Ther Adv Gastroenterol

2025, Vol. 18: 1–16

DOI: 10.1177/17562848251359015

The application of EUS-guided portal pressure gradient measurement with concomitant EUS-liver elastography and EUS-guided liver biopsy in patients with chronic liver disease: a single center experience

Muhammad Nadeem Yousaf, Ahmad Hassan Ali, Sohum A. Patwa, Sanket Basida, Nicholas McGee, Jacob Cebulko, Darian Fard, Alexander Malik, Xheni Deda and Ghassan M. Hammoud

Abstract

Background: Risk stratification in liver disease includes liver elastography (LE) and portal pressure gradient (PPG) measurement.

Objectives: We examined the efficacy and safety of endoscopic ultrasound (EUS)-liver biopsy (EUS-LB) and the correlation between EUS-PPG and EUS-LE in patients with liver disease.

Study design: This is a prospective and retrospective, single-center study.

Methods: Data from patients who underwent concomitant EUS-LE, EUS-PPG, and EUS-LB were analyzed. Histologically, significant fibrosis (SF) was considered F2–F4, non-significant fibrosis (NSF) as F0–F1, advanced fibrosis (AF) as F3–F4, and non-advanced fibrosis (NAF) as F0–F2.

Results: In total, 25 patients underwent EUS-PPG measurement; 60% were male (mean age, 60 years). EUS-LE and EUS-LB were performed in 88% and 96% of patients, respectively (the technical success rate was 100%). The mean number of portal tracts was 14.3. Histological diagnosis was achieved in all patients; 67% had SF. The mean EUS-LE was 24.1 kPa, and the mean PPG was 4.6 mmHg. Portal hypertension (PH; PPG >5 mmHg) and clinically significant PH (PPG >10 mmHg) were found in 44% and 12%, respectively. Patients with SF had a higher mean PPG (5.9 vs 2.8 mmHg; $p=0.003$) and mean shear wave measurement (SWM; 30.0 vs 15.6 kPa; $p=0.02$) compared to the NSF group. Patients with AF had a higher mean PPG (6.0 vs 3.4 mmHg; $p=0.01$) and mean SWM (32.0 vs 18.8 kPa; $p=0.04$) compared to the NAF group. There were no significant adverse events.

Conclusion: Concomitant EUS-LB and PPG is safe. EUS-PPG and EUS-LE correlate with the degree of fibrosis on histology. Larger studies are needed to optimize their values in clinical practice.

Correspondence to:
Ghassan M. Hammoud
Division of Gastroenterology and Hepatology, Department of Medicine, University of Missouri School of Medicine, 1 Hospital Drive, Columbia, MO 65212, USA
hammoudg@health.missouri.edu

Muhammad Nadeem Yousaf
Ahmad Hassan Ali
Sohum A. Patwa
Sanket Basida
Nicholas McGee
Jacob Cebulko
Darian Fard
Alexander Malik
Xheni Deda
Division of Gastroenterology and Hepatology, Department of Medicine, University of Missouri School of Medicine, Columbia, MO, USA

Plain language summary

Does the use of endoscopic ultrasound help doctors in the management of patients with liver disease?

1. What is known:
   - Liver elastography, using shear wave measurement (SWM) and portal pressure gradient (PPG) measurement are used in clinical practice for risk assessment and stratification in patients with chronic liver disease.
   - Endoscopic ultrasound (EUS) incorporating SWM and PPG has recently emerged as an important tool for evaluation of patients with suspected chronic, including advanced liver disease.
2. What is new here:
   - There is a correlation between liver fibrosis stage (on histology) and EUS-PPG and EUS-SWM, i.e., patients with advanced fibrosis were found to have higher SWM and PPG measurements on EUS.
   - These findings have important implications in the management of patients with chronic liver disease and in those with suspected advanced liver disease.

Keywords: advanced liver disease, endoscopic ultrasound, liver biopsy, liver elastography, portal hypertension, portal pressure gradient

Received: 25 February 2025; revised manuscript accepted: 30 June 2025.

Background

Portal hypertension (PH) is a serious complication of advanced liver disease that may result in high mortality from associated complications, including esophageal and gastric varices, ascites, and hepatic encephalopathy.[1] Per the 2016 American Association for the Study of Liver Diseases (AASLD) practice guidelines on portal hypertensive bleeding in cirrhosis, a normal portal pressure gradient (PPG) ranges between 3 and 5 mmHg.[2] PH is an abnormal increase in the PPG >5 mmHg, commonly complicating advanced liver diseases, but can also be seen in patients with right-sided heart failure, pulmonary hypertension, and hepatic veno-occlusive disease.[1,2] Clinically significant PH (CSPH), defined as a PPG of ⩾10 mmHg, strongly correlates with poor outcomes due to associated decompensation events, including ascites, hepatic encephalopathy, and esophageal/gastric variceal bleeding.[2–4] Thus, measurement of PPG plays a key role in the management of patients with cirrhosis. Furthermore, if uncertainty exists in patients without cirrhosis or preexisting risk factors, PPG measurement can help identify patients with CSPH who might benefit from screening for esophagogastric varices.

Traditionally, hepatic venous pressure gradient (HVPG) is used as a surrogate marker of PPG.[2] The procedure is generally performed via a transjugular approach using a balloon-tipped catheter introduced into the hepatic vein (HV) under fluoroscopic guidance.[5,6] HVPG can be obtained by recording the difference between free and occluded hepatic venous pressures (HVP), that is, wedge HVP. This technique provides an indirect measurement of PPG across the hepatic venous sinusoids. However, there is limited utility of HVPG in patients with pre-sinusoidal and post-sinusoidal causes of PH due to lack of direct PPG measurement.[7] In addition, this technique exposes patients to radiation and intravenous contrast agent administration, limiting its utility in patients with kidney injury and those allergic to contrast agents. A percutaneous approach to measuring direct portal venous pressure gradient is also available; however, it is not routinely used in clinical practice due to technical challenges in obtaining venous access and associated risks of significant adverse events (AEs).[4]

The widespread availability of endoscopic ultrasound (EUS) and advances in endosonographic

tools have paved the way for minimally invasive measurement of portal pressure. EUS-PPG using a novel compact manometer has been recently approved by the Food and Drug Administration (FDA). Advantages of EUS-PPG include direct and accurate measurement of PPG in the assessment of sinusoidal, pre-, and post-sinusoidal causes of PH; concomitant use of EUS-liver elastography (EUS-LE) by shear wave measurement (SWM), EUS-PPG, and EUS-guided liver biopsy (EUS-LB) enables evaluation of the upper gastrointestinal (GI) tract and complications of liver disease during a single procedure. Prior studies have demonstrated the safety of EUS-PPG measurement and its good correlation with HVPG performed by interventional radiology and the degree of fibrosis determined by LB.[8–13] Furthermore, it has been demonstrated that EUS-PPG can be performed alongside EUS-LB safely and effectively.[12,14,15]

The primary aim of this pilot study is to determine the efficacy and safety of EUS-PPG measurement with concomitant EUS-LB. We also aim to determine the relationship between EUS-LE, EUS-PPG values, and histological stages of liver fibrosis in patients who underwent concomitant EUS-LB.

