IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 23, Issue 12 Ser. 1 (December. 2024), PP 76-84
www.iosrjournals.org

Diagnostic Accuracy of Portal Vein Duplex Ultrasound in Predicting Oesophageal Varices: A Cross-sectional Study

Dr. Ahmed Imran[1], Dr. Nargis Akter[2], Dr Toufiqe-E-Ealahi[3], Dr. Tasmia Tanjum[4], Dr Afsana Naznin[5], Professor Dr. Shahara Haque [6]

[1]*MCPS (Radiology & Imaging), MD Resident, Department of Radiology & Imaging, Dhaka Medical College Dhaka, Bangladesh.*
[2]*Lecturer, Department of Pharmacology & Therapeutics Comilla Medical College, Cumilla, Bangladesh.*
[3]*Registrar, Department of Neurology, Sher e Bangla Medical College, Hospital, Barisal, Bangladesh.*
[4]*Radiologist, Sir Salimullah Medical College & Mitford Hospital, Dhaka, Bangladesh.*
[5]*Lecturer, Department of Pharmacology & Therapeutics, Dhaka Medical College, Dhaka, Bangladesh.*
[6]*Professor & Head, Department of Radiology & Imaging, Dhaka Medical College, Dhaka, Bangladesh*
***Corresponding Author:** Dr. Ahmed Imran, MCPS, MD, MD Resident, Department of Radiology & Imaging, Dhaka Medical College, Dhaka, Bangladesh.*

Abstract:
Background: *Variceal rupture is the most common fatal complication of cirrhosis and liver disease severity increases the likelihood of varices and hemorrhage. The medical team must accurately forecast oesophageal varices (EV) bleeding in liver cirrhosis patients. Today, comprehensive diagnosis of portal hypertension (PHT) needs measurement of the portosystemic gradient, the most precise indicator of EV development.* ***Objective:*** *The aim of the current study is to investigate the relation between the Duplex sonographic portal vein indices (PVV, PVD & HCI) with oesophageal 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. The main objective of this study was to evaluate the usefulness of Duplex study of portal vein for prediction of esophageal varices in liver cirrhosis by measuring congestion index, velocity & diameter of portal vein***:** *Purposive type of Non-random sampling was done. Eligibility criteria of Inclusion criteria were patient with known case of cirrhosis of liver on the basis of history, physical examination, liver biochemistry & USG and adult patient of both genders. 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:*** *Majority of the study participants (17, 29.3%) were aged between 40 to 49 years old. Mean ± SD of the study participants was 50.17 ± 12.26 years, with range 27 - 73. Most of the participants (45, 77.65%) were male. Male female ratio was Male: Female = 3.46:1. Every participant was presented with anorexia and fatigue, none of the participants presented with hepatic encephalopathy. Majority of the participants (45, 77.6%) were infected with hepatitis B virus, followed by (9, 15.5%) participants who were infected by hepatitis C virus and rest of the participants were suffering from due to liver cirrhosis due to other causes. Majority of the participants (42, 72.4%) had increased portal vein diameter and the mean ± SD was 13.89 ± 1.59.* ***Conclusion:*** *Except for portal vein velocity, all studied portal vein indices demonstrated a significant correlation with the presence of EV on EGD ($p<0.05$). The sensitivity of each of these three parameters was 94.87%. The congestion index had the highest specificity at 84.21% and the highest negative predictive value at 88.89%. Positive predictive value was also highest for the congestion index at 92.50%, and accuracy was highest at 91.38%. This research indicates that the congestion index is the superior predictive tool.*

Keywords: *EV, PVD, PVV, congestion index, cirrhosis.*

Date of Submission: 05.12.2024 Date of Acceptance: 16.12.2024

I. Introduction

Liver cirrhosis is defined as a chronic disease of the liver with destruction of the hepatic parenchymal cells. Pathologically, it is characterized by hepatic parenchymal necrosis, and fibrosis of the perivascular connective tissue. There is degeneration of the hepatocyte and formation of irregular regenerating nodules.

