



Endoscopic ultrasound-guided portal pressure gradient measurement in managing portal hypertension

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Abstract

Portal hypertension (PH) is still a challenging clinical condition due to its silent manifestations in the early stage and needs to be measured accurately for early detection. Hepatic vein pressure gradient measurement has been considered as the gold standard measurement for PH; however, it needs special skill, experience, and high expertise. Recently, there has been an innovative development in using endoscopic ultrasound (EUS) for the diagnosis and management of liver diseases, including portal pressure measurement, which is commonly known as EUS-guided portal pressure gradient (EUS-PPG) measurement. EUS-PPG measurement can be performed concomitantly with EUS evaluation for deep esophageal varices, EUS-guided liver biopsy, and EUS-guided cyanoacrylate injection. However, there are still major issues, such as different etiologies of liver disease, procedural training, expertise, availability, and cost-effectiveness in several situations with regard to the standard management.

Key Words: Portal hypertension; Hepatic vein; Endoscopic ultrasound; Portal pressure

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Core Tip: Portal hypertension (PH) is a challenging clinical condition due to its silent manifestations in the early stage. Hepatic vein pressure gradient measurement is still the gold standard for PH diagnosis; however, it is not recommended for a routine measurement in daily practice. Esophagogastroduodenoscopy is still the main procedure for variceal screening due to PH. Recently, there has been a development in using endoscopic ultrasound (EUS) for managing liver diseases. EUS-guided portal pressure gradient measurement seems to be a promising method in the future for early detection and management of PH.

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INTRODUCTION

Portal hypertension (PH) is a challenging clinical condition due to its silent manifestations in the early stage and it needs to be measured accurately for early diagnosis. PH is defined when there is an increase of portal pressure above 5 mmHg. Clinically significant PH (CSPH) is defined when the portal pressure reaches 10 mmHg and above. CSPH is an important clinical condition because of its clinical consequences, such as the presence of esophageal and gastric varices, ascites, kidney dysfunction, as well as cardiopulmonary complications. These conditions are mostly observed in liver cirrhotic patients with liver disease progression, even though there are non-cirrhotic conditions with PH[1,2]. Hepatic vein pressure gradient (HVPG) measurement has been considered as the gold standard measurement for PH; however, it needs special skill, experience, and high expertise. This procedure also needs to be performed in a dedicated catheterization procedure room[3]. Esophagogastroduodenoscopy (EGD) is a standard procedure for early detection of PH complications, *i.e.*, the presence of varices[4,5]. A major drawback is that these two procedures might not be performed in the same session. Another issue in clinical practice is that not all cases might have accurate portal pressure measurement through this indirect measurement procedure due to the pathology of the portal vein (PV), which does not include the liver architecture disturbance[6,7]. Recently, there has been innovation for portal pressure measurement through endoscopic ultrasound (EUS). The liver images as well as the liver vascularity will be shown clearly for puncture location. However, it needs special skill and knowledge to perform the procedure[8]. In our center, this procedure is also only performed by endoscopists with more than ten years of clinical experience (Figures 1A and B). This review will discuss the role of EUS in portal pressure measurement and its impact in clinical practice.

PH, portal pressure measurement, and issues in clinical practice

PH has been divided into prehepatic, intrahepatic, and post-hepatic. This condition happens due to increased portal blood flow resistance, where it is mostly caused by intrahepatic vascular resistance in chronic liver disturbances. Imbalanced activation between vasoconstrictors and vasodilators due to liver architectural disturbance is the main key to the development of PH. In non-cirrhotic condition, or commonly known as non-cirrhotic PH (NCPH), PV fibrosis or thrombosis is the main issue[9,10].

HVPG measurement is the gold standard for PH assessment. This measurement technique is considered safer than direct measurement *via* transhepatic or transvenous catheterization because a more advanced approach to the inferior vena cava will be required for portal pressure gradient (PPG) measurement. HVPG has been considered as a safe procedure. However, there are several patient conditions which need special attention, such as cardiopulmonary disorders, hepatic encephalopathy, history of cardiac arrhythmias, and evidence of vena cava thrombosis. There are also some possible conditions which can happen during the procedure itself, such as allergic reaction to contrast agent, cardiac arrhythmia during catheter insertion *via* the transjugular route, and bleeding in patients with a very low platelet count or prolonged international normalized ratio[11,12]. On the other hand, this procedure is preferable in patients with significant ascites[3]. Based on HVPG measurement, the strategy of further management has been clearly defined with possible mortality rate. In the early stage, CSPH complications can be prevented with early medication. A randomized controlled trial of carvedilol *vs* endoscopic band ligation (EBL) by Tripathi *et al*[4] has showed that carvedilol has the same efficacy as EBL primary prophylaxis in terms of bleeding prevention. This study has also been supported by another more recent study by Shah *et al*[13] in a multicentre randomized controlled trial. A recent systematic review and meta-analysis by Dwinata *et al*[14] showed that carvedilol had similar efficacy to EBL for primary variceal bleeding prevention. Follow-up HVPG value can also be used to determine the response to the treatment and change to another strategy if needed. In the late stage of the disease or decompensated condition, more advanced complication prevention or advanced mana-



