Original Article

Duplex Ultrasound Evaluation of Portal Vein Congestion Index as a Predictor of Esophageal Varices: A Cross- sectional Study

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Abstract:

Background: The assessment of esophageal varices is critical in managing patients with portal hypertension, particularly those with liver cirrhosis. Duplex ultrasound offers a non-invasive method to evaluate portal hemodynamics, including the portal vein congestion index (PVCI), which is defined as the ratio of the cross-sectional area of the portal vein to the portal vein velocity. **Objectives:** The aim of the study was to evaluate the duplex ultrasound evaluation of portal vein congestion index as a predictor of esophageal varices. **Methods:** This cross-sectional study was conducted in the Department of Radiology & Imaging, Dhaka Medical College Hospital, Dhaka, from July 2021 to June 2023. Duplex study was done on 58 patients known case of cirrhosis of liver patients who attended the outpatient department or indoor of department of Dhaka Medical College Hospital, Dhaka. Statistical analyses of the results were be obtained by using window-based Microsoft Excel and Statistical Packages for Social Sciences (SPSS-24). **Results:** According to age, the majority of the study participants (17, 29.3%) were between the ages of 40 and 49, with 77.60% being male. The congestion index demonstrated a significant correlation with the presence of EV on EGD ($p<0.05$). The sensitivity of congestion index was 94.87%. The congestion index had the highest specifity at 84.21% and highest negative predictive value at 88.89%. Positive predicative value was also highest for the congestion index at 92.50% and accuracy was highest at 91.38%. **Conclusion:** PVCI is a reliable, non-invasive predictor of esophageal varices and could be used as a screening tool to reduce the need for routine endoscopic examinations.

Keywords: PVCI, Esophageal varices, Portal hypertension, Duplex ultrasound, Non-invasive method..

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Introduction:

Portal hypertension is a common complication of chronic liver diseases, often leading to the development of esophageal varices (EV), a potentially life-threatening condition due to the risk of variceal bleeding. Early detection and monitoring of EV are critical for timely intervention and prevention of complications.[1] However, current diagnostic methods, such as endoscopy, are invasive, expensive, and not always accessible, especially in resource-limited settings.

Portal hypertension (PHT), a progressive consequence of liver cirrhosis, is described as a pathological increase in the portal venous pressure between the portal vein and the inferior vena cava to a higher-than-normal level (normal range is $\leq$ 5 mmHg).[2] A clinically substantial PHT (hepatic venous pressure gradient $\geq$ 10 mmHg) is required for the

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development of EV, variceal hemorrhage, and decompensation.[3] Variceal hemorrhage affects 25-40% of people with cirrhosis. Each episode of variceal bleeding is associated with about a 20% fatality rate.[4] Over the course of two years, one in every four patients with EV is likely to experience variceal hemorrhage.[5] EGD, the gold standard for the diagnosis of EV and management of its complications, is recommended in all patients at the time of initial diagnosis of cirrhosis to screen for the presence of EV.[6] During screening EGD, 9-36% of patients with cirrhosis are found to have esophageal varices.[7]

In recent years, non-invasive techniques have gained attention as potential alternatives for evaluating portal hypertension and its complications. Duplex ultrasound, which combines B-mode imaging and Doppler flow measurements, has emerged as a promising modality for assessing hemodynamic changes in the portal venous system.[8] Among its various parameters, the portal vein congestion index (PVCI)-calculated as the ratio of the cross-sectional area of the portal vein to its blood flow velocity-has been proposed as a non-invasive indicator of portal hypertension and esophageal varices.[9]

This study explores the utility of duplex ultrasound evaluation of PVCI as a predictor of esophageal varices in patients with portal hypertension. By correlating PVCI values with the presence and severity of EV, this approach aims to offer a non-invasive, cost-effective, and widely available tool for risk stratification and management in clinical practice.

