>NPV</b>	<b>PLR</b>	<b>NLR</b>	
97% (90–99)	10.78 (4.1–18.5)	0.03 (0.01–0.07)	
Variable	Odds ratio	95% CI	p value
<i>EVH</i>			
Main coronary vein size	1.541	1.058–2.821	=0.023
Para-esophageal collateral	9.625	1.594–39.300	<0.001
Short gastric collateral	3.241	1.302–8.070	=0.012
Gastric varicosities	7.576	1.644–14.406	<0.001
Child class C	17.499	5.266–38.149	<0.001
Size of EVs > 4 mm	21.874	9.098–33.541	<0.001
<b>Accuracy</b>	<b>Sensitivity</b>	<b>Specificity</b>	<b>PPV</b>
89.5% (81–97)	98% (92–99)	81% (74–88)	84% (74–93)
<b>NPV</b>	<b>PLR</b>	<b>NLR</b>	
97.5% (92–99)	5.16 (2.9–6.8)	0.02 (0.01–0.05)	

**Table 3** Cutoff values based on ROC curve and Youden’s J analyses

Variable	Cutoff (mm)	AUC (95% CI)	Youden’s J	p value
<i>EV</i>				
Main coronary vein size	3.5	0.952 (0.889–1.000)	0.784	<0.001
Gastric varicosities	1.5	0.998 (0.989–1.000)	0.785	<0.001
<i>EVH</i>				
SGC size	2.5	0.567 (0.501–0.715)	0.166	=0.042
Main coronary vein size	3.5	0.687 (0.512–0.804)	0.201	=0.031
Gastric varicosities	2.0	0.994 (0.973–1.000)	0.633	=0.005
Size of EVs	>4	0.981 (0.873–0.991)	0.722	<0.001



EVs, gastric varicosities, MCV, and Child Class C. The Logistic regression model had 98% (92–99) sensitivity, 81% (74–88) specificity, 84% (74–93) PPV, 97.5% (92–99) NPV, and 89.5% (81–97) accuracy in the prediction of EVH. Based on the ROC curve and Youden’s J index, we suggested 2.5 mm, 3.5 mm, 2.0 mm, and > 4 mm as cut off values for the size of SGC, MCV, gastric varicosities, and EVs, respectively (Table 3) (Figs. 1, 2 and 3).

The reliability of observers in the detection of EVs was excellent (K Value = 0.826,  $p < 0.001$ ), (AUC = 0.931,  $p < 0.001$ ) (Table 4). Inter-observer agreement was high to almost perfect between the three observers (W. Kappa = 0.71–0.88,  $p < 0.001$ ). The agreement was higher between observers no. 1 and both no. 2 (W. Kappa = 0.88,  $p < 0.001$ ) and no. 4 (W. Kappa = 0.86,  $p < 0.001$ ), with a lower agreement with observers no. 3 (W. Kappa = 0.71,  $p < 0.001$ ). Also, observer no. 3 elicited better agreement with no. 4 (W. Kappa = 0.79,  $p < 0.001$ ) than no. 2 (W. Kappa = 0.77,  $p < 0.001$ ) (Table 5).