Clinically, fibrosis and distortion of the portal and periportal architecture causes portal hypertension with the resulting ascites and variceal hemorrhage. [1]

Ooesophageal varices refer to the enlargement of submucosal veins located in the distal oesophagus, which serve as a connection between the portal and systemic circulatory systems. This phenomenon occurs as a consequence of portal hypertension which is frequently associated with cirrhosis as well as resistance to the flow of portal blood and an elevation in portal venous blood inflow. Variceal rupture is the prevailing fatal complication associated with cirrhosis whereby the severity of liver disease exhibits a positive correlation with the occurrence of varices and the subsequent risk of bleeding. [2]

Portal hypertension is one of the most serious complications of cirrhosis of the liver. The most significant clinical manifestation of portal hypertension is gastrooesophageal varices. Oesophageal varices (OV) are present in approximately 50% of cirrhotic patients. [3] Approximately 50% of patients with cirrhosis develop gastrooesophageal varices. A cirrhotic patient who does not have varices has not yet developed portal hypertension or his or her portal pressure is not yet high enough for varices to develop. As portal pressure increases, the patient may progress to having small varices. With time as the hyperdynamic circulation increases, blood flow through the varices will increase, thus raising the tension in the wall. Variceal hemorrhage resulting from rupture occurs when the expanding force exceeds the maximal wall tension if there is no modification in the tension of the wall, there will be a high risk of recurrence. [4] Multiple liver vascular indices are in use now e.g., Splenoportal index (SPI), Hepatic artery pulsatility index (HAPI), Hepatic artery resistivity index (HARl), Splenic artery pulsatility index (SAPI), Splenic artery resistivity index (SARI) etc. [5] Among them there are very few studies investigated the relationship between sonographic portal vein diameter (PVD), portal vein velocity (PVV) and congestion index (Cl) with portal hypertension or development of early oesophageal varices. Some studies showed positive relationship among CI and early oesophageal varices and thus proposed Duplex sonography as a good alternative diagnostic modality, while others have totally questioned the role of sonography in diagnosis of cirrhosis. [6]

Duplex sonography is a non-invasive method to assess splanchnic arterial and venous vasculature. Portal vein diameter >13 mm suggests portal hypertension. [7] Thus, a large portal vein suggests portal hypertension. In portal hypertension, portal vein velocity tends to fall and when less than 16 cm per sec, portal hypertension is likely. Congestive index is another portal vein indices calculated as the ratio between cross sectional area of portal vein and mean portal vein velocity. Normal value of congestion index is 0.07± 0.029. This is high in patients with varices. [8] When congestion index exceeds 0.1, portal hypertension was diagnosed with 95% sensitivity and specificity. [9]

II. Methodology

This cross-sectional study was carried out in the Department of Radiology & Imaging, Dhaka Medical College Hospital, Dhaka, during July, 2021 to June, 2023 (2 years). A total of 58 patients were participated in the study. 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. **Eligibility criteria**: Inclusion criteria were patient with known case of cirrhosis of liver on the basis of history, physical examination, liver biochemistry & USG and adult patient of both genders. Exclusion criteria were patient who refuse to be enrolled in study, patient who has previously sclerotherapy or band ligation of oesophage transjugular intrahepatic portosystemic stent shunt or surgery from portal hypertension, patients taking drug for primary prophylaxis of variceal bleeding, patient with heart failure, patient with cavernous transformation of portal vein, patient with hepatic, splenic or portal vein thrombosis and patient with severe abdominal and chest or renal disease. **Data Collection and Processing:** After taking consent and matching eligibility criteria, data were collected from patients on variables of interest using the predesigned structured questionnaire by interview, observation. To collect data, face to face interview has been carried out with a standardized semi-structured questionnaire. Alongside, the medical records of the patients have been reviewed. Data regarding sociodemographic background, diabetic and smoking status has been collected and recorded. Collected data were edited and Statistical analyses of the results were be obtained by using window-based Microsoft Excel and Statistical Packages for Social Sciences (SPSS-24). Frequency and percentages have been depicted for qualitative data and mean and standard deviation has been calculated for quantitative data.