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Figure 1 Endoscopic ultrasound procedure. A: Endoscopic ultrasound evaluation in a liver cirrhosis patient with portal hypertension; B: Endoscopic ultrasound-guided portal pressure gradient measurement. Non-surgical Integrated Procedural Room, Hepatobiliary Endoscopy Unit, Dr. Cipto Mangunkusumo National General Hospital, Jakarta, Indonesia.

gement can be decided based on HVPg value[2]. Moitinho *et al*[15] showed the usefulness of early portal pressure measurement in acute variceal bleeding scenario. This prospective study concluded that higher HVPg value is associated with a longer interval between each hospital admission and lower mortality rate. Another study conducted by Ripoll *et al*[16] on 213 liver cirrhosis (LC) patients within a 6-year period showed that HVPg value with a 10 mmHg cut-off can be a good predictor of liver decompensation. The hazard ratio for liver decompensation of HVPg is higher than those of albumin level and model for end-stage liver disease score.

There has been a development of non-invasive methods for PH assessment. A prospective study by Bureau *et al*[17] on the use of transient elastography for PH prediction showed that there was a good correlation between liver stiffness and HVPg ($P < 0.001$). However, based on further analysis, the sensitivity and specificity were becoming higher in line with the increase of the liver stiffness. The main issues were the high value of liver stiffness due to the severity of liver fibrosis condition and varied etiologies of liver diseases[17]. Another prospective study conducted by Palaniyappan *et al*[18] on patients with advanced liver disease using magnetic resonance imaging (MRI) parameters, where the patients also underwent liver stiffness measurement (LSM) before the MRI examination, showed that two MRI parameters, *i.e.*, liver T1 relaxation time and splenic artery velocity, were significantly associated with HVPg values ($r = 0.90$, $P < 0.001$). Even though the LSM was significantly correlated to HVPg ($r = 0.791$, $P < 0.001$), no significant correlation was found in the subgroup of patients with an HVPg value more than 10 mmHg[18]. Another innovation of non-invasive method for assessing PH in clinical practice has been showed in a study by Frankova *et al*[19], where liver stiffness measured by ultrasound-based shear-wave elastography has been correlated well with HVPg values in all LC patients as well as in a subgroup of patients. The liver stiffness values of 16 and 20 mmHg were considered as the best predictive values associated with HVPg. In daily practice, non-invasive methods are still debatable due to their different study results and early detection for PH. MRI examination is also a major issue at present as a routine follow-up examination due to its cost, availability, and patients' comfort[20].

Metabolic condition, such as non-alcoholic fatty liver disease (NAFLD), now well-known as metabolic dysfunction associated fatty liver disease, might be a new challenge in the field of hepatology. It has been postulated that this condition might not have liver fibrosis progression and PH condition in the same line[21]. A prospective study published by Hirooka *et al*[22] revealed that there was a hemodynamic change in early course of the disease process in NAFLD patients, where patients were still in the early liver fibrosis condition based on the median hepatic arteriportal ratio together with splenic elasticity evaluation. Another database study conducted by Mendes *et al*[23] on 354 NAFLD patients showed that 6% of NAFLD patients without evidence of LC had PH complications. NCPH is another issue, where HVPg measurement may not be as good as it is. The complexity of the vascular system and liver pathology assessment for confirming diagnosis have been a challenging issue in clinical practice[24].

EGD is still the main procedure in daily practice to diagnose PH condition based on the presence of esophageal or gastric varices[25,26]. However, luminal evaluation does not always show a significant parameter for the presence of PH as well as in further management for PH[27].

EUS-PPG measurement in PH

Recently, there has been an innovative development in using EUS for diagnosis and management of liver diseases. It has been proposed as “endo-hepatology”, where endoscopic technique innovation can be used in the field of hepatology. It is started from EUS-guided liver biopsy, followed by the use of

EUS for abdominal fluid paracentesis, portal circulation, and EUS-guided intravascular injection for gastroesophageal varices[28,29].