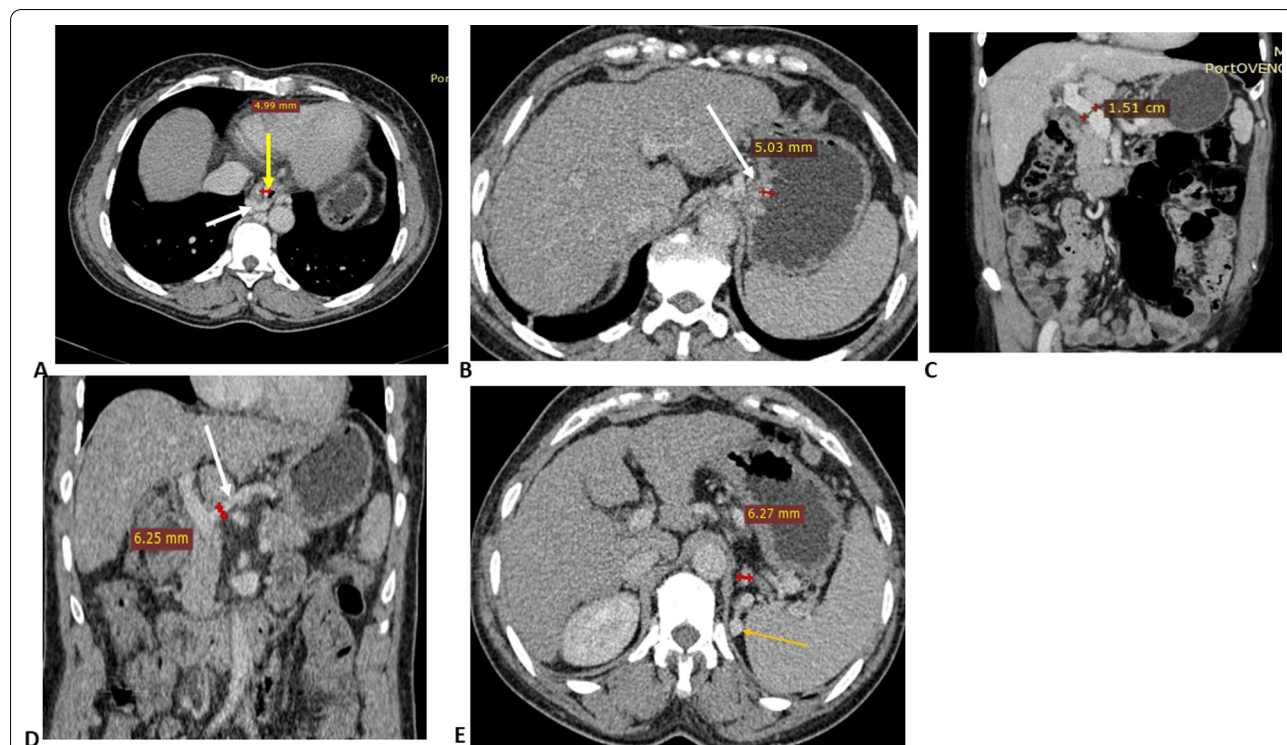
### Discussion

The use of non-invasive methods for screening and surveillance of EVs has been addressed by the recent BAVENO VI Consensus. Currently, UGIT endoscopy remains the primary EV screening method with variable surveillance intervals. However, new considerations have been raised due to the high cost of the screening and surveillance programs urging multicentre studies and long-term data [25].

Contrast-enhanced CT is considered an effective imaging modality for the diagnosis of EVs due to its wide availability, cost-effectiveness, and high tolerability [18–20].

In the current study, we prospectively investigated the accuracy of MDCT in the prediction of EVs and EVH. MDCT had 81.1% sensitivity, 89% specificity, and 85% accuracy in the prediction of EVs. After regressing out the confounders, we proposed a highly sensitive, specific, and accurate CT-based model for the prediction of EVs as well as clinical EVH according to UGIT endoscopy.

Several studies [26–28] assessed the accuracy of MDCT in the prediction of EVs with variable results. Salahshour et al. [26] reported 63.49% sensitivity, 81.97% specificity, and 72.58% accuracy. Hassan et al. [27] reported 98%



**Fig. 1** A 63-year-old female with liver cirrhosis and portal hypertension. MDCT portal phase, Axial images (a, b, e) showed esophageal varices seen as enhancing dots in the mucosa and sub-mucosa of the esophageal wall (yellow arrow, a) and para esophageal collaterals (white arrow, a), multiple tortuous gastric varices causing gastric wall thickening (white arrow, b), perisplenic collaterals (arrow, e). Coronal images (c, d) showed dilated main portal vein, dilated main coronary vein which communicating gastric veins with main portal vein (arrow, d). UGIT endoscopy confirmed grade II EVs. Two months later, patient experienced UGIT bleeding and received endoscopic variceal ligation