III. Result

This cross-sectional study was carried out in the Department of Radiology & Imaging, Dhaka Medical College Hospital, Dhaka, during July, 2021 to June, 2023 (2 years). A total of 58 patients were participated in the study. 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.

Table-I: Age distribution of the participants (N=58)

Age (years)	n=58	%
27-30	2	3.4
30-39	12	20.7
40-49	17	29.3
50-59	12	20.7
60-69	11	19
70-73	4	6.9
Mean ± SD	50.17 ± 12.26	
Range	27 to 73	

Table-I shows that majority of the study participants (17, 29.3%) 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.

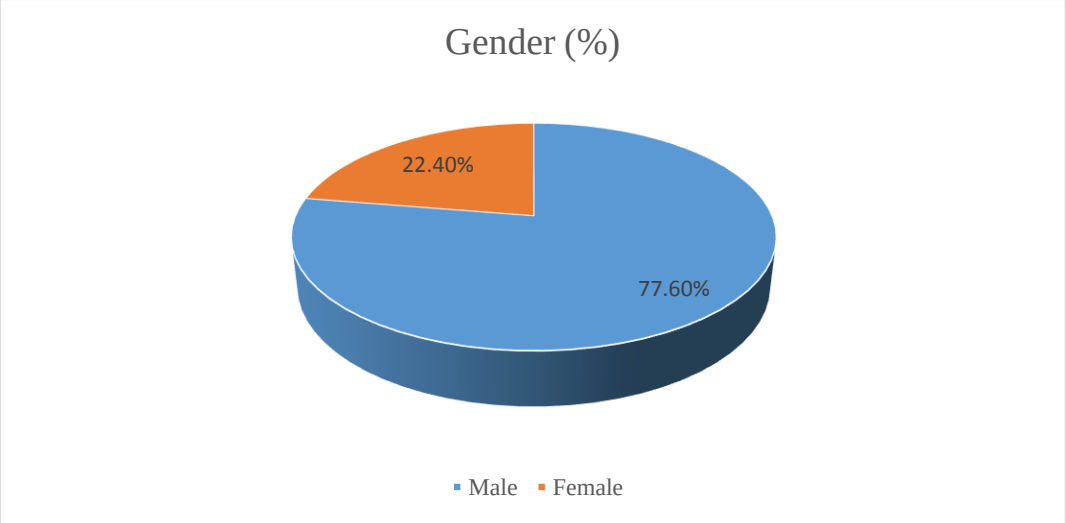

Figure-I: Gender distribution of the study participants (N=58)

Figure I show that most of the participants (45, 77.65%) were male where Male to Female ratio was 3.46: 1