The initial animal study by Lai *et al*[30] on feasibility of EUS-guided PV catheterization showed a good correlation between PV pressure (PVP) obtained through EUS procedure and *via* the transhepatic route ($r = 0.91$). Giday *et al*[31] conducted EUS-guided direct PVP measurement in pigs, and this study showed that there has been consistency in the pressure results, and no evidence of complications was recorded. Another pioneered animal study which used a novel device (compact manometer) was published by Huang *et al*[32], where the authors were able to show a good correlation between EUS approach and transjugular approach for right hepatic vein, PV, and aorta pressure measurements ($r = 0.985$). An innovative animal study on EUS-PPG measurement using a digital pressure wire showed that this method was safe, and there were no complications such as thrombus or bleeding[33]. A human pilot study was subsequently published by Huang *et al*[34], where 28 patients underwent EUS-PPG without any complications. The technical success rate was 100% and the PPG had a good correlation with varices ($P = 0.002$), low platelet count ($P = 0.036$), and gastropathy ($P = 0.007$). A recent study was conducted by Zhang *et al*[35] on the role of EUS-PPG measurement in patients with acute or subacute PH. In this study, the technical success was achieved in 91.7% of the cases, where EUS-PPG measurement had a higher success rate than HVPG measurement. A good correlation was showed through the manometry result between EUS-PPG value and HVPG value ($r = 0.852$). No adverse events were observed during examination. Recently, a retrospective study conducted by Choi *et al*[36] was looking at the correlation between portal pressure and clinical manifestations of PH. In that study, the PPG value was significantly higher in patients with LC (9.46 *vs* 3.61 mmHg; $P < 0.0001$), presence of gastroesophageal varices (13.88 *vs* 4.34 mmHg; $P < 0.0001$), and low platelet count (9.25 *vs* 4.71 mmHg; $P = 0.0022$). Seventy-one of 83 subjects underwent liver biopsy through EUS. No adverse events or complications were observed during and after the procedures. Lesmana[37] has recently published a technique innovation where EUS-PPG was conducted by using a standard manometer set in 13 patients diagnosed with PH. In this case series, two LC patients with Child-Pugh C liver function were included. One patient was diagnosed with NCPH. There were no adverse events or complications occurring during and after the procedure. Another more recent case report using a standard pressure monitor was published just to show the procedural steps and safety[38]. A systematic review and meta-analysis on EUS-PPG to diagnose cirrhosis showed that successful portal pressure measurement was achieved in 91.61% of the cases, with no post-procedural complications, such as bleeding, perforation, and infection (95% confidence interval: 0-2.85). However, based on pooled analysis, abdominal pain developed in 6.15% of cases, emergency department visit in 3.11%, and sore throat in 2.82%[39]. A very recent publication from Lei *et al*[40] on EUS-PPG in 52 LC patients showed that this method was successfully performed in 98% of the cases. The authors showed an innovative puncture location, *i.e.*, transduodenal route, where it can be an alternative location if conventional puncture location was difficult. This study also showed that none of the patients experienced any adverse event (Table 1).

Future directions

EUS-PPG measurement is a better method in portal pressure measurement and diagnosing all PH conditions, not limited to chronic liver disease patients only. However, there are several issues that still need to be discussed before it becomes a clinical recommendation in daily practice. First, EUS-PPG measurement can be performed concomitantly with EUS evaluation for the presence of deep esophageal varices or gastroesophageal varices. The clinical impact of EUS evaluation in the presence of deep esophageal varices in naïve patients as well as in patients with recurrent esophageal varices has been reported in several studies[41-43]. However, whether EUS evaluation is needed in the first setting in all patients with LC for deep varices evaluation is still debatable because there is no strong clinical evidence yet regarding its impact as the first-line examination, and there is a different course of liver disease progression based on each etiology. Second, EUS-PPG measurement can be performed together with EUS-guided liver biopsy; however, EUS-guided liver biopsy is not considered as a routine procedure yet in clinical practice due to the unavailability of standard training, limited experience and availability, and high cost when compared to percutaneous liver biopsy[44,45]. Last but not least, EUS-PPG measurement can be performed and then followed by EUS-guided cyanoacrylate injection for large or deep gastroesophageal varices as well as isolated gastric varices[37,46]. However, the need of EUS approach in acute variceal bleeding and the impact of interventional radiology procedures, such as transjugular intrahepatic porto-systemic shunt or balloon-occluded retrograde transvenous obliteration, are still becoming a long way discussion for managing PH complications[30,47].