**Fig. 2** A 70-year-old female with liver cirrhosis and portal hypertension. MDCT portal phase, axial image (a) shows esophageal varices as enhancing dots in the esophageal wall (white arrow) and ascites (yellow arrow). Coronal images (b–f) showed para esophageal collaterals (arrow, b), gastric varices (arrow, c), and short gastric collaterals which communicating gastric veins with splenic vein (yellow arrow, d). Coronal MIP image showing coronary collateral which connecting gastric and para esophageal collaterals with the portal vein (arrow, e), there was dilated main portal vein (f). UGIT endoscopy confirmed grade III EVs. Four months later, patient experienced UGIT bleeding and received endoscopic variceal ligation

sensitivity and 100% specificity. Deng et al. [28] reported 95% sensitivity and 71% specificity. These variable results may be related to the retrospective design of their studies, different categorizations of EVs, and the unspecified time interval between UGIT endoscopy procedure and CT examination. The time interval was 2 weeks in the present study. We should consider that improvement or some progression of the disease may occur during this interval; however, it is known that at 1 year the natural progression rates of EVs from no varices to small varices are 5% and from small to large varices the rate was 12% [29]. We observed higher accuracy similar to what was previously reported in a meta-analysis (AUC=0.86) [10].

To the best of our knowledge, no prospective study has predicted EVs or EVH based on the presence and size of different collaterals and systemic veins.

Patients with portal hypertension develop different collateral veins to divert the blood flow and decrease portal pressure. However, they eventuate in higher blood flow and the bleeding risk may not be reduced [30].

There is a debate regarding the relationship between the occurrence of EVs or EVH and the presence and size of collaterals and veins (especially PUV) [31].

The protective effect of PUV on EVH with a significant association between higher PUV size and lower EVH

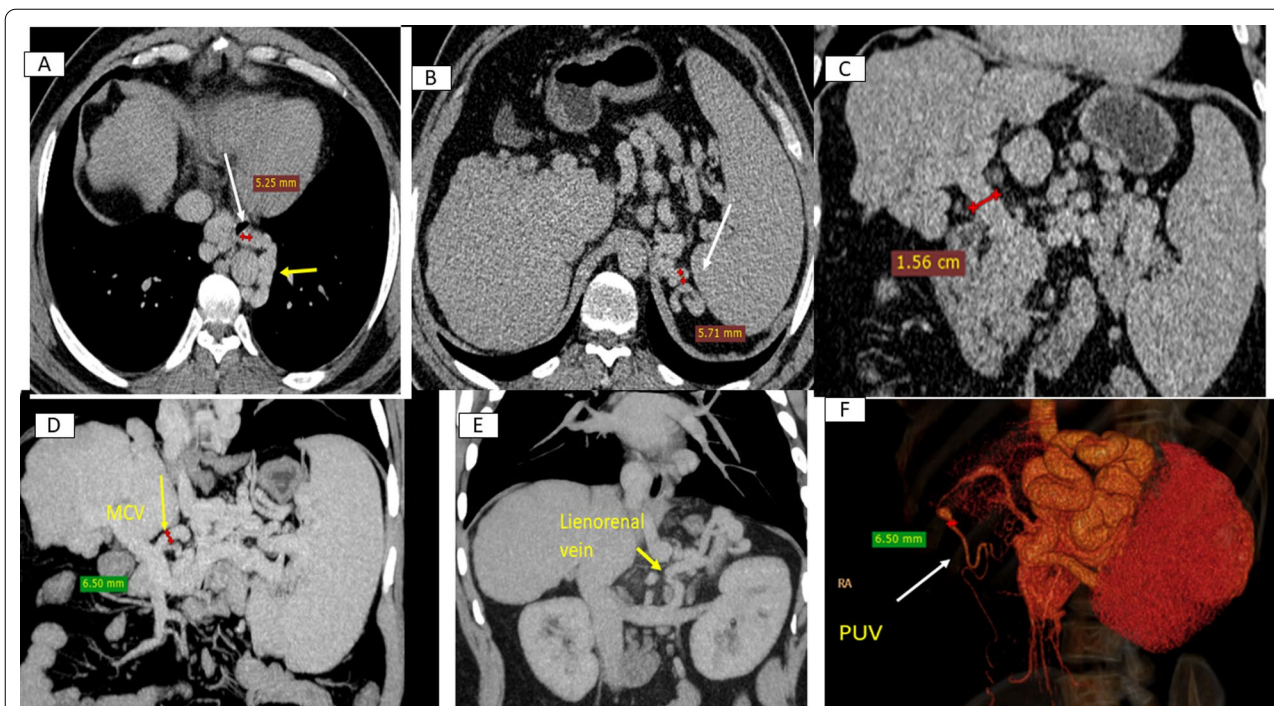
risk has been previously reported [22]. Meanwhile, contrariwise results have been reported by Kondo et al. [31] who showed the positive influence of PUV on EVs. small/absent PUV was significantly associated with a first EVH ( $p < 0.001$ ) [22]. Our results demonstrated a lower size of PUV in a patient with EVH; however, these results are not statistically significant, which is consistent with [22, 26].