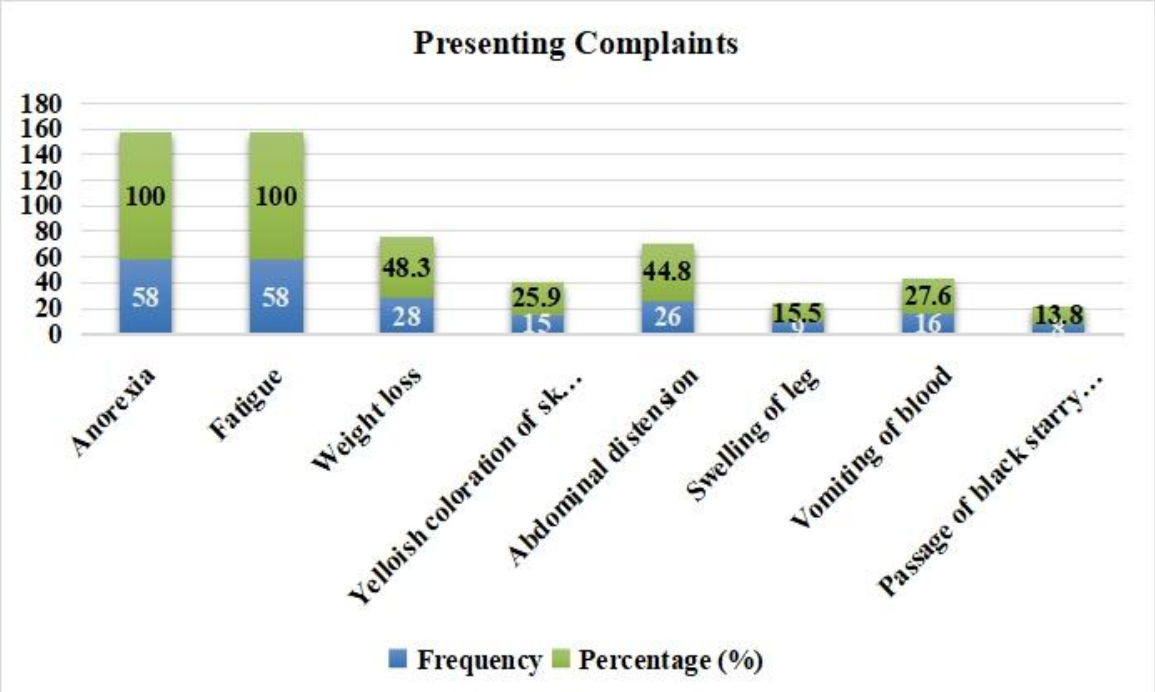

Figure II: Presenting complaints of the study participants (N=58)

Figure-II shows that, every participant was presented with anorexia and fatigue, followed by weight loss (24, 48.3%), abdominal distension (26, 44.8%), vomiting of blood (16, 27.6%), yellowish coloration of skin, sclera and urine (15, 25.9%), swelling of leg (9, 15.5%) and passage of black tarry stool (8, 13.8%).

Table-II: 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-II shows 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.

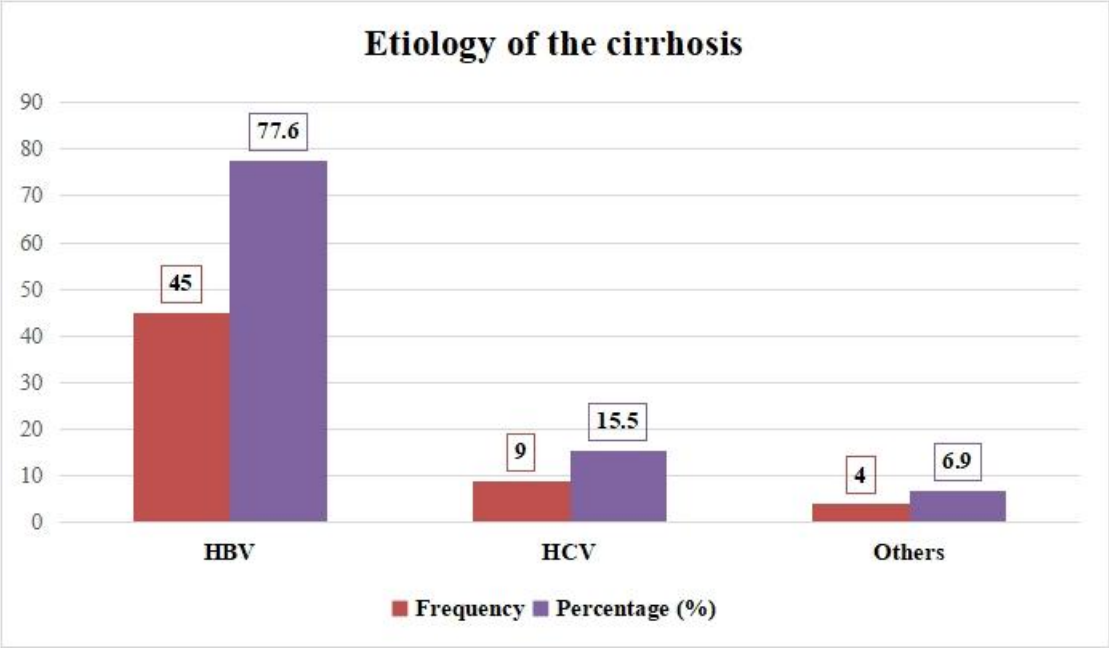

Figure III: Etiology of the liver cirrhosis of the study participants (N=58)

Figure-III shows that, majority of the participants (45, 77.6%) were infected with hepatitis B virus, followed by (9, 15.5%) participants who were infected by hepatitis C virus and rest of the participants were suffering from liver cirrhosis due to other causes.