Materials and methods

Study design and patient selection

This prospective and retrospective study was conducted at a tertiary care academic medical center. The STROBE guidelines have been used in our study for the reporting of the retrospective portion of the study, which has been endorsed and used by a growing number of biomedical journals (https://www.equator-network.org/reporting-guidelines/strobe).[16] The study included patients who were evaluated by their treating hepatologist at the University of Missouri Liver Clinic with clinical suspicion of advanced liver disease or diagnostic uncertainty based on clinical evaluation, laboratory tests, and radiological imaging. Patients underwent concomitant EUS-LE, EUS-PPG measurement, and EUS-LB between January 2021 and September 2024. Informed consent was obtained from all patients prior to the procedures. All EUS procedures were conducted at the outpatient GI Endoscopy unit of the University Hospital, University of Missouri-Columbia, and were performed by an experienced advanced therapeutic endosonographer under monitored anesthesia care or general anesthesia.

Patients were excluded if they met at least one of the following criteria: age <18 or >75 years; pregnancy; breastfeeding; severe coagulopathy (international normalized ratio (INR) >1.5, platelet count $<50{,}000/mm^3$); clinically suspected or confirmed active infections (e.g., cholangitis, liver abscess, bacteremia); use of antiplatelets or anticoagulation agents within 48–72 h before the planned procedure; active GI bleeding; and patients deemed unfit for anesthesia due to high-risk comorbid illness(es).

Apparatus setup

The PPG measuring system consists of a 5.2 French (Fr) transducer sheath, a 25-gauge (G) fine-needle aspirate (FNA) needle (Cook Medical, Winston-Salem, NC, USA), an 8 cm adjustable needle extension, a self-calibrated pressure transducer, a compact manometer, and a 90 cm non-compressible connecting tube (Cook Medical, Bloomington, IN, USA). The compact manometer has a digital display measuring 2 cm × 3 cm × 2 cm and can show pressure ranging from −199 to +999 mmHg. This FDA-approved device has been commercially available since 2020. Setting up the apparatus is straightforward and typically takes less than 5 min. A 10 mL sterile heparinized saline syringe is connected to the Luer lock on the proximal end of the transducer and the proximal (female) end of the non-compressible tubing, which is secured with a Luer lock. The other end of the connecting tube is attached tightly to the inlet of the FNA needle using a Luer lock. To remove any air bubbles, the system is flushed with heparinized saline. The manometer is zeroed by holding it along the left mid-axillary line at the level of the heart.

LE assessment using EUS-SWM

LE was measured according to the previously described method by Ohno et al.[17] EUS-SWM was performed using a GF-UCT180P Curvilinear array echoendoscope (Olympus Co. Ltd, Tokyo, Japan) and an ARIETTA 850 ultrasound machine (Hitachi, Ltd, Tokyo, Japan). The right liver lobe was used as the prime location for LE assessment. To decrease the rate of potential artifacts, LE measurement was performed during minimal respiratory fluctuations. A rectangular region of

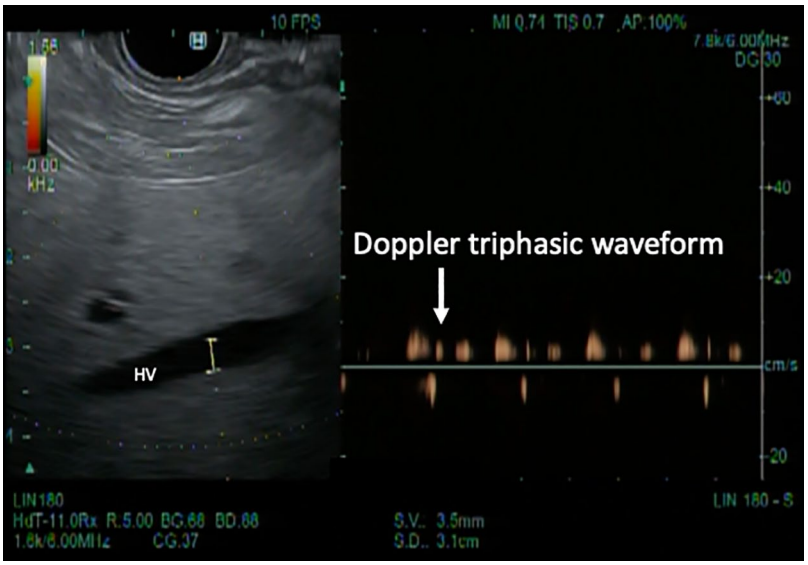

Figure 1. EUS Doppler flow signals of the middle HV demonstrate a typical triphasic waveform.
EUS, endoscopic ultrasound; HV, hepatic vein.

interest measuring 10 mm × 5 mm was identified and used for LE measurement. Ten measurements of LE were obtained between 5 and 10 mm depth from the probe.

EUS-guided PPG measurement procedure

All patients received prophylactic intravenous antibiotic (a single dose of ciprofloxacin 400 mg) prior to the procedure and underwent monitored anesthesia care or general anesthesia with endotracheal intubation based on the anesthesiologist's recommendation. An esophagogastroduodenoscopy (EGD) was performed in all patients in the supine or left lateral position using a forward viewing standard gastroscope (GIF-190 HQ; Olympus) with carbon dioxide (CO_2) insufflation. This allowed examination of the upper GI tract with simultaneous assessment for clinical features of PH, such as esophageal or gastric varices and portal hypertensive gastropathy. After the EGD, an EUS was performed using a curvilinear echoendoscope (GF-UC140P-AL5 or GF-UC180O-AL5; Olympus). This allowed for evaluation of the hepatic vascular anatomy and morphological changes of the liver, including surface contour, porto-splenic vein dilation, presence of collaterals, and ascites. The HV and its branches, that is, the right, middle, and left hepatic veins (RHV, MHV, and LHV, respectively), were identified by positioning the echoendoscope just below the gastroesophageal junction and tracing the HV back to the inferior vena cava. The LHV is initially visualized, followed by the MHV and RHV. The MHV was the preferred target for EUS-guided HVP measurements due to its wider caliber lumen and the straight trajectory of the needle on linear EUS, similar to the technique described by Samarasena et al.[18] Doppler flow analysis of the HV branches displayed characteristic pulsatile triphasic flow signals (Figure 1), in contrast to the portal vein (PV) which exhibited typical venous "hum" with monophasic flow signals. Once the positioning of the MHV (or LHV in some cases) was confirmed, the HV was punctured about 2 cm from its ostium using a 25G FNA needle through a transgastric transhepatic approach (Figure 2). A very small amount of heparinized saline was flushed through the needle to visualize bubbles, confirming the proper positioning of the needle tip within the vessel lumen. Three steady-state pressure readings were sequentially measured, and the average of these readings was calculated as the final HVP to minimize variations or errors.