In contrast to our results, several studies have shown higher spleen size [22, 32] and volume [31] in patients who experienced EVH. It may be attributed to either the different inclusion and exclusion criteria of these studies or their smaller sample sizes.

Our results are consistent with the results of Manchec et al. [18] who reported that EVs  $\geq 4$  mm on MDCT correlated with the presence of high-risk EVs at UGIT endoscopy (with 80% sensitivity and 87% specificity), and these patients were more likely to have EVH and should be considered for treatment as needed.

Predictive models for EVs or EVH have been previously recommended [22, 26]. Calame et al. [22] investigated the following features as a predictive model for EVs: spleen size, the presence and size of PUV, the presence of enlarged and tortuous LGV, and ascites. They reported a weighted score ranging from 0 to 5, the risk





**Fig. 3** A 66-year-old male with liver cirrhosis and portal hypertension. MDCT portal phase axial images showed esophageal varices (white arrow, **a**), para esophageal varices (yellow arrow, **a**), and perisplenic collaterals (white arrow, **b**). Coronal images (**c–e**) showed dilated main portal vein (**c**), dilated main coronary vein which communicating gastric veins with main portal vein (yellow arrow, **d**), and dilated lienorenal collateral which connect splenic vein with left renal vein (yellow arrow, **e**). 3D volume rendering image showed PUV (arrow, **f**) which communicates the sub-cutaneous veins of the anterior abdominal wall with the LT portal vein. UGIT endoscopy confirmed grade III EVs. One month later, patient experienced UGIT bleeding and received endoscopic variceal ligation

**Table 4** Inter-observer reliability and performance

Observer no	K Value*	AUC versus diagnosis	p value
<i>EV-CT</i>			
Observer 1	0.942 (0.842–0.981)	0.964 (0.924–1.000)	<0.001
Observer 2	0.865 (0.689–0.921)	0.946 (0.891–1.000)	<0.001
Observer 3	0.691 (0.624–0.879)	0.870 (0.792–0.848)	<0.001
Observer 4	0.829 (0.753–0.954)	0.940 (0.886–0.994)	<0.001
Overall	0.826 (0.720–0.911)	0.931 (0.875–0.988)	

AUC area under the curve

\*Fleiss K Value and 59% CI (Confidence Interval)

of EVH was 33% when scoring = 4–5. Salahshour et al. [26] proposed an imaging-based model for the prediction of EVs (75.86% sensitivity, 76.92% specificity, and 76.36% accuracy) and presented another model for the prediction of EVH (75.86% sensitivity, 76.92% specificity, and 76.36% accuracy).

Our results suggested two models with 94% accuracy in the prediction of EVs and 89.5% accuracy in the prediction of EVH. Higher accuracy in our models could

be attributed to the prospective design of the study and the omission of the effect of confounders.

Finally, the presence of EVs, coronary collaterals, short gastric collaterals, gastric varicosities (size > 1.5 mm), and MCV size > 3.5 mm at MDCT can predict high-risk EVs with an accuracy of 94%, while the presence of para-esophageal collaterals, the presence of EVs (size > 4 mm), the presence of short gastric collaterals (SGC size > 2.5 mm), the presence of gastric varicosities (size > 2 mm), MCV size > 3.5 mm, MPV > 15 mm, and child category C can predict EVH with an accuracy of 89.5%.