Table-III: B-mode USG findings of the participants (N=58)

Variables	n	%
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
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	

Table-III shows 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-IV: Color doppler study findings of the participants (N=58)

Variables	n	%
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

Table-IV shows 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-V: Endoscopy findings of the participants (N=58)

Variables	n	%
Oesophageal varices		
Present	39	67.2
Absent	19	32.8

Grading		
Grade-I	14	35.9
Grade-II	22	56.4
Grade-III	3	7.7

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

Table-VI: Correlation of portal vein diameter and oesophageal varices (N=58)

Endoscopic diagnosis	**Portal Vein diameter (mm)**		**Total**	**p-value**
	PV diameter > 13	PV diameter ≤ 13		
	Frequency (%)	Frequency (%)		
Present	37 (94.9) (TP)	2 (5.1)(FN)	39	
Absent	5 (26.3)(FP)	14 (73.7) (TN)	19	
Total	42	16	58	< 0.001[s]

Table-VI shows that, out of 58 cases 42 were diagnosed as oesophageal varices by PVD more than 13mm and among them 37 were confirmed by endoscopy. They were true positive cases. 5 cases were diagnosed by PVD more than 13mm, 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 PVD more than 13mm. They were false negative cases.

Table-VII: Validity parameter of portal vein diameter in prediction of oesophageal varices

Validity parameter	**Value (%)**	**95% Confidence Interval**	
		Lower limit	Upper Limit
Prevalence of varices	67.24%	0.5366	0.7899
Sensitivity	94.87%	0.8268	0.9937
Specificity	73.68%	0.4880	0.9085
Positive predictive value	88.10%	0.7437	0.9602
Negative predictive value	87.50%	0.6165	0.9845
Accuracy	87.93%	0.7670	0.9501

Table-VII shows the Validity test results. Sensitivity, Specificity, Positive predictive value (PPV), Negative predictive value (NPV) and Accuracy of portal vein diameter study findings in prediction of oesophageal varices were 94.87%, 73.68%, 88.10%, 87.50% and 87.93%, respectively.

Table-VIII: Correlation of portal vein velocity and oesophageal varices (N=58)

Endoscopic diagnosis	**Portal Vein velocity (cm/s)**		**Total**	**p-value**
	PV velocity < 16	PV velocity ≥ 16		
	Frequency (%)	Frequency (%)		
Present	37 (94.9) (TP)	2 (5.1) (FN)	39	
Absent	16 (84.2) (FP)	3 (15.8) (TN)	19	
Total	53	5	58	>[a]0.318[ns]

Table-VIII shows that, out of 58 cases 53 were diagnosed as oesophageal varices by PVV less than 16cm/s and among them 37 were confirmed by endoscopy. They were true positive cases. 16 cases were diagnosed by PVV less than 16cm/s, 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 PVV less than 16cm/s. They were false negative cases. Rest of the 3 cases were neither confirmed by endoscopy nor by PVV. So, they were true negative cases.

Table-IX: Validity parameter of portal vein velocity in prediction of oesophageal varices

Validity parameter	**Value (%)**	**95% Confidence Interval**	
		Lower limit	Upper Limit
Prevalence of varices	67.24%	0.5366	0.7899
Sensitivity	94.87%	0.8268	0.9937
Specificity	15.79%	0.0338	0.3958
Positive predictive value	69.81%	0.5566	0.8166
Negative predictive value	60%	0.1466	0.9473

Accuracy	68.97%	0.5546	0.8046

Table-IX shows the Validity test results. Sensitivity, Specificity, Positive predictive value (PPV), Negative predictive value (NPV) and Accuracy of portal vein velocity study findings in prediction of oesophageal varices were 94.87%, 15.79%, 69.81%, 60% and 68.97%, respectively.