Methodology:

Type of study: Cross sectional study. Place of study: This study was carried out in the department of Radiology & Imaging, Dhaka Medical College Hospital, Dhaka. Period of study: This study was carried out over a period of 2 years from July, 2021 to June, 2023. Study population: This study was carried out known case of cirrhosis of liver patients who attended the outpatient department or indoor of department of Dhaka Medical College Hospital, Dhaka referred to Radiology and Imaging department for imaging investigation. Sampling technique: Purposive type of Non random sampling was done. Inclusion criteria: Patient with known case of cirrhosis of liver on the basis of history, physical examination, liver biochemistry & USG, adult patient of both gender. Exclusion criteria: Patient who refused to be enrolled in study, patient who has previously sclerotherapy or band ligation of oesophageal varices, trans jugular intrahepatic portosystemic stent shunt or surgery from portal hypertension, patient with active gastrointestinal bleeding, patients taking drug for primary prophylaxis of variceal bleeding, patient with hepatocellular carcinoma, patient with heart failure, patient with hepatic, splenic or portal vein thrombosis and patient with severe abdominal, chest or renal disease. Sample size determination: Sample size was calculated directly from the following equation: (Hajian- Tilaki, 2014)

$$n = \frac{Z\alpha^2 \times P(1-P)}{d^2 \times Prev}$$

Here,

Pre-determined value of specificity (P) ascertained by previous published data and for α = 0.05, Z value =1.96 at 95% confidence level & prevalence of disease 50% sample size is calculated.

P = Value of specificity = 92.84%, [Specificity from previous study] (Nouh et al., 2022)

Prev = prevalence = 0.5 (50%)

d= Degree of error = 0.10 (10%)

Therefore, = Sample size.

-value at definite level of significance, For α = 0.05, Z value 1.96 at 95% confidence level.

Putting the value in above equation the sample n was estimates as

$$n = \frac{(1.96)^2 \times 0.9284\ (1-0.9284)}{0.10^2 \times 0.5}$$

$$n = \frac{3.8416 \times 0.9284 \times 0.0716}{0.10^2 \times 0.5}$$

$$n = \frac{0.2553643671}{0.005}$$

$$n = 51.07287 \approx 52$$

So, n = 52, According to this formula the estimated sample size was 52.

To compensate dropout of patients, inadequate data and instrumental fault the sample size was increased by 10%. So, the total sample size was = 52 + 5.2 = 57.2 ≈ 58. Finally, 58 patients were analyzed in this study fulfilling the inclusion and exclusion criteria.

After taking consent and matching eligibility criteria, data were collected from patients on variables of interest using the predesigned structured questionnaire by interview, observation.

Data Analysis: The results were be obtained by using window-based Microsoft Excel and Statistical Package for Social Sciences version 25 (SPSS-25). 95% Confidence Intervals were included and $p<0.05$ was the threshold for statistical significance.

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Results:

This cross-sectional study was conducted at the department of Radiology and Imaging, Dhaka Medical College Hospital, Dhaka, from July 2021 to June 2023. 58 participants were selected after inclusion criteria and data was collected by using a preformed data sheet. Patient's information was obtained using information sheet which includes questionnaire, clinical findings & imaging findings. Duplex study reports & endoscopic reports were collected. According to age, the majority of the study participants 29.3% (17) were between the ages of 40 and 49, with 77.60% being male. The congestion index demonstrated a significant correlation with the presence of EV on EGD ($p<0.05$). The sensitivity of congestion index was 94.87%. The congestion index had the highest specifity at 84.21% and highest negative predictive value at 88.89%. Positive predicative value was also highest for the congestion index at 92.50% and accuracy was highest at 91.38%.