CONCLUSION

EUS-PPG is a promising method in future clinical practice for managing PH condition and complications. However, it needs further studies and re-evaluation before it can be recommended as a routine clinical procedure.

Table 1 Endoscopic ultrasound portal pressure gradient study for portal hypertension assessment

Ref.	Type of study	Study design	Results	Technical success rate	Adverse events
Lai <i>et al</i> [30], 2004	Animal	Experimental	EUS-PVP correlated well with transhepatic catheterization ($r = 0.91$)	100%	None
Giday <i>et al</i> [31], 2008	Animal	Experimental	Consistent results of portal pressure measurements for 1 h	100%	None
Huang <i>et al</i> [32], 2016	Animal	Experimental	Excellent correlation between EUS and IR methods in all pressure range ($r = 0.985-0.99$)	100%	None
Schulman <i>et al</i> [33], 2017	Animal	Experimental	EUS-PPG results did not differ from transhepatic portal venule measurement	100%	None
Huang <i>et al</i> [34], 2017	Human ($n = 28$)	Pilot	EUS-PPG had an excellent correlation with clinical parameters of portal hypertension ($P < 0.05$)	100%	None
Zhang <i>et al</i> [35], 2021	Human ($n = 12$)	Cohort prospective	Good correlation between EUS-PPG and HVPG ($r = 0.923$)	91.7%	None
Choi <i>et al</i> [36], 2022	Human ($n = 83$)	Retrospective	EUS-PPG correlates well with clinical markers of portal hypertension ($P < 0.05$)	100%	None
Lesmana[37], 2022	Human ($n = 13$)	Case series	EUS-PPG showed consistent pattern of portal pressure	100%	None
Reddy <i>et al</i> [39], 2022	Human ($n = 128$)	Systematic review and meta-analysis	Good correlation between clinical portal hypertension and portal pressure gradients	91.61%	None
Lei <i>et al</i> [40], 2023	Human ($n = 52$)	Case series	EUS-PPG results are significantly higher in patients with a history of gastro-esophageal bleeding ($P < 0.05$)	98%	None

EUS-PPG: Endoscopic ultrasound portal pressure gradient; HVPG: Hepatic vein pressure gradient; PVP: Portal vein pressure; IR: Interventional radiology.

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FOOTNOTES

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REFERENCES

- Simonetto DA, Liu M, Kamath PS. Portal Hypertension and Related Complications: Diagnosis and Management. *Mayo Clin Proc* 2019; **94**: 714-726 [PMID: 30947834 DOI: 10.1016/j.mayocp.2018.12.020]
- Berzigotti A. Advances and challenges in cirrhosis and portal hypertension. *BMC Med* 2017; **15**: 200 [PMID: 29121925 DOI: 10.1186/s12916-017-0966-6]