Table-X: Correlation of congestion index and oesophageal 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	

Table-X shows that, out of 58 cases 40 were diagnosed as oesophageal 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. Rest of the 16 cases were neither confirmed by endoscopy nor by congestion index. So, they were true negative cases.

Table-XI: Validity parameter of congestion index in prediction of oesophageal varices

Validity parameter	Value (%)	95% Confidence Interval	
		Lower limit	Upper Limit
Prevalence of varices	67.24%	0.5366	0.7899
Sensitivity	94.87%	0.8268	0.9937
Specificity	84.21%	0.6042	0.9662
Positive predictive value	92.50%	0.7961	0.9843
Negative predictive value	88.89%	0.6529	0.9862
Accuracy	91.38%	0.8102	0.9714

Table-XI shows the Validity test results. Sensitivity, Specificity, Positive predictive value (PPV), Negative predictive value (NPV) and Accuracy of Congestion Index study findings in prediction of oesophageal varices were 94.87%, 84.21%, 92.50%, 88.89% and 91.38%, respectively.

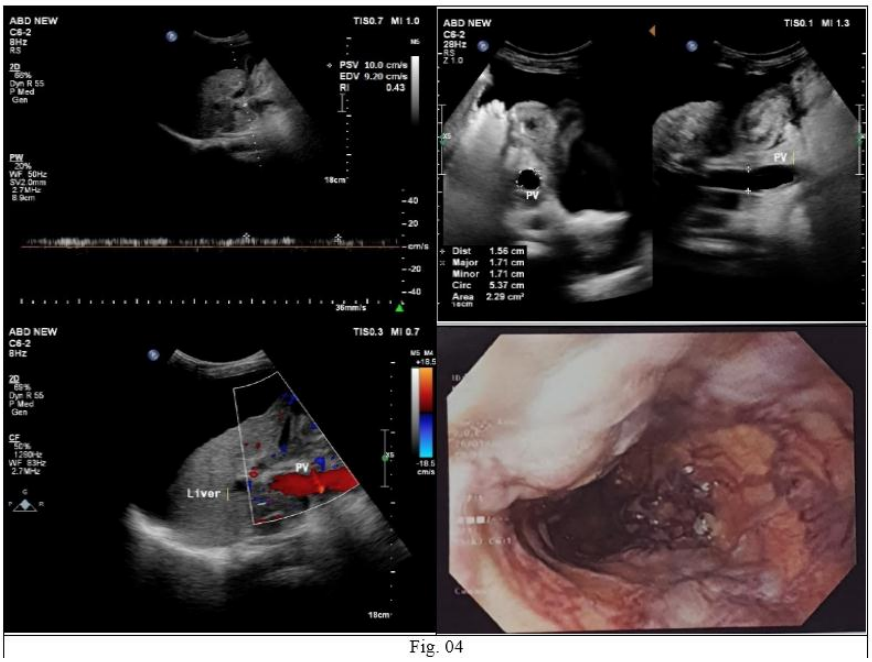

Fig. 04

Endoscopic Correlation with Duplex Ultrasound Fig. 04. 59y female patient with chronic liver disease Doppler US of PV showing portal vein diameter 15.6mm, portal vein mean velocity 9.66cm/sec, hepatopetal flow and calculated congestion index >0.1, Upper GI endoscopy showing grade III esophageal varices.