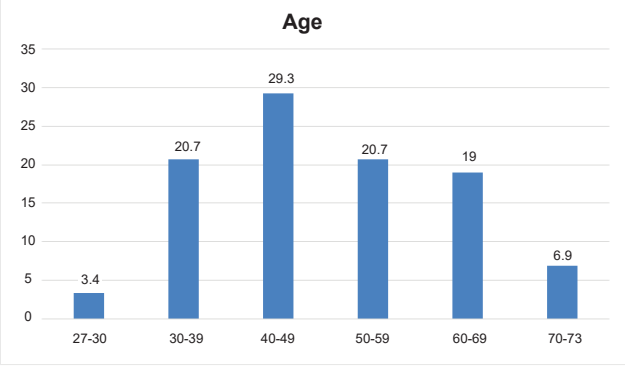

Figure-I: Age distribution of the participants (n=58)

Figure-I showed that majority of the study participants 29.3% (17) were aged between 40 to 49 years old. Mean ± SD of the study participants was 50.17 ± 12.26 years, with range 27 to 73.

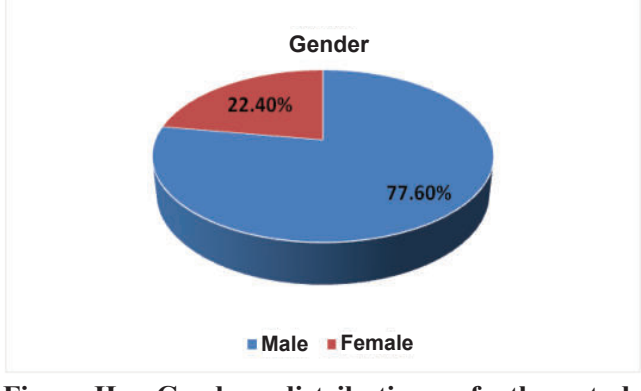

Figure-II: Gender distribution of the study participants (n=58)

Figure-II showed that most of the participants 77.60% were male where Male to Female ratio was 3.46:1

Table-I: Investigation findings of the participants (n=58).

Investigation findings	Mean ± SD	
Serum bilirubin (mg/dl)	1.95 ± 0.63	
Serum albumin (g/dl)	4.19 ± 4.00	
Serum ALT (U/L)	65.15 ± 17.64	
Serum AST (U/L)	75.62 ± 29.00	
Serum alkaline phosphatase (U/L)	173.89 ± 57.19	
Prothrombin time (seconds)	20.25 ± 4.58	
INR	1.65 ± 0.42	
Viral Markers	**n**	**(%)**
HbsAg		
Positive	39	67.2
Negative	13	22.4
Reactive	6	10.3
HBV DNA		
Detected	34	58.6
Not detected	24	41.4
Anti HCV		
Positive	9	15.5
Negative	49	84.5

Table-I showed the investigation findings of the study participants. Most of the participants (39, 67.2%) was HBsAg positive. HBV DNA detected in (34, 58.6%) participants. Maximum participants (49, 84.5%) were found to be Anti HCV negative.

Table-II: B-mode USG findings of the participants (n=58)

Variables	Frequency	Percentage (%)
Liver Size (cm)		
Enlarged (>15cm)	14	24.1
Shrunken (<12cm)	18	31
Normal (12-15cm)	26	44.8
Mean ± SD	13.07 ± 2.43	
Range (min-max)	12.97 (8.23-21.20)	
Margin of the Liver		
Regular	4	6.9
Irregular	54	93.1
Spleen Size (cm)		
Enlarged (>12cm)	39	67.2
Normal (7-12)	19	32.8

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Ascites		
Present	37	63.8
Absent	21	36.2
Portal vein diameter (mm)		
Increased (>13 mm)	42	72.4
Normal (<13 mm)	16	27.6
Mean ± SD	13.89 ± 1.59	
Range (min -max)	7.40 (11-18.40)	
Cross-sectional area of the portal vein (cm^2)		
Median	1.71	
IQR	1.49-2.12	

Data presented as frequency, percentage over columns, and mean ± SD over rows.