To determine the portal vein pressure (PVP), the left PV was the preferred target identified using EUS Doppler signals displaying a typical monophasic waveform (Figure 3). The left PV was punctured using a 25-G FNA needle through a transgastric transhepatic approach (Figure 4). A very small amount of heparinized saline was flushed through the needle to visualize bubbles,

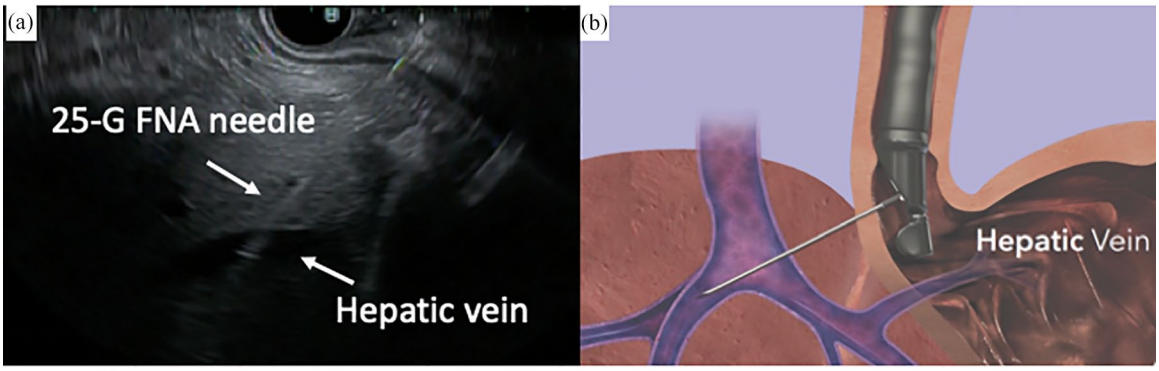

Figure 2. EUS-guided puncture of the middle hepatic vein with 25-G FNA needle (panels (a) and (b)).
Source: Diagram in panel (b) adopted from Cook Medical USA.
EUS, endoscopic ultrasound; FNA, fine needle aspirate.

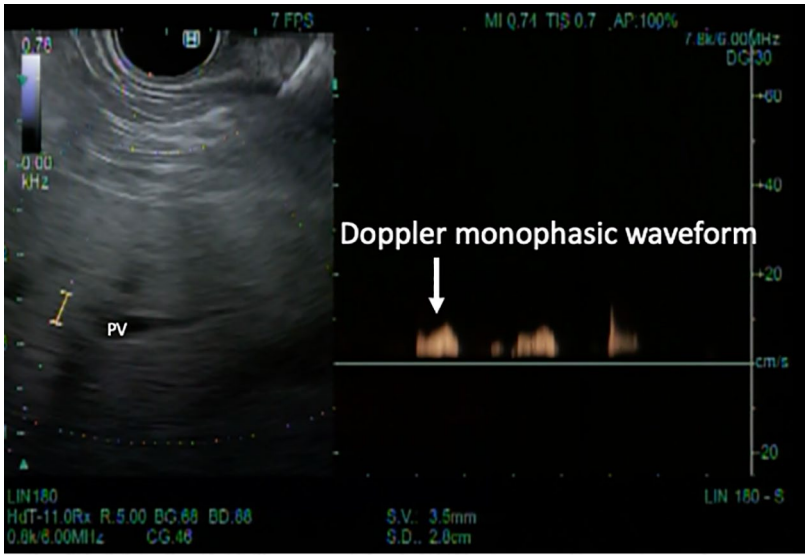

Figure 3. EUS Doppler flow signals of PV demonstrate a typical monophasic waveform.
EUS, endoscopic ultrasound; PV, portal vein.

confirming the proper positioning of the needle tip within the vessel lumen. Three steady-state pressure readings were sequentially measured, and the average of these readings was calculated as the final PVP to minimize variations or errors.

EUS Doppler was used to observe the needle tract, ensuring no significant blood flow signals indicating active bleeding. The PPG was then calculated by subtracting the mean PVP from the mean HVP.

EUS-guided LB procedure

EUS-LB was performed following PPG measurement using either a 19G Franseen Acquire® (Boston Scientific, Boston, MA, USA) or Fork-tip SharkCore® (Medtronic Corporation, Newton, MA, USA) biopsy needle, depending on device availability. The wet suction technique was used to obtain liver tissue samples, which included flushing the needle with heparin before attaching it to a syringe with maximum suction. Color Doppler was used to identify a safe window for

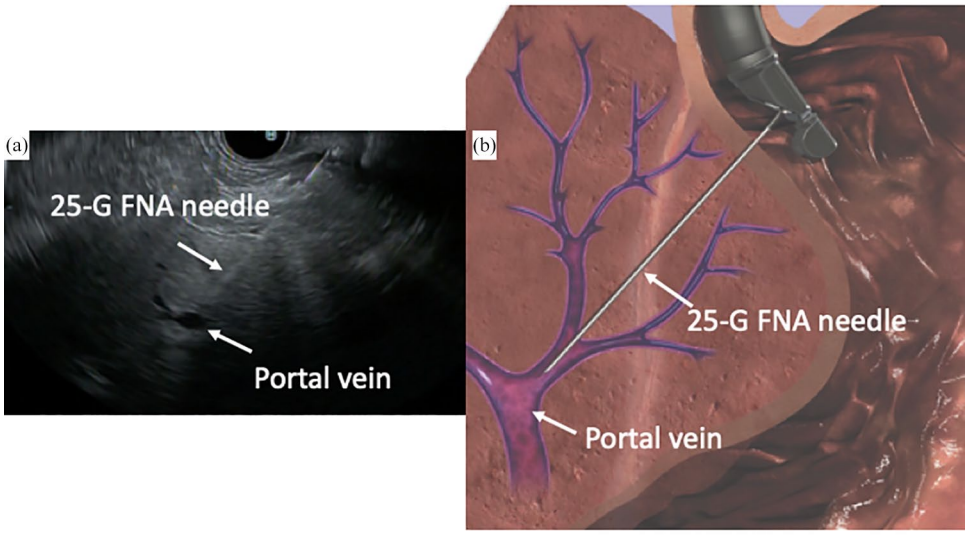

Figure 4. EUS-guided puncture of left portal vein with 25-G FNA needle (panels (a) and (b)).
Source: Diagram in panel (b) adopted from Cook Medical USA.
EUS, endoscopic ultrasound; FNA, fine-needle aspirate.

needle insertion, ensuring avoidance of hepatic vessels during puncture. The needle was inserted into the right hepatic lobe through a transduodenal transhepatic approach. Suction was activated, and one to three intrahepatic actuations were performed to obtain sufficient liver tissue. After each actuation, the needle suction was switched off and then withdrawn from the liver to minimize blood aspiration. Doppler evaluation of the needle track was performed to detect any flow signals indicative of bleeding. The specimen was flushed from the needle with a saline push into a filter, then placed in a container filled with 10% formalin. Following the procedure, patients were observed in the recovery area for 30–60 min and discharged on the same day if they had a stable hemodynamic condition and an uneventful recovery. Post-procedural antibiotics (usually ciprofloxacin) were prescribed for 3 days. Patients were advised to avoid heavy lifting and strenuous activities for 72 h. All patients had a post-procedure phone call within 48 h to monitor for severe AEs. All patients had a follow-up in the liver clinics 2–4 weeks after the procedure.