- 3 **Berzigotti A**, Seijo S, Reverter E, Bosch J. Assessing portal hypertension in liver diseases. *Expert Rev Gastroenterol Hepatol* 2013; **7**: 141-155 [PMID: [23363263](#) DOI: [10.1586/egh.12.83](#)]
- 4 **Tripathi D**, Ferguson JW, Kochar N, Leithead JA, Therapondos G, McAvoy NC, Stanley AJ, Forrest EH, Hislop WS, Mills PR, Hayes PC. Randomized controlled trial of carvedilol versus variceal band ligation for the prevention of the first variceal bleed. *Hepatology* 2009; **50**: 825-833 [PMID: [19610055](#) DOI: [10.1002/hep.23045](#)]
- 5 **Garcia-Tsao G**, Bosch J, Groszmann RJ. Portal hypertension and variceal bleeding--unresolved issues. Summary of an American Association for the study of liver diseases and European Association for the study of the liver single-topic conference. *Hepatology* 2008; **47**: 1764-1772 [PMID: [18435460](#) DOI: [10.1002/hep.22273](#)]
- 6 **Hillaire S**, Bonte E, Denninger MH, Casadevall N, Cadranet JF, Lebrec D, Valla D, Degott C. Idiopathic non-cirrhotic intrahepatic portal hypertension in the West: a re-evaluation in 28 patients. *Gut* 2002; **51**: 275-280 [PMID: [12117894](#) DOI: [10.1136/gut.51.2.275](#)]
- 7 **Pande C**, Kumar A, Sarin SK. Non-cirrhotic portal fibrosis. A clinical profile of 366 patients. *Am J Gastroenterol* 2006; **101**: S191 [DOI: [10.14309/00000434-200609001-00439](#)]
- 8 **Lesmana CRA**, Paramitha MS, Gani RA, Lesmana LA. The role of endoscopic ultrasound for portal hypertension in liver cirrhosis. *J Med Ultrason (2001)* 2022; **49**: 359-370 [PMID: [34797476](#) DOI: [10.1007/s10396-021-01165-4](#)]
- 9 **Rodríguez-Vilarrupla A**, Fernández M, Bosch J, García-Pagán JC. Current concepts on the pathophysiology of portal hypertension. *Ann Hepatol* 2007; **6**: 28-36 [PMID: [17297426](#) DOI: [10.1016/S1665-2681\(19\)31950-7](#)]
- 10 **Khanna R**, Sarin SK. Non-cirrhotic portal hypertension - diagnosis and management. *J Hepatol* 2014; **60**: 421-441 [PMID: [23978714](#) DOI: [10.1016/j.jhep.2013.08.013](#)]
- 11 **Parikh S**. Hepatic venous pressure gradient: worth another look? *Dig Dis Sci* 2009; **54**: 1178-1183 [PMID: [18975087](#) DOI: [10.1007/s10620-008-0491-8](#)]
- 12 **Cueto-Robledo G**, Tapia-Paredes A, Garcia-Cesar M, Torres-Rojas MB, Flores-Romero RA, Roldan-Valadez E. Evaluation of Hepatic Hemodynamics (Hepatic Venous Pressure Gradient) During Right Heart Catheterization: A Comprehensive Review. *Curr Probl Cardiol* 2022; **47**: 101278 [PMID: [35671897](#) DOI: [10.1016/j.cpcardiol.2022.101278](#)]
- 13 **Shah HA**, Azam Z, Rauf J, Abid S, Hamid S, Jafri W, Khalid A, Ismail FW, Parkash O, Subhan A, Munir SM. Carvedilol vs. esophageal variceal band ligation in the primary prophylaxis of variceal hemorrhage: a multicentre randomized controlled trial. *J Hepatol* 2014; **60**: 757-764 [PMID: [24291366](#) DOI: [10.1016/j.jhep.2013.11.019](#)]
- 14 **Dwinata M**, Putera DD, Adda'i MF, Hidayat PN, Hasan I. Carvedilol vs endoscopic variceal ligation for primary and secondary prevention of variceal bleeding: Systematic review and meta-analysis. *World J Hepatol* 2019; **11**: 464-476 [PMID: [31183006](#) DOI: [10.4254/wjh.v11.i5.464](#)]
- 15 **Moitinho E**, Escorsell A, Bandi JC, Salmerón JM, García-Pagán JC, Rodés J, Bosch J. Prognostic value of early measurements of portal pressure in acute variceal bleeding. *Gastroenterology* 1999; **117**: 626-631 [PMID: [10464138](#) DOI: [10.1016/S0016-5085\(99\)70455-5](#)]