Table-II showed that, majority of the participants (26, 44.8%) had normal sized liver. Maximum participants (39, 67.2%) had enlarged spleen. Also, most of the participants (37, 63.8%) had ascites. Majority of the participants (42, 72.4%) had increased portal vein diameter and the mean ± SD was 13.89 ± 1.59.

Table-III: Color Doppler study findings of the participants (n=58)

Variables	Frequency	Percentage (%)
Portal vein velocity **(cm/s)**		
Decreased (<16 cm/s)	53	91.4
Normal (16 -40 cm/s)	5	8.6
Mean ± SD	11.38 ± 2.90	
Range (min -max)	6.08-17.50	
Portal congestion index		
>0.1	40	69
<0.1	18	31
Median	0.15	
IQR	0.10-0.22	
Portal vein flow direction		
Hepatopetal	47	81
Hepatofugal	11	19

Data presented as frequency, percentage over columns, and mean ± SD over rows.

Table-III showed that, most of the participants (55, 94.8%) had decreased portal vein velocity, with a Mean ± SD of 11.38 ± 2.90. Majority of the participants (40, 69%) had congestion index > 0.1, with a Median 1.71 and IQR 0.10-0.22. Maximum participants (47, 81%) had hepatopetal flow.

Table-IV: Endoscopy findings of the participants (n=58)

Variables	Frequency	Percentage (%)
Oesophagealvarices		
Present	39	67.2
Absent	19	32.8
Grading		
Grade -I	14	35.9
Grade -II	22	56.4
Grade -III	3	7.7

Data presented as frequency, percentage over columns.

Table-IV showed that, among 58 participants, (19, 32.8%) had no varices and (39, 67.2%) participants had oesophagealvarices. Among them (14, 35.9%) had grade-I, (22, 56.4%) had grade-II and (3, 7.7%) had grade-III.

Table-V: Correlation of congestion index and esophageal varices (N=58).

Endoscopic diagnosis	Congestion Index		Total	p-value
	>0.1	≤ 0.1		
	Frequency (%)	Frequency (%)		
Present	37 (94.9) (TP)	2 (5.1) (FN)	39	< 0.001[s]
Absent	3 (15.8) (FP)	16 (84.2) (TN)	19	
Total	40	18	58	

Data presented as frequency and percentage over rows. p-value reached through chi-square test for categorical variables. s = significant.

Table-V showed that, out of 58 cases 40 were diagnosed as esophageal varices by congestion index more than 0.1 and among them 37 were confirmed by endoscopy. They were true positive cases. 3 cases were diagnosed by congestion index more than 0.1, but not confirmed by endoscopy. They were false positive cases. Out of 39 cases, which were confirmed by endoscopy, 2 cases were not diagnosed by congestion index more than 0.1. They were false negative cases. Rests of the 16 cases were neither confirmed by endoscopy nor by congestion index. So, they were true negative cases. P-value reached through chi-square test reflects that the difference was statistically significant ($p < 0.05$).

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Table-VI: Validity parameter of congestion index in prediction of esophageal varices.

Variable	Cutoff point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	AUC
Congestion index in prediction of esophageal varices	0.977	94.87	84.21	92.5	88.89	91.38	0.907

Table-VI showed the Validity test results. Cut off point, Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), Accuracy and Area Under the Curve (AUC)of Congestion Index study findings in prediction of esophageal varices were 0.977, 94.87%, 84.21%, 92.50%, 88.89%, 91.38% and 0.907 respectively.

Discussion:

This cross-sectional study was conducted at the Department of Radiology and Imaging, Dhaka Medical College Hospital, Dhaka, from July 2021 to June 2023. 58 participants were selected after meeting inclusion criteria and data was collected by using a preformed data sheet. Patient's information was obtained using information sheet which includes questionnaire, clinical findings & imaging findings. Duplex study reports & endoscopic reports were collected.