Data collection

Patient data were collected through detailed review of the electronic medical records, including demographics (age, gender, ethnicity); weight; body mass index; medical history related to liver diseases (metabolic dysfunction-associated steatotic liver disease (MASLD), metabolic dysfunction-associated steatohepatitis (MASH), alcohol-associated liver disease, viral hepatitis B or C, and chronic liver disease due to other causes); laboratory results (liver biochemistry, platelet count, coagulation profile, lipid panel, hemoglobin A1C, and the Model for End-stage Liver Disease 3.0 score (MELD 3.0)); and imaging findings relevant to the study, such as hepatic parenchymal changes and ascites.

EGD findings of esophageal or gastric varices, portal hypertensive gastropathy, SWM on EUS-LE, and EUS-PPG measurements were recorded. EUS-LB data, including the overall quality of the tissue sample by inspection, number of needle passes, actuations, and specimen length, were also collected.

Definitions

PH was defined and graded in severity according to the published AASLD guidelines as PPG of $\geqslant$5 mmHg, and CSPH as PPG $\geqslant$10 mmHg. Procedure-related AEs were defined as minor AEs that could be managed conservatively and major AEs that require additional endoscopic or surgical interventions or hospitalization to manage symptoms.

LB interpretation

All LB specimens had been interpreted at the University of Missouri Department of Pathology

by two experienced GI and liver pathologists. The pathologists were blinded to the patients' clinical and laboratory data. Reticulin, iron, periodic acid-Schiff (PAS), PAS with diastase, hematoxylin and eosin, and Masson's trichrome stains were performed on all LB samples. In addition to the stains, each LB sample was subjected to microscopic assessment of the quality of the LB, including length of the LB sample, number of portal tracts, and fragmentation. LB specimens containing $\geqslant$11 portal tracts were considered adequate based on previously published studies.[19,20] The pathological diagnosis regarding each LB specimen was done based on published histological criteria (AASLD guidelines), and fibrosis staging was reported based on the METAVIR scoring system.[21,22] Non-significant fibrosis (NSF) was defined as stage F0–F1, significant fibrosis (SF) as F2–F4 fibrosis, non-advanced fibrosis (NAF) as F0–F2, and advanced fibrosis (AF) as F3–F4 fibrosis.[23–30]

Statistical analysis

Continuous variables are expressed as mean with standard deviation, and categorical variables are expressed as frequency and percentage. Baseline clinical, laboratory, and histological variables were compared using Fisher's exact test for categorical variables and the Wilcoxon rank-sum test for continuous variables. A p value <0.05 was considered statistically significant. Data analysis was performed using STATA v12.1 (StataCorp LP, College Station, TX, USA).

Results

Demographic characteristics of the study cohort

Between January 2021 and September 2024, a total of 25 patients were identified in our database. All were retrospectively enrolled. No patients were prospectively recruited. Sixty percent ($n=15$) of the participants were male, and all underwent EUS-PPG measurement, EUS-LE, and concomitant EUS-LB except for one patient who did not undergo EUS-LB. The demographics and patient characteristics are summarized in Table 1. The mean age of patients at the time of EUS was 60 years. The vast majority were Caucasian (92%; $n=23$); the remaining were African American (8%; $n=2$). Forty-eight percent ($n=12$) were found to have type 2 diabetes mellitus, 56% ($n=14$) were found to have dyslipidemia, and 52% ($n=13$) were found to have either a history of or were recorded as active cigarette smokers. The indications for EUS examination are illustrated in Table 2. Histological diagnosis was established in 91.6% of patients, the majority of whom were found to have MASLD and MASH totaling 48% ($n=12$) of the entire study cohort. Regarding fibrosis stage, six patients were found to be stage 0, four patients were found to be stage 1, four patients were found to be stage 2, three patients were found to be stage 3, and eight patients were found to be stage 4 fibrosis. In total, 10 patients were categorized as NSF, and 15 were categorized as SF. Similarly, 14 patients were categorized as NAF, and 11 patients were categorized as AF.

Pre-procedural laboratory and noninvasive assessment

Pre-procedural labs are summarized in Table 1. The mean total bilirubin and INR were 0.6 mg/dL and 1.1, respectively. The mean MELD 3.0 score was 9.3. Thirty-two percent ($n=8$) of patients were found to have imaging findings compatible with cirrhosis. Twenty percent ($n=5$) of patients had ascites on radiologic imaging at the time of EUS.

Procedural findings and outcomes

Twenty-eight percent ($n=7$) were found to have portal hypertensive gastropathy, and an additional 16% ($n=4$) were found to have small esophageal varices on EGD. The technical success rate of EUS-LE, EUS-PPG, and EUS-LB was 100%. The mean procedure time (defined as the time from scope insertion to removal, which also includes time to exchange a standard gastroscope with a linear echoendoscope) was 55.6 min. The mean post-procedure stay in the recovery room was 77.6 min.

PPG measurements

The technical success rate of EUS-PPG measurement was 100% (Table 2). The HVP was measured from the MHV in 76% ($n=19$), and from the LHV in 24% ($n=6$) of patients. The mean HVP was found to be 7.9 mmHg. The PVP was measured from the left PV in all patients. The mean PVP was found to be 11.8 mmHg, and the mean PPG was found to be 4.6 mmHg. PH was identified in 44% ($n=11$) of patients, of whom 27% ($n=3$) were found to have CSPH.

Table 1. Demographics and clinical characteristics of patients.

Variables	Value
Total patients	25
Age, years	60 ± 11.0
Gender, male:female	60 (15):40 (10)
Weight, kg	110.7 ± 30.2
BMI (kg/m^2)	35.8 ± 12.1
Race	
Caucasian, yes, % (*n*)	92 (23)
African American, yes, % (*n*)	8 (2)
Diabetes mellitus, yes, % (*n*)	48 (12)
Dyslipidemia, yes, % (*n*)	56 (14)
Smoking, yes, % (*n*)	52 (13)
Etiology of liver disease based on histological assessment % (*n*)	
MASLD	20 (5)
MASH	40 (10)
MASH + AIH	4 (1)
Primary biliary cholangitis	4 (1)
Alcohol-related liver disease	4 (1)
Chronic hepatitis C	4 (1)
Chronic hepatitis B	4 (1)
Chronic hepatitis (non-specific)	4 (1)
Non-cirrhotic portal hypertension	4 (1)
Non-specific findings	4 (1)
No evidence of chronic liver disease[a]	8 (2)
Laboratory and non-invasive assessments	
Total bilirubin (mg/dL)	0.6 ± 0.5
ALT (U/L)	51.5 ± 61.8
AST (U/L)	42.7 ± 32.0
ALK (U/L)	132.6 ± 60.2
Platelet count (10^3/μL)	243.9 ± 127.5
INR	1.1 ± 0.3
Serum glucose (mg/dL)	135.1 ± 68.0
Hemoglobin A1C (g/dL)	6.6 ± 1.6
Total cholesterol (mg/dL)	173.8 ± 60.0
Triglyceride (mg/dL)	189.7 ± 164.9
MELD 3.0 score	9.3 ± 3.4
Ascites, yes, % (*n*)	20 (5)

Continuous data are expressed as mean with standard deviation. Categorical data are expressed as frequency and percentage.
[a]These patients were found to have abnormal radiological findings concerning for chronic liver disease.
AIH, autoimmune hepatitis, ALK, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; INR, international normalized ratio; MASH, metabolic dysfunction-associated steatohepatitis; MASLD, metabolic dysfunction-associated steatotic liver disease; MELD-Na, model for end-stage liver disease-sodium; *n*, number.