IV. Discussion

In this present study, majority of the study participants (17, 29.3%) were aged between 40 to 49 years old, which means, most of the participants were lied in fourth decade of life. Mean ± SD of the study participants was 50.17 ± 12.26 years, with range (27 to 73). The finding of this study was almost similar with Mahmoud et al. where they observed a mean age of 50.7 ± 11.7 years of their participants. [10] In this study, most of the participants (45, 77.65%) were male. This Finding was almost similar with Mansoor et al., 2019, where they performed their study on 200 patients and observed that 137 (68.50%) were males and 63 (31.50%) were females with male to female ratio of 2.17:1. [11]

Here, every participant was presented with anorexia and fatigue, followed by weight loss (24, 48.3%), abdominal distension (26, 44.8%), vomiting of blood (16, 27.6%), yellowish coloration of skin, sclera and urine (15, 25.9%), swelling of leg (9, 15.5%) and passage of black tarry stool (8, 13.8%). None of the participants presented with hepatic encephalopathy. Similar symptoms and signs were reflected in the studies performed by Devrajani et al. where clinical manifestation of 100 patients were splenomegaly in 82, clinical jaundice in 78, ascites in 77, palmer erythema in 67, hematemesis in 26 patients. [12] The clinical signs noted among the patients were most commonly ascites and icterus constituting 90% and pedal edema accounting to about 80%.

The study finding was slightly different from Mahmoud et al. where they found, the etiology of liver cirrhosis in their patients was due to hepatitis C virus (HCV) infection in 64 patients (79.1%) and hepatitis B virus (HBV) infection in eight patients (9.8%), while other etiologies were found in nine patients (11.1%). [13] In this study, 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. Shastri et al. found that (40, 80%) had ascites and splenomegaly. [14] Here, majority of the participants (42, 72.4%) had increased portal vein diameter and the mean ± SD was 13.89 ± 1.59.

In this study, among 58 participants, (19, 32.8%) had no varices and (39, 67.2%) participants had oesophageal varices. Among them (14, 35.9%) had grade-I, (22, 56.4%) had grade-II and (3, 7.7%) had grade-III. Tarzamni et al. stated that 13 patients had EV grade-I, 37 grade-III and 19 grade -III. [15] Elhady Sheta et al. observed that among 100 cirrhotic patients, 43 patients had no varices. [16] 10 patients were found to have grade I EV, 15 patients were found to have grade II EV and 32 were found to have grade III EV.

As evident from the results above, except portal vein velocity, other portal vein indices under study correlated significantly with the presence of EV on EGD ($p < 0.05$). Among these parameters, sensitivity of all three parameters was 94.87%. Congestion index had the highest specificity of 84.21%, highest negative predictive value of 88.89%. Positive predictive value was also highest for congestion index at 92.50% and accuracy at 91.38%. Shastri et al., observed that all the portal vein indices under study correlated significantly with the presence of EV on EGD ($p < 0.05$). [14] Among these parameters, PVV had the highest sensitivity of 84%. PVD and HCI had the highest specificity of 55% and highest negative predictive value of 38%. Positive predictive value was highest for PVV at 76%. In our study, we found that congestion index is the better prediction tool, which is consistent with findings of previous studies done by Nouh et al. [17]

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.

V. Conclusion

By evaluating the congestion index, portal vein diameter and velocity can help physicians as noninvasive predictors of esophageal varices in cirrhotic patients, reducing the need for unnecessary endoscopic screening. This is particularly valuable in clinical settings where there are limited resources and endoscopic facilities are not available in all areas. The congestion index is a reliable indicator for predicting the occurrence of bleeding oesophageal varices. Patients with a portal congestion index exceeding 0.10 are particularly susceptible to experiencing bleeding oesophageal varices. Considering the other duplex parameter, it can be concluded that the congestion index is a useful diagnostic tool for predicting oesophageal varices.

VI. 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.

Acknowledgements

The wide range of disciplines involved in the determination of congestion index, portal vein diameter & velocity by duplex study for prediction of oesophageal varices in cirrhotic patient's. We were very much thankful to the patients who participated in the current study.

References

[1]. Shateri K, Mohammadi A, Moloudi F, Nosair E, Ghasemi-rad M. Correlation between sonographic portal vein diameter and flow velocity with the clinical scoring systems MELD and CTP in cirrhotic patients: is there a relationship? Gastroenterology Research. 2012 Jul 7;5(3):112-9.

[2]. Nigatu A, Yap JE, Chuy KL, Go B, Doukky R. Bleeding risk of transesophageal echocardiography in patients with esophageal varices. Journal of the American Society of Echocardiography. 2019 May 1;32(5):674-6.