One of the most common cirrhosis consequences is the development of portal hypertension and esophageal varices.[10] There are numerous noninvasive approaches for detecting portal hypertension, but none of them are perfect. Several researchs have been conducted in the past to create non-invasive markers to predict the development of EV, hence lowering the expense and complications associated with EGD. It is now understood that having a palpable spleen and a low platelet count are independent predictors of lower esophageal varices in cirrhosis patients.[11] Another study found that patients with at least two of the following three conditions: ascites, splenomegaly, and drinking are more likely to develop extensive esophageal varices.[12]

In individuals at high risk of EV hemorrhage, endoscopic screening is currently suggested in conjunction with primary prophylaxis. In addition to being invasive, endoscopic screening may not be offered on a constant basis, particularly in underdeveloped nations.[13] As a result, in certain instances, a non-invasive diagnosis of portal hypertension may be beneficial. Non-invasive predictors of esophageal varices include prothrombin time, splenomegaly, spider naevi, Child-Pugh class, hyperbilirubinemia, platelet count/spleen diameter ratio, and blood markers of fibrosis.[14] However, all of these require validation. Ultrasonography is a well-established imaging modality that is extremely useful in the early stages of diagnosing cirrhosis and portal hypertension.[15] Color Doppler of the portal circulation has been demonstrated to be effective in predicting variceal hemorrhage in cirrhosis. In the examination of many patients with advanced liver disease, ultrasound has taken the place of contrast angiography, which is intrusive, uncomfortable, and expensive.[16]

The study revealed that, 40 were diagnosed as esophageal varices with a congestion index greater than 0.1, and 37 of these were confirmed by endoscopy. These were true positive cases. Three instances were diagnosed with a congestion index greater than 0.1 but not verified by endoscopy. These were false positive cases. Out of 39 instances verified by endoscopy, two were not diagnosed with a congestion score greater than 0.1. These were false negative cases. The remaining 16 instances were not confirmed by either endoscopic or congestion index. And the validity test findings. The Congestion Index study's cut off point, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy and Area Under Curve (AUC) in predicting esophageal varices were 0.977, 94.87%, 84.21%, 92.50%, 88.89%, 91.38% and 0.907 respectively.

Previous research has revealed that the hemodynamics of the left gastric vein are superior than those of the portal vein in predicting patients with cirrhosis who are more likely to bleed.[17] However, it has not been found to be more effective than the portal vein in detecting the existence of esophageal varices. Similarly, the ratio of splenic vein flow volume to portal trunk flow volume (SV/PT) could be useful in predicting esophageal variceal bleed.[18] The liver vascular index, which is determined as the ratio of portal venous velocity to hepatic artery pulsatility index, has also been found to be beneficial in the diagnosis of portal hypertension. Some recent research investigating non-invasive approaches to predict the occurrence of EV and PHT failed to demonstrate the utility of PVI in identifying EV or PHT.[19]

A cross-sectional analysis was conducted on patients with confirmed portal hypertension who underwent endoscopic screening for esophageal varices and Duplex ultrasound. PVCI measurements were compared with endoscopic findings to establish

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correlations. Results indicated that a higher PVCI was significantly associated with the presence of esophageal varices and their grading. The optimal PVCI cutoff value for predicting clinically significant varices was identified, demonstrating high sensitivity and specificity.

Limitations of the study:
The present study was conducted in a very short period due to time constraints and funding limitations. The small sample size was also a limitation of the present study.

Conclusion:
The Duplex Ultrasound evaluation of the Portal Vein Congestion Index (PVCI) demonstrates promising utility as a non-invasive predictor of esophageal varices in patients with portal hypertension. By quantifying hemodynamic changes in the portal vein, the PVCI serves as an indirect marker for variceal development. The integration of PVCI measurement into clinical practice could improve the management of portal hypertension and its complications, offering a safer and more accessible alternative to traditional diagnostic methods.

Recommendation:
This study can serve as a pilot to much larger research involving multiple centers that can provide a nationwide picture, validate regression models proposed in this study for future use and emphasize points to ensure better management and adherence.

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