EUS-LE and EUS-LB outcomes

EUS revealed evidence of advanced liver disease in 15 (60%) patients. Overall, the mean EUS-LE by SWM was found to be 24.1 kPa. EUS-LE was not performed in three patients because the referring provider did not request EUS-LE measurement. All patients underwent successful EUS-LB except one, who had undergone a percutaneous LB 9 months prior to endoscopic evaluation and showed noncirrhotic PH. This patient was referred for EUS-LE and PPG measurement only. The Franseen Acquire needle was used in 96% ($n=23$) of patients and the Fork-tip SharkCore in 4% ($n=1$). The LB was obtained from the right hepatic lobe in 92% ($n=22$), the left hepatic lobe in 4% ($n=1$), and from both lobes in 4% ($n=1$). The mean number of needle passes was 1.4, and the mean number of actuations was 2.5. The mean length of the LB specimen was 2.0 cm. The mean number of portal tracts was 14.3, and 87.5% ($n=21$) of patients had ⩾11 portal tracts on LB specimens.

Table 2. Procedure outcomes.

Variables/parameters	Value % (*n*)
Procedure indications	
Suspect advanced liver disease	64 (16)
Steatotic liver disease	20 (5)
Elevated liver enzymes	8 (2)
Primary biliary cholangitis	4 (1)
Alcohol-associated liver disease	4 (1)
Technical success rate	
EUS-LE	100 (22)
EUS-PPG	100 (25)
EUS-LB	100 (24)
Procedure time, minutes	55.6 ± 16.6
Post-procedure stay, minutes	77.6 ± 20.6
Portal hypertensive gastropathy, yes, % (*n*)	28 (7)
Varices, yes, % (*n*)	16 (4)
EUS-LE, kPa (*n* = 22)	24.1 ± 14.0
EUS-PPG measurements data (*n* = 25)	
Hepatic vein pressure, mmHg	7.9 ± 4.9
Portal vein pressure, mmHg	11.8 ± 6.2
PPG, mmHg	4.6 ± 4.2
Portal hypertension, yes, % (*n*)	44 (11)
Clinically significant portal hypertension, yes, % (*n*)	12 (3)
EUS-LB data (*n* = 24)	
Type of needle used	
Franseen Acquire	96 (23)
Fork-tip SharkCore	4 (1)
Number of needle passes	1.4 ± 0.5
Number of actuations	2.5 ± 0.5
Length of specimen, cm	2.0 ± 0.6
Number of portal tracts	14.3 ± 11.0
Histology data	
Fibrosis stage 0 (F0)	24 (6)
Fibrosis stage 1 (F1)	16 (4)
Fibrosis stage 2 (F2)	16 (4)
Fibrosis stage 3 (F3)	12 (3)
Fibrosis stage 4 (F4)	32 (8)
SF	60 (15)
Non-SF	40 (10)
AF	44 (11)
Adverse events (minor), yes, % (*n*)	
Abdominal pain	4 (1)
Adverse events (major), yes, % (*n*)	0 (0)

Continuous data are expressed as mean with standard deviation. Categorical data are expressed as frequency and percentage.
EUS, endoscopic ultrasound; EUS-LB, EUS-guided liver biopsy; EUS-LE, EUS-guided liver elastography; EUS-PPG, EUS-guided portal pressure gradient; *n*, number.

Relationship between EUS-LE, EUS-PPG, and liver fibrosis

The relationship between PPG, LE, and liver fibrosis is shown in Table 3 and Figure 5. The mean LE was similar between the group with no evidence of PH (i.e., PPG <5 mmHg ($n = 14$) vs the PH (PPG ⩾5 mmHg; $n = 11$) group (24.3 ± 4.8 vs 23.7 ± 3.4 kPa, respectively; $p = 0.91$). There was a positive relationship between liver fibrosis stage, PPG, and LE (Figure 6). Specifically, patients who were found to have a higher PPG and LE on EUS were found to have a higher fibrosis stage on liver histology. To further elaborate, upon categorizing patients into NSF (F0–F1) and SF (F2–F4) groups, the mean PPG and mean LE were found to be statistically significantly higher in the SF compared to the NSF group (2.5 vs 5.9 mmHg, respectively, $p = 0.003$; and 15.6 vs 30.0 kPa, respectively, $p = 0.02$). Furthermore, when categorizing patients into NAF (F0–F2) and AF (F3–F4) groups, the mean PPG and mean LE were found to be statistically significantly higher in the AF compared to the NAF group (3.4 vs 6.0 mmHg, respectively,

Table 3. Correlation of PPG and liver fibrosis by histology.

Patients with/ without PH & SF	PH, $n=8$	No PH, $n=2$	p Value
SF, % (n)	42.8 (6)	81.8 (9)	0.048

PH, portal hypertension (defined as PPG ⩾5 mmHg); PPG, portal pressure gradient; SF, significant fibrosis.

$p=0.01$; and 18.8 vs 32.0 kPa, respectively, $p=0.04$; Table 4; Figure 6). We sought to examine the correlation between patients with CSPH (PPG ⩾ 10 mmHg) and the presence of esophageal varices. Of the entire cohort, 3 (12%) patients were found to have CSPH, of whom none had esophageal varices. Similarly, of the entire cohort, 4 (16%) patients had esophageal varices, none of whom had CSPH.

Periprocedural and post-procedural AEs

One patient (4%) experienced mild abdominal pain (rated 4 out of 10 on pain scale) in the post-procedure recovery room, which was successfully managed with oral analgesics. No major AEs such as severe pain, bleeding, or perforation were observed during or after the procedure within 48 h follow-up assessment.