[3]. Merli M, Nicolini G, Angeloni S, Rinaldi V, De Santis A, Merkel C, Attili AF, Riggio O. Incidence and natural history of small esophageal varices in cirrhotic patients. Journal of hepatology. 2003 Mar 1;38(3):266-72.

[4]. LaBrecque D, Khan AG, Sarin SK, Le Mair AW. Esophageal varices. World Gastroenterology Organisation global guidelines [Internet]. 2014.

[5]. Liu CH, Hsu SJ, Liang CC, Tsai FC, Lin JW, Liu CJ, Yang PM, Lai MY, Chen PJ, Chen JH, Kao JH. Esophageal varices: noninvasive diagnosis with duplex Doppler US in patients with compensated cirrhosis. Radiology. 2008 Jul;248(1):132-9.

[6]. Shateri K, Mohammadi A, Moloudi F, Nosair E, Ghasemi-rad M. Correlation between sonographic portal vein diameter and flow velocity with the clinical scoring systems MELD and CTP in cirrhotic patients: is there a relationship? Gastroenterology Research. 2012 Jul 7;5(3):112-9.

[7]. Rumack CM, Wilson SR, William J, Levine D. Diagnostic ultrasound 4th edition. Chapter-9: the kidney and urinary tract. 2011:317-91.

[8]. Sherlock S. Diseases of the liver and biliary system. 2011.

[9]. Haag K, Rössle M, Ochs A, Huber M, Siegerstetter V, Olschewski M, Berger E, Lu SH, Blum HE. Correlation of duplex sonography findings and portal pressure in 375 patients with portal hypertension. AJR. American journal of roentgenology. 1999 Mar;172(3):631-5.

[10]. Mahmoud HS, Mostafa EF, Mohammed MA. Role of portal haemodynamic parameters in prediction of oesophageal varices in cirrhotic patients. Arab Journal of Gastroenterology. 2014 Sep 1;15(3-4):130-4.

[11]. Mansoor A, Shaukat R, Chaudhary AN, Jehan G. Diagnostic accuracy of Doppler ultrasonography in predicting presence of esophageal varices in patients with hepatitis-C induced cirrhosis. J Coll Physicians Surg Pak. 2019 Jul 1;29(7):612-5.

[12]. Devrajani BR, Soomro AA, Attra KM, Qureshi GA. Variceal bleeding and its dependence on portal vein size in liver cirrhotic patients. Advances in Medical and Dental Sciences. 2009 Sep 1:60-5.

[13]. Mahmoud HS, Mostafa EF, Mohammed MA. Role of portal haemodynamic parameters in prediction of oesophageal varices in cirrhotic patients. Arab Journal of Gastroenterology. 2014 Sep 1;15(3-4):130-4.

[14]. Shastri M, Kulkarni S, Patell R, Jasdanwala S. Portal vein Doppler: a tool for non-invasive prediction of esophageal varices in cirrhosis. Journal of clinical and diagnostic research: JCDR. 2014 Jul;8(7):MC12.

[15]. Tarzamni MK, Somi MH, Farhang S, Jalilvand M. Portal hemodynamics as predictors of high-risk esophageal varices in cirrhotic patients. World Journal of Gastroenterology: WJG. 2008 Mar 3;14(12):1898.

[16]. Elhady Sheta, Yousef M, Abd-Elsalam S, Mohamed RE, Ismail A, El-Kalla F, Mansour L, Kobtan A, Elhendawy M, Elsabagh HM. Noninvasive diagnosis of esophageal varices: can it replace screening endoscopy. Int J Curr Microbiol App Sci. 2016;5(5):701-15.

[17]. Nouh MA, Abd-Elmageed MK, Amer AA, ELhamouly MS. Role of portal color Doppler ultrasonography as noninvasive predictive tool for esophageal varices in cirrhotic patients. Egyptian Journal of Radiology and Nuclear Medicine. 2022 Dec; 53:1-1.