Our models for the prediction of high-risk EVs and EVH have good reliability and reproducibility. Radiologists should report in their everyday practice the presence and size of the mentioned collaterals including short gastric, coronary, and gastric varicosities, because they have a significant association with high-risk EVs, especially in patients not receiving prophylactic treatment. Our suggested models with acceptable accuracy help clinicians to provide prophylactic measures for high-risk patients aiming to avoid mortal complications.



**Table 5** Interobserver agreement

	No	Yes	Weighted kappa*
<i>Observer 1</i>			
<i>Observer 2</i>			
No	34 (40%)	4 (4.7%)	0.88 (0.69–0.95)
Yes	1 (1.2%)	46 (54.1%)	$p < 0.001$
<i>Observer 3</i>			
No	35 (41.2%)	13 (15.3%)	0.71 (0.61–0.85)
Yes	0 (0%)	37 (43.5%)	$p < 0.001$
<i>Observer 4</i>			
No	35 (41.2%)	6 (7.1%)	0.86 (0.72–0.89)
Yes	0 (0%)	44 (51.8%)	$p < 0.001$
<i>Observer 2</i>			
<i>Observer 3</i>			
No	38 (44.7%)	10 (11.8%)	0.77 (0.69–0.85)
Yes	0 (0%)	37 (43.5%)	$p < 0.001$
<i>Observer 4</i>			
No	35 (41.2%)	6 (7.1%)	0.79 (0.68–0.88)
Yes	3 (3.5%)	41 (48.2%)	$p < 0.001$
<i>Observer 3</i>			
<i>Observer 4</i>			
No	40 (47.1%)	1 (1.2%)	0.79 (0.72–0.81)
Yes	8 (9.4%)	36 (42.4%)	$p < 0.001$

\*Weighted K Value and 59% CI (confidence interval)

The limitation of our study was related to CT compared to qualitative UGIT endoscopic appearance (including the presence of red signs such as cherry-red spots, red wale markings, and diffuse redness) which cannot be detected by MDCT. It is known that the presence of a red sign on UGIT endoscopy is one of the predictors of EVH [33]. Fortunately, red signs were detected by endoscopy in only two patients (2.4%) with low-risk (grade 1) EVs in our study.

## Conclusion

MDCT is an effective modality in the diagnosis of EVs. At MDCT, the presence and/or size of various collaterals including para-esophageal, short gastric, coronary collaterals, and gastric varicosities are accurate predictors for either EVs existence or EVH. We suggested two CT imaging-based models with high reproducibility and acceptable accuracy for the prediction of EV and EVH. With cirrhotic patients, we recommend that radiologists report collaterals in their daily practice.

## Abbreviations

MDCT: Multidetector computed tomography; UGIT: Upper gastrointestinal tract; EVs: Endoscopy, esophageal varices; EVH: Esophageal variceal hemorrhage; MPV: Main portal vein; IHRPV: Intrahepatic right portal vein; IHLPV: Intrahepatic left portal vein; SV: Splenic vein; LGV: Left gastric vein; MCV: Main coronary vein; SGC: Short gastric vein.

## Acknowledgements

The authors thank all members of the Departments of Internal Medicine and Radio-diagnosis at Assiut University Hospitals, Assiut University, Assiut, Egypt for supporting this work.

## Authors' contributions

MS, SA: substantial contributions to the conception, design of the work, the acquisition, analysis, interpretation of data; have drafted the work or substantially revised it and approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work. DG: substantial contributions to the conception, design of the work, the acquisition, analysis, interpretation of data; have drafted the work or substantially revised it and approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work. MH: substantial contributions to the conception, design of the work, the acquisition, analysis, interpretation of data; have drafted the work or substantially revised it and approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work. All authors read and approved the final manuscript.

## Funding

None.

## Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

This study was approved by the Ethical Committee, Faculty of Medicine, Assiut University with an IRB No. 17100414. All patients were informed about the study, and a written consent was obtained from each patient.

### Consent for publication

Not applicable.

### Competing interest

I declare that the authors have no competing interest.

### Author details

<sup>1</sup>Department of Diagnostic Radiology, Assiut University Hospitals, Assiut, Egypt. <sup>2</sup>Department of Diagnostic Radiology, South Egypt Cancer Institute, Assiut University, Assiut, Egypt.

Received: 21 November 2021 Accepted: 25 February 2022

Published online: 07 March 2022

## References

- Mathur AK, Chakrabarti AK, Mellinger JL et al (2017) Hospital resource intensity and cirrhosis mortality in United States. *World J Gastroenterol* 23:1857–1865
- Ho SB, Matheny ME, Schnabl BE (2016) Changes in hospital admissions and mortality for complications of cirrhosis: implications for clinicians and health systems. *Gut Liver* 10:8–9
- Moed S, Zaman MH (2019) Towards better diagnostic tools for liver injury in low-income and middle-income countries. *BMJ Glob Heal* 4:e001704
- Wan S, Wei Y, Zhang X, Yang C et al (2021) CT-derived quantitative liver volumetric parameters for prediction of severe esophageal varices and the risk of first variceal hemorrhage. *Eur J Radiol*. <https://doi.org/10.2139/ssrn.3814768>
- Graça BM, Freire PA, Brito JB et al (2010) Gastroenterologic and radiologic approach to obscure gastrointestinal bleeding: How, why, and when? *Radiographics* 30:235–252