Discussion

In this pilot study of 25 patients evaluated in our liver clinics and referred for EUS-guided LB and concomitant PPG to assess for chronic liver disease and its complications, we demonstrated that EUS-LE and EUS-PPG measurement with concomitant EUS-LB was performed with a 100% technical success rate. Furthermore, LB specimens obtained during EUS were of high quality for histopathological assessment and establishing a clinical diagnosis in the majority of patients, with ⩾11 complete portal tracts found in 87.5% of LB specimens obtained during hepatic parenchymal exam upon EUS, a finding that we have shown in our previously published randomized controlled trial evaluating the efficacy and safety of EUS-LB where a diagnosis was established in 92.5%.[31] Moreover, a histological diagnosis was accomplished in >90% of the patients. The main finding of our study is that there seems to be clinical value in the use of EUS-PPG and EUS-LE in the diagnostic workup of patients with suspected chronic liver disease. Specifically, we found a significant relationship between EUS-PPG and the degree of liver fibrosis; patients with SF have been found to have higher PPG and SWM values compared to those with NSF, and, similarly, patients with AF have been found to have higher PPG and SWM values compared to those with NAF. Moreover, there was a correlation between

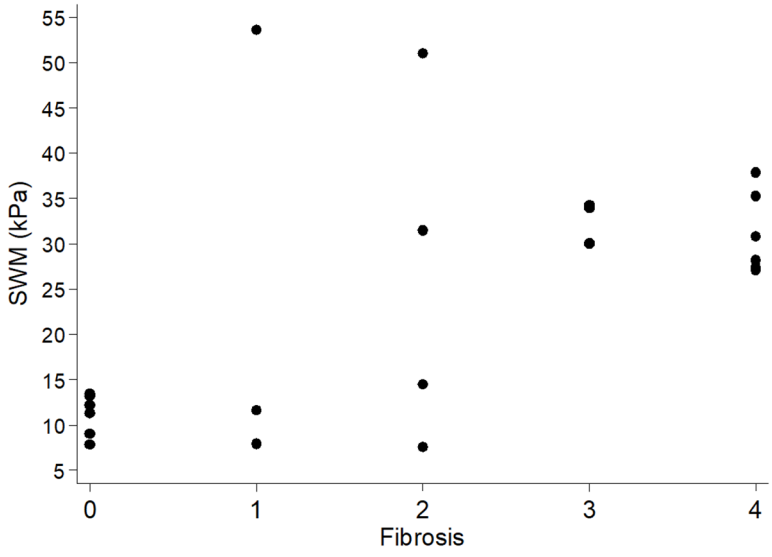

Figure 5. Scatter plot of EUS-SWM (kPa) in relation to the degree of fibrosis on histology.
EUS, endoscopic ultrasound; SWM, share wave measurement.

Table 4. Correlation of categories of stages of liver fibrosis with PPG and LE by shear wave measurement.

Stages of liver fibrosis	No. of patients % (*n*)	PPG (mmHg) ± SD	*p* Value	LE (kPa) mean ± SD	*p* Value
NSF (F0–F1)	40 (10)	2.5 ± 4.8^{a}	$0.044^{a,b}$	15.6 ± 14.4^{e}	$0.014^{e,f}$
SF (F2–F4)	60 (15)	5.9 ± 3.2^{b}		30.0 ± 10.5^{f}	
NAF (F0–F2)	56 (14)	3.4 ± 4.8^{c}	$0.132^{c,d}$	18.8 ± 16.1^{g}	$0.03^{g,h}$
AF (F3–F4)	44 (11)	6.0 ± 2.7^{d}		32.0 ± 14.8^{h}	

[a]represents the value of the mean PPG of patients with NSF.
[b]represents the value of the mean PPG of patients with SF.
[c]represents the value of the mean PPG of patients with NAF.
[d]represents the value of the mean PPG of patients with AF.
[e]represents the value of the mean LE of patients with NSF.
[f]represents the value of the mean LE of patients with SF.
[g]represents the value of the mean LE of patients with NAF.
[h]represents the value of the mean LE of patients with AF.
AF, advanced fibrosis; LE, liver elastography; NAF, non-advanced fibrosis; NSF, non-significant fibrosis; PPG, portal pressure gradient; SD, standard deviation; SF, significant fibrosis.

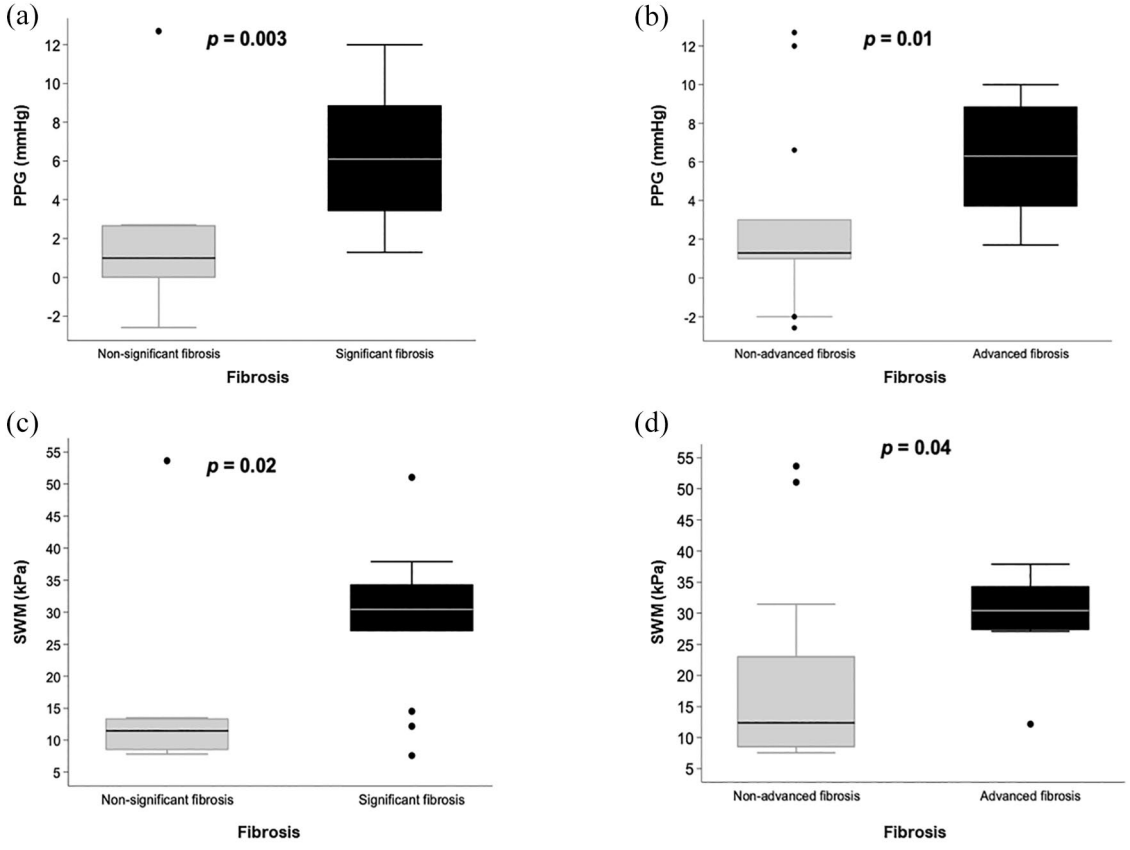

Figure 6. Correlation of PPG with non-significant versus significant fibrosis (a), correlation of PPG with non-advanced versus advanced fibrosis (b), correlation of EUS-LE with non-significant versus significant fibrosis (c), and correlation of EUS-LE with non-advanced versus advanced fibrosis (d).
EUS-LE, endoscopic ultrasound-liver elastography; PPG, portal pressure gradient.

EUS-PPG and SF. Specifically, we found that the percentage of patients with SF was statistically significantly higher in the PH group (81.8% vs 42.9%, respectively; $p = 0.048$). Finally, our study confirms the safety of concomitant PPG and LB procedure; there were essentially no severe AEs such as severe pain, bleeding, or perforation encountered during or after the procedure at 48 h follow-up. Collectively, our findings emphasize the potential utility of EUS-guided interventions as a minimally invasive and valuable tool in the assessment of patients with suspected chronic liver disease. These findings have a potential impact on establishing guidelines in the newly emerging field of endohepatology.