- 16 **Ripoll C**, Groszmann R, Garcia-Tsao G, Grace N, Burroughs A, Planas R, Escorsell A, Garcia-Pagan JC, Makuch R, Patch D, Matloff DS, Bosch J; Portal Hypertension Collaborative Group. Hepatic venous pressure gradient predicts clinical decompensation in patients with compensated cirrhosis. *Gastroenterology* 2007; **133**: 481-488 [PMID: [17681169](#) DOI: [10.1053/j.gastro.2007.05.024](#)]
- 17 **Bureau C**, Metivier S, Peron JM, Selves J, Robic MA, Gourraud PA, Rouquet O, Dupuis E, Alric L, Vinel JP. Transient elastography accurately predicts presence of significant portal hypertension in patients with chronic liver disease. *Aliment Pharmacol Ther* 2008; **27**: 1261-1268 [PMID: [18397389](#) DOI: [10.1111/j.1365-2036.2008.03701.x](#)]
- 18 **Palaniyappan N**, Cox E, Bradley C, Scott R, Austin A, O'Neill R, Ramjas G, Travis S, White H, Singh R, Thurley P, Guha IN, Francis S, Aithal GP. Non-invasive assessment of portal hypertension using quantitative magnetic resonance imaging. *J Hepatol* 2016; **65**: 1131-1139 [PMID: [27475617](#) DOI: [10.1016/j.jhep.2016.07.021](#)]
- 19 **Frankova S**, Lunova M, Gottfriedova H, Senkerikova R, Neroldova M, Kovac J, Kieslichova E, Lanska V, Urbanek P, Spicak J, Jirsa M, Sperl J. Liver stiffness measured by two-dimensional shear-wave elastography predicts hepatic vein pressure gradient at high values in liver transplant candidates with advanced liver cirrhosis. *PLoS One* 2021; **16**: e0244934 [PMID: [33411729](#) DOI: [10.1371/journal.pone.0244934](#)]
- 20 **Qi X**, Berzigotti A, Cardenas A, Sarin SK. Emerging non-invasive approaches for diagnosis and monitoring of portal hypertension. *Lancet Gastroenterol Hepatol* 2018; **3**: 708-719 [PMID: [30215362](#) DOI: [10.1016/S2468-1253\(18\)30232-2](#)]
- 21 **Baffy G**. Origins of Portal Hypertension in Nonalcoholic Fatty Liver Disease. *Dig Dis Sci* 2018; **63**: 563-576 [PMID: [29368124](#) DOI: [10.1007/s10620-017-4903-5](#)]
- 22 **Hirooka M**, Koizumi Y, Miyake T, Ochi H, Tokumoto Y, Tada F, Matsuura B, Abe M, Hiasa Y. Nonalcoholic fatty liver disease: portal hypertension due to outflow block in patients without cirrhosis. *Radiology* 2015; **274**: 597-604 [PMID: [25302830](#) DOI: [10.1148/radiol.14132952](#)]
- 23 **Mendes FD**, Suzuki A, Sanderson SO, Lindor KD, Angulo P. Prevalence and indicators of portal hypertension in patients with nonalcoholic fatty liver disease. *Clin Gastroenterol Hepatol* 2012; **10**: 1028-33.e2 [PMID: [22610002](#) DOI: [10.1016/j.cgh.2012.05.008](#)]
- 24 **Nicoară-Farcău O**, Rusu I, Ștefănescu H, Tanțău M, Badea RI, Procopet B. Diagnostic challenges in non-cirrhotic portal hypertension - porto sinusoidal vascular disease. *World J Gastroenterol* 2020; **26**: 3000-3011 [PMID: [32587444](#) DOI: [10.3748/wjg.v26.i22.3000](#)]
- 25 **Sarin SK**, Kumar A, Angus PW, Baijal SS, Baik SK, Bayraktar Y, Chawla YK, Choudhuri G, Chung JW, de Franchis R, de Silva HJ, Garg H, Garg PK, Helmy A, Hou MC, Jafri W, Jia JD, Lau GK, Li CZ, Lui HF, Maruyama H, Pandey CM, Puri AS, Reknimitr R, Sahni P, Saraya A, Sharma BC, Sharma P, Shiha G, Sollano JD, Wu J, Xu RY, Yachha SK, Zhang C; Asian Pacific Association for the Study of the Liver (APASL) Working Party on Portal Hypertension. Diagnosis and management of acute variceal bleeding: Asian Pacific Association for Study of the Liver recommendations. *Hepatol Int* 2011; **5**: 607-624 [PMID: [21484145](#) DOI: [10.1007/s12072-010-9236-9](#)]
- 26 **Lesmana CRA**, Raharjo M, Gani RA. Managing liver cirrhotic complications: Overview of esophageal and gastric varices. *Clin Mol Hepatol* 2020; **26**: 444-460 [PMID: [33053928](#) DOI: [10.3350/cmh.2020.0022](#)]
- 27 **Lesmana CRA**, Nababan SH, Kalista KF, Kurniawan J, Jasirwan COM, Sanityoso A, Hasan I, Gani R. Impact of