6. Wan S, Wei Y, Yu H et al (2020) Computed tomographic portography with esophageal variceal measurements in the evaluation of esophageal variceal severity and assessment of esophageal variceal volume efficacy. *Acad Radiol* 27:528–535
7. Ngwa T, Orman E, Gomez EV et al (2020) Non-selective beta blocker use is associated with improved short-term survival in patients with cirrhosis referred for liver transplantation. *BMC Gastroenterol* 20:4–10
8. Komori K, Kubokawa M, Ihara E et al (2017) Prognostic factors associated with mortality in patients with gastric fundal variceal bleeding. *World J Gastroenterol* 23:496–504
9. Li S, Huang P, Jeyarajan AJ et al (2021) Assessment of non-invasive markers for the prediction of esophageal variceal hemorrhage. *Front Med (Lausanne)* 8:770836
10. Tseng YJ, Zeng XQ, Chen J et al (2016) Computed tomography in evaluating gastroesophageal varices in patients with portal hypertension: a meta-analysis. *Dig Liver Dis* 48:695–702
11. Singh S, Eaton JE, Murad MH et al (2014) Accuracy of spleen stiffness measurement in detection of esophageal varices in patients with chronic liver disease: systematic review and meta-analysis. *Clin Gastroenterol Hepatol* 12:935–45.e4
12. Takuma Y, Nouse K, Morimoto Y et al (2013) Measurement of spleen stiffness by acoustic radiation force impulse imaging identifies cirrhotic patients with esophageal varices. *Gastroenterology* 144:92–101.e2
13. Ye X-P, Ran H-T, Cheng J et al (2012) Liver and spleen stiffness measured by acoustic radiation force impulse elastography for noninvasive assessment of liver fibrosis and esophageal varices in patients with chronic hepatitis B. *J Ultrasound Med* 31:1245–1253
14. Chakrabarti R, Sen D, Khanna V (2016) Is non-invasive diagnosis of esophageal varices in patients with compensated hepatic cirrhosis possible by duplex Doppler ultrasonography? *Indian J Gastroenterol* 35:60–66
15. Mahmoud HS, Mostafa EF, Mohammed MA (2014) Role of portal haemodynamic parameters in prediction of oesophageal varices in cirrhotic patients. *Arab J Gastroenterol* 15:130–134
16. Qi X, Li H, Chen J et al (2015) Serum liver fibrosis markers for predicting the presence of gastroesophageal varices in liver cirrhosis: a retrospective cross-sectional study. *Gastroenterol Res Pract* 2015:534–543
17. Deng H, Qi X, Peng Y et al (2015) Diagnostic accuracy of APRI, AAR, FIB-4, FI, and king scores for diagnosis of esophageal varices in liver cirrhosis: a retrospective study. *Med Sci Monit* 21:3961–3977
18. Manchec B, Pham E, Noor M et al (2015) Contrast-enhanced CT may identify high-risk esophageal varices in patients with cirrhosis. *AJR Am J Roentgenol* 215:617–623
19. Dessouky BAM, Abdel Aal ESM (2013) Multidetector CT oesophagography: an alternative screening method for endoscopic diagnosis of oesophageal varices and bleeding risk. *Arab J Gastroenterol* 14:99–108
20. Lipp MJ, Broder A, Hudesman D et al (2011) Detection of esophageal varices using CT and MRI. *Dig Dis Sci* 56:2696–2700
21. Ebada H, Ebrahim A, Elbareedy A et al (2021) Novel score for prediction of esophageal varices in HCV-related chronic liver disease patients. *Afro-Egypt J Infect Endem Dis* 11:343–353
22. Calame P, Ronot M, Bouveresse S et al (2017) Predictive value of CT for first esophageal variceal bleeding in patients with cirrhosis: value of paraumbilical vein patency. *Eur J Radiol* 87:45–52
23. El-Assaly H, Metwally LIA, Azzam H et al (2020) A comparative study of multi-detector CT portography versus endoscopy in evaluation of gastroesophageal varices in portal hypertension patients. *Egypt J Radiol Nucl Med* 51:145–162
24. Abby Philips C, Sahney A (2016) Oesophageal and gastric varices: historical aspects, classification and grading: everything in one place. *Gastroenterol Rep (Oxf)* 4:186–195
25. De Franchis R (2010) Revising consensus in portal hypertension: Report of the Baveno V consensus workshop on methodology of diagnosis and therapy in portal hypertension. *J Hepatol* 53:762–768
26. Salahshour F, Mehrabinejad MM, Rashidi Shahpasandi MH et al (2020) Esophageal variceal hemorrhage: the role of MDCT characteristics in predicting the presence of varices and bleeding risk. *Abdom Radiol (NY)* 45:2305–2314
27. Hassan M, Husen Y, Abbasi SU et al (2019) Diagnostic accuracy of multidetector computed tomography in detection of esophageal varices. *Cureus* 11:e3933
28. Deng H, Qi X, Zhang Y et al (2017) Diagnostic accuracy of contrast-enhanced computed tomography for esophageal varices in liver cirrhosis: a retrospective observational study. *J Evid Based Med* 10:46–52
29. Boregowda U, Umopathy C, Halim N et al (2019) Update on the management of gastrointestinal varices. *World J Gastrointest Pharmacol Ther* 10:1–21
30. Kawanaka H, Akahoshi T, Nagao Y et al (2018) Customization of laparoscopic gastric devascularization and splenectomy for gastric varices based on CT vascular anatomy. *Surg Endosc* 32:114–126
31. Kondo T, Maruyama H, Sekimoto T et al (2014) Influence of paraumbilical vein patency on the portal hemodynamics of patients with cirrhosis. *J Clin Gastroenterol* 48:178–183
32. Cunningham ME, Parastandeh-Chehr G, Cerocchi O et al (2019) Noninvasive predictors of high-risk varices in patients with non-cirrhotic portal hypertension. *Can J Gastroenterol Hepatol* 2019:30–46
33. Kothari HG, Gupta SJ, Gaikwad NR et al (2019) Samarth AR. Role of non-invasive markers in prediction of esophageal varices and variceal bleeding in patients of alcoholic liver cirrhosis from central India. *Turk J Gastroenterol* 30:1036–1043

### Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen® journal and benefit from:

- Convenient online submission
- Rigorous peer review
- Open access: articles freely available online
- High visibility within the field
- Retaining the copyright to your article

Submit your next manuscript at ► [springeropen.com](https://www.springeropen.com)