The accurate measurement of the degree of PH is crucial in the diagnosis and management of patients with advanced liver disease and cirrhosis, given the poor outcomes associated with PH. Traditionally, HVPG measured by the transjugular approach is considered the diagnostic test of choice for measurement of PPG; however, its availability is limited to specialized centers and requires special interventional radiology training.[4,11,15] Measurement of the HVPG by the transjugular approach is relatively invasive, exposes patients to contrast, radiation, and provides indirect measurement of PPG.[4,11,15] Our study suggests that EUS-LE and EUS-PPG measurement are an alternative minimally invasive approach that can provide direct and accurate measurement of PPG in patients with suspected sinusoidal, pre-, and post-sinusoidal PH. Moreover, concomitant EUS-LB enables the evaluation of suspected PH and its complications during a single procedure.[4]

The first human case report by Fujii-Lau et al.[32] in 2014 introduced EUS-PPG for evaluating PH and arteriovenous malformations in a patient with Noonan syndrome, showcasing the strong correlation between EUS-PPG and HVPG. Huang et al.[33] conducted a prospective pilot study in 28 patients with known or suspected cirrhosis using a 25-G FNA needle, demonstrating a 100% technical success rate for EUS-PPG measurement through a transgastric transhepatic approach. The study revealed an average PPG of 8.2 mmHg, with 66.7% of patients exhibiting CSPH associated with esophageal/gastric varices, portal hypertensive gastropathy, and thrombocytopenia. Zhang et al.[34] compared the efficacy and safety of EUS-PPG with HVPG in patients with acute and subacute PH, reporting a high technical success rate (91.7%) and excellent correlation between the two modalities. Martínez-Moreno et al.[9] demonstrated a 92.3% success rate in EUS-PPG measurement in patients with suspected cirrhosis, with comparable results to invasive radiological-guided HVPG, emphasizing the potential of EUS-PPG as a minimally invasive alternative. Our study demonstrated comparable efficacy and safety of EUS-PPG measurement in the assessment of PH regardless of the etiology of chronic liver disease.

Our results also demonstrate a clear correlation between PPG, LE, and the stages of liver fibrosis by histology. Advanced stages of liver fibrosis were found to be associated with elevated mean PPG and LE values, suggesting that both EUS-LE and EUS-PPG are effective modalities in assessing liver fibrosis and PH in patients with chronic liver disease. A higher PPG is directly proportional to a high LE measurement by SWM. In patients with PH, the corresponding mean value of the LE value was 24 kPa. Our pilot study results may aid in providing the baseline data to determine the LE cutoff value in patients with PH; however, there is a need for a prospective clinical trial to validate these findings on a large cohort.

In the current study, in patients with NSF (F0–F1), the mean PPG was low (2.5 mmHg), with a corresponding lower mean LE value (15.6 kPa), indicating a lesser degree of liver stiffness and PH. On the other hand, patients with SF (F2–F4) were found to have a higher mean PPG (5.9 mmHg) and mean LE value (30.0 kPa), indicating more severe liver stiffness and PH. A similar pattern was seen in patients with non-advanced (F0–F2) versus AF (F3–F4); the latter group had a markedly higher mean PPG (6.0 vs 3.4 mmHg) and a higher mean LE value (32.0 vs 18.8 kPa), underscoring the progression of fibrosis and its impact on portal pressure. These results indicate that the cutoff value of EUS-PPG is different than the HVPG. Larger multicenter clinical trials are needed to validate our findings. In the study by Bureau et al.,[35] transient elastography (TE) was shown to reliably predict PH, particularly in patients with cirrhosis or SF. TE measurements closely corresponded with liver stiffness and PPG, echoing the results of our study, where patients with AF (F3–F4) displayed significantly higher LE values and PPG compared to those with mild fibrosis.[36] Similarly, Vizzutti et al.[37] demonstrated that liver stiffness measured through elastography can predict severe PH in patients with hepatitis C-related cirrhosis. This highlights the role of LE in assessing both fibrosis stage and portal pressure

without the need for invasive procedures such as LB.[36]

Two retrospective studies by Choi et al.[11,12] and a prospective pilot study by Hajifathalian et al.[4] and Kim et al.[15] demonstrated an excellent safety profile and 100% technical success rate of EUS-PPG with concomitant EUS-LB during the same session. They established a strong correlation between EUS-PPG (with clinical markers of PH) and histological stage of liver fibrosis; a proposed PPG cutoff of 10 mmHg or greater has been found to predict risk of cirrhosis, esophageal or gastric varices, portal hypertensive gastropathy, and thrombocytopenia.[12] Similarly, an EUS-PPG cutoff of 5 mmHg or greater has been shown to have a sensitivity of 57.9%, a specificity of 87.5%, negative predictive value (NPV) of 72.4%, and a positive predictive value (PPV) of 78.6% for predicting stage 3–4 liver fibrosis.[11] However, Hajifathalian et al.[4] found no significant correlation between EUS-PPG and the stage of liver fibrosis. A recent meta-analysis with systematic review including four studies ($n = 147$ patients) revealed a high pooled EUS-PPG technical success rate of 98.61% (95% confidence interval (CI): 95.20%–99.82%).[38] The pooled success rate of simultaneous EUS-LB in 95 patients has been reported to be 100%, with a 99% rate of adequacy of liver specimen required for histological assessment.[38] Overall, the EUS-PPG procedure showed a favorable safety profile, with abdominal pain (6.1%) and sore throat (5.4%) being the predominant AEs.[38] Our study validated the safety and efficacy of EUS-PPG measurement with concomitant EUS-LB and reported the lowest AE percentage compared to the published literature.

Several strengths of this study are worth noting. The use of EUS in the management of patients with chronic liver disease has recently expanded. A state-of-the-art comprehensive endohepatology approach using EGD, EUS-LE, EUS-PPG, and EUS-LB, all performed in a single session in a relatively shorter period of time compared to the interventional radiology approach, allowed the so-called " one-stop shop" in which assessment of the upper GI tract was conducted while simultaneously evaluating the hepatic parenchyma (echosonographically and histologically) and the portal venous circulation for changes in patients with suspected advanced liver disease. Indeed, 16% of patients in this study have been found to have small esophagogastric varices that were not amenable to endoscopic variceal band ligation. Furthermore, the use of monitored anesthesia care or general anesthesia during the EUS-guided assessment improved patient comfort and pain level throughout the entire procedure. Moreover, as we previously reported, the quality of liver tissue samples obtained by EUS was high. This study investigated the relationship between EUS-PPG, EUS-LE, and liver fibrosis, revealing a positive relationship between PPG values and the degree of liver fibrosis on histology. This relationship strengthens the clinical relevance of EUS-PPG, further supporting EUS's utility in assessing the severity of liver disease and its related morbidity. Compared to the traditional LE measurement using FibroScan, EUS-LE by SWM is a safe procedure, providing assessment of the liver stiffness by calculating the propagation velocity of the shear waves. Its feasibility and the relatively shorter time required to perform while acquiring liver tissue samples make it a more attractive tool compared to FibroScan. Finally, as the EUS techniques continue to rapidly advance and expand, EUS-LE by SWM has the potential to revolutionize patient care, especially in the era of personalized medicine, and therefore should be incorporated into the armamentarium in the endohepatology field.