- endoscopic ultrasound examination for deep esophageal collateral veins evaluation in liver cirrhosis patients prior to endoscopic treatment: A case series. *PH&C* 2022; **1**: 76-81 [DOI: [10.1002/poh2.19](https://doi.org/10.1002/poh2.19)]
- 28 **Chang KJ**, Samarasena JB, Iwashita T, Nakai Y, Lee JG. Endo-hepatology: a new paradigm. *Gastrointest Endosc Clin N Am* 2012; **22**: 379-385, xi [PMID: [22632959](https://pubmed.ncbi.nlm.nih.gov/22632959/) DOI: [10.1016/j.giec.2012.04.010](https://doi.org/10.1016/j.giec.2012.04.010)]
 - 29 **Rudnick SR**, Conway JD, Russo MW. Current state of endohepatology: Diagnosis and treatment of portal hypertension and its complications with endoscopic ultrasound. *World J Hepatol* 2021; **13**: 887-895 [PMID: [34552695](https://pubmed.ncbi.nlm.nih.gov/34552695/) DOI: [10.4254/wjgh.v13.i8.887](https://doi.org/10.4254/wjgh.v13.i8.887)]
 - 30 **Lai L**, Poneris J, Santilli J, Brugge W. EUS-guided portal vein catheterization and pressure measurement in an animal model: a pilot study of feasibility. *Gastrointest Endosc* 2004; **59**: 280-283 [PMID: [14745408](https://pubmed.ncbi.nlm.nih.gov/14745408/) DOI: [10.1016/s0016-5107\(03\)02544-6](https://doi.org/10.1016/s0016-5107(03)02544-6)]
 - 31 **Giday SA**, Clarke JO, Buscaglia JM, Shin EJ, Ko CW, Magno P, Kantsevov SV. EUS-guided portal vein catheterization: a promising novel approach for portal angiography and portal vein pressure measurements. *Gastrointest Endosc* 2008; **67**: 338-342 [PMID: [18226699](https://pubmed.ncbi.nlm.nih.gov/18226699/) DOI: [10.1016/j.gie.2007.08.037](https://doi.org/10.1016/j.gie.2007.08.037)]
 - 32 **Huang JY**, Samarasena JB, Tsujino T, Chang KJ. EUS-guided portal pressure gradient measurement with a novel 25-gauge needle device versus standard transjugular approach: a comparison animal study. *Gastrointest Endosc* 2016; **84**: 358-362 [PMID: [26945557](https://pubmed.ncbi.nlm.nih.gov/26945557/) DOI: [10.1016/j.gie.2016.02.032](https://doi.org/10.1016/j.gie.2016.02.032)]
 - 33 **Schulman AR**, Thompson CC, Ryou M. Endoscopic Ultrasound-Guided Direct Portal Pressure Measurement Using a Digital Pressure Wire with Real-Time Remote Display: A Survival Study. *J Laparoendosc Adv Surg Tech A* 2017; **27**: 1051-1054 [PMID: [28445104](https://pubmed.ncbi.nlm.nih.gov/28445104/) DOI: [10.1089/lap.2017.0032](https://doi.org/10.1089/lap.2017.0032)]
 - 34 **Huang JY**, Samarasena JB, Tsujino T, Lee J, Hu KQ, McLaren CE, Chen WP, Chang KJ. EUS-guided portal pressure gradient measurement with a simple novel device: a human pilot study. *Gastrointest Endosc* 2017; **85**: 996-1001 [PMID: [27693644](https://pubmed.ncbi.nlm.nih.gov/27693644/) DOI: [10.1016/j.gie.2016.09.026](https://doi.org/10.1016/j.gie.2016.09.026)]
 - 35 **Zhang W**, Peng C, Zhang S, Huang S, Shen S, Xu G, Zhang F, Xiao J, Zhang M, Zhuge Y, Wang L, Zou X, Lv Y. EUS-guided portal pressure gradient measurement in patients with acute or subacute portal hypertension. *Gastrointest Endosc* 2021; **93**: 565-572 [PMID: [32615178](https://pubmed.ncbi.nlm.nih.gov/32615178/) DOI: [10.1016/j.gie.2020.06.065](https://doi.org/10.1016/j.gie.2020.06.065)]
 - 36 **Choi AY**, Kolb J, Shah S, Chahine A, Hashimoto R, Patel A, Tsujino T, Huang J, Hu KQ, Chang K, Samarasena JB. Endoscopic ultrasound-guided portal pressure gradient with liver biopsy: 6 years of endo-hepatology in practice. *J Gastroenterol Hepatol* 2022; **37**: 1373-1379 [PMID: [35513894](https://pubmed.ncbi.nlm.nih.gov/35513894/) DOI: [10.1111/jgh.15875](https://doi.org/10.1111/jgh.15875)]
 - 37 **Lesmana CRA**. Technique innovation of endoscopic ultrasound portal pressure gradient measurement using standard manometer set for portal hypertension assessment. *Clin Case Rep* 2022; **10**: e6658 [PMID: [36478968](https://pubmed.ncbi.nlm.nih.gov/36478968/) DOI: [10.1002/ccr3.6658](https://doi.org/10.1002/ccr3.6658)]
 - 38 **Guzmán-Calderón E**, Martínez-Moreno B, Aparicio JR. Endoscopic ultrasound-guided portal pressure gradient measurement. *Endoscopy* 2022; **54**: E1009-E1010 [PMID: [36002008](https://pubmed.ncbi.nlm.nih.gov/36002008/) DOI: [10.1055/a-1909-1515](https://doi.org/10.1055/a-1909-1515)]
 - 39 **Reddy S**, Panathur Y, Puli S. EUS guided-portal pressure gradient measurements to diagnose cirrhosis: a systematic review and meta-analysis. *Am J Gastroenterol* 2022; **117**: p e44 [DOI: [10.14309/01.ajg.0000856876.24045.2f](https://doi.org/10.14309/01.ajg.0000856876.24045.2f)]
 - 40 **Lei Z**, Luo R, Lu H, Zhang R, Luo H, Luo S, Song J, Wu Y, Jiang Z, Peng Q, Yin X, Liu X, Huang F, Deng G. [Endoscopic ultrasound-guided portal pressure gradient measurement in patients with cirrhotic portal hypertension: a report of 52 cases]. *Chin J Gen Surg* 2023; **32**: 101-109 [DOI: [10.7659/j.issn.1005-6947.2023.01.009](https://doi.org/10.7659/j.issn.1005-6947.2023.01.009)]
 - 41 **Choudhuri G**, Dhiman RK, Agarwal DK. Endosonographic evaluation of the venous anatomy around the gastro-esophageal junction in patients with portal hypertension. *Hepatogastroenterology* 1996; **43**: 1250-1255 [PMID: [8908559](https://pubmed.ncbi.nlm.nih.gov/8908559/)]
 - 42 **Irisawa A**, Saito A, Obara K, Shibukawa G, Takagi T, Shishido H, Sakamoto H, Sato Y, Kasukawa R. Endoscopic recurrence of esophageal varices is associated with the specific EUS abnormalities: severe periesophageal collateral veins and large perforating veins. *Gastrointest Endosc* 2001; **53**: 77-84 [PMID: [11154493](https://pubmed.ncbi.nlm.nih.gov/11154493/) DOI: [10.1067/mge.2001.108479](https://doi.org/10.1067/mge.2001.108479)]
 - 43 **Hino S**, Kakutani H, Ikeda K, Uchiyama Y, Sumiyama K, Kuramochi A, Kitamura Y, Matsuda K, Arakawa H, Kawamura M, Masuda K, Suzuki H. Hemodynamic assessment of the left gastric vein in patients with esophageal varices with color Doppler EUS: factors affecting development of esophageal varices. *Gastrointest Endosc* 2002; **55**: 512-517 [PMID: [11923763](https://pubmed.ncbi.nlm.nih.gov/11923763/) DOI: [10.1067/mge.2002.122333](https://doi.org/10.1067/mge.2002.122333)]
 - 44 **Li QQ**, Li HY, Bai ZH, Philips CA, Guo XZ, Qi XS. Esophageal collateral veins in predicting esophageal variceal recurrence and rebleeding after endoscopic treatment: a systematic review and meta-analysis. *Gastroenterol Rep (Oxf)* 2020; **8**: 355-361 [PMID: [33163190](https://pubmed.ncbi.nlm.nih.gov/33163190/) DOI: [10.1093/gastro/goaa004](https://doi.org/10.1093/gastro/goaa004)]
 - 45 **Johnson KD**, Laoveeravat P, Yee EU, Perisetti A, Thandassery RB, Tharian B. Endoscopic ultrasound guided liver biopsy: Recent evidence. *World J Gastrointest Endosc* 2020; **12**: 83-97 [PMID: [32218888](https://pubmed.ncbi.nlm.nih.gov/32218888/) DOI: [10.4253/wjge.v12.i3.83](https://doi.org/10.4253/wjge.v12.i3.83)]
 - 46 **Kalista KF**, Hanif SA, Nababan SH, Lesmana CRA, Hasan I, Gani R. The Clinical Role of Endoscopic Ultrasound for Management of Bleeding Esophageal Varices in Liver Cirrhosis. *Case Rep Gastroenterol* 2022; **16**: 295-300 [PMID: [35814797](https://pubmed.ncbi.nlm.nih.gov/35814797/) DOI: [10.1159/000524529](https://doi.org/10.1159/000524529)]
 - 47 **Ang TL**, Wong YJ. Endohepatology: More progress but not yet ready for prime time. *J Gastroenterol Hepatol* 2022; **37**: 1207-1208 [PMID: [35801993](https://pubmed.ncbi.nlm.nih.gov/35801993/) DOI: [10.1111/jgh.15914](https://doi.org/10.1111/jgh.15914)]



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