Our study has several limitations, including a small sample size and the retrospective design, which did not allow a direct comparison with the diagnostic and prognostic performance of interventional radiology-guided HVPG measurement and percutaneous LB. In addition, the fact that >90% of the study patients were Caucasian and the procedure being performed by one experienced endosonographer in a single center may limit its generalizability. Furthermore, post-procedure follow-up duration was rather short; as such, AEs occurring past 48 h may have been missed. However, all our patients had follow-up visits in the liver clinic within 8–12 weeks to discuss their LB pathology findings and management of their liver disease; their treating hepatologist reported no severe AEs. Moreover, only a few studies have demonstrated a strong correlation between liver stiffness measured by EUS-SWM and clinically SF identified on liver histology.[39,40] However, differences in EUS-SWM between the right and left hepatic lobes, as well as the diverse range of liver diseases included in one of the two studies (del Valle) make it challenging to establish definitive cutoff values for EUS-guided liver stiffness corresponding to

various stages of liver disease. Consequently, there are currently no consensus guidelines for risk stratification of liver disease based on liver stiffness assessed by EUS-SWM.

Conclusion

EUS-PPG measurement, EUS-LE, and concomitant EUS-LB during a single session are a feasible and safe alternative approach offering a comprehensive endohepatology assessment of patients with advanced liver disease as opposed to standard of care. EUS-PPG, a novel endoscopic technique, has been found to have a clinically meaningful relationship with clinical markers of PH and the histological stage of fibrosis. Our findings need to be validated in future larger studies, which should also focus on identifying optimal cutoff values for predicting AF by SWM.

Authors' note

All authors approved the final draft for submission.

Declarations

Ethics approval and consent to participate

For the retrospective part, the study was conducted in accordance with the Declaration of Helsinki and was approved by the institutional review board (IRB) of the University of Missouri-Columbia (IRB protocol #2032102) on January 12, 2022, with the need for written informed consent to participate in research waived. Regarding the prospective part, the study protocol and written informed consent were approved by the University of Missouri-Columbia under the same IRB protocol (i.e., IRB protocol #2032102) on January 12, 2022. For the retrospective part, the University of Missouri IRB waived the requirement for informed consent. For the prospective part, no patient was enrolled in the prospective study at the time of final data analysis.

Consent for publication

Written informed consents include statements that patients and participants give permission to use images, photographs, and video recordings of the procedure, which will not include any portrait images or any identifiable images of the patients and participants.

Author contributions

Muhammad Nadeem Yousaf: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing – original draft; Writing – review & editing.

Ahmad Hassan Ali: Formal analysis; Writing – review & editing.

Sohum A. Patwa: Data curation.

Sanket Basida: Data curation.

Nicholas McGee: Data curation.

Jacob Cebulko: Data curation.

Darian Fard: Data curation.

Alexander Malik: Data curation.

Xheni Deda: Data curation.

Ghassan M. Hammoud: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

Acknowledgements

None.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Competing interests

The authors declare that there is no conflict of interest.

Availability of data and materials

Not applicable.

ORCID iD

Ahmad Hassan Ali https://orcid.org/0000-0001-8553-7744

References

1. Sanyal AJ, Bosch J, Blei A, et al. Portal hypertension and its complications. *Gastroenterology* 2008; 134: 1715–1728.
2. Garcia-Tsao G, Abraldes JG, Berzigotti A, et al. Portal hypertensive bleeding in cirrhosis: risk stratification, diagnosis, and management: 2016 practice guidance by the American Association for the study of liver diseases. *Hepatology* 2017; 65: 310–335.

3. Bosch J, Garcia-Pagán JC, Berzigotti A, et al. Measurement of portal pressure and its role in the management of chronic liver disease. *Semin Liver Dis* 2006; 26: 348–362.
4. Hajifathalian K, Westerveld D, Kaplan A, et al. Simultaneous EUS-guided portosystemic pressure measurement and liver biopsy sampling correlate with clinically meaningful outcomes. *Gastrointest Endosc* 2022; 95: 703–710.
5. Bochnakova T. Hepatic venous pressure gradient. *Clin Liver Dis* 2021; 17: 144–148.
6. Maleux G, Willems E, Fieuws S, et al. Prospective study comparing different indirect methods to measure portal pressure. *J Vasc Interv Radiol* 2011; 22: 1553–1558.
7. Berzigotti A, Seijo S, Reverter E, et al. Assessing portal hypertension in liver diseases. *Expert Rev Gastroenterol Hepatol* 2013; 7: 141–155.
8. Samarasena JB, Huang JY, Tsujino T, et al. EUS-guided portal pressure gradient measurement with a simple novel device: a human pilot study. *VideoGIE* 2018; 3: 361–363.
9. Martínez-Moreno B, Guilabert L, Martínez J, et al. EUS-guided portal pressure gradient measurement (EUS-PPG). Preliminary results compared with hepatic venous pressure gradient (HVPG). *Endoscopy* 2022; 54: S97.
10. Reddy S, Panathur Y and Puli S. S59 EUS-guided portal pressure gradient measurements to diagnose cirrhosis: a systematic review and meta-analysis. *Am J Gastroenterol* 2022; 117: e44.
11. Choi AY, Chang KJ, Samarasena JB, et al. Endoscopic ultrasound-guided porto-systemic pressure gradient measurement correlates with histological hepatic fibrosis. *Dig Dis Sci* 2022; 67: 5685–5692.
12. Choi AY, Kolb J, Shah S, et al. Endoscopic ultrasound-guided portal pressure gradient with liver biopsy: 6 years of endo-hepatology in practice. *J Gastroenterol Hepatol* 2022; 37: 1373–1379.
13. Martinez-Moreno B, Martínez Martínez J, Herrera I, et al. Correlation of endoscopic ultrasound-guided portal pressure gradient measurements with hepatic venous pressure gradient: a prospective study. *Endoscopy* 2025; 57(1): 62–67.
14. Yousaf MN, Deda X, Ali AH, et al. Endoscopic ultrasound-guided portal pressure gradient measurement, is it ready for prime time? *Eur Soc Med* 2022; 10(11).
15. Kim S, Lewey S, Meuller L, et al. Endohepatology in clinical practice: EUS-guided portal pressure measurement combined with EUS-guided liver biopsy and variceal screening and treatment in outpatients. *Endosc Ultrasound* 2024; 13: 89–93.
16. von Elm E, Altman DG, Egger M, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ* 2007; 335: 806–808.
17. Ohno E, Hirooka Y, Kawashima H, et al. Feasibility of EUS-guided shear-wave measurement: a preliminary clinical study. *Endosc Ultrasound* 2019; 8: 215–216.
18. Samarasena JB, Yu AR and Chang KJ. EUS-guided portal pressure measurement (with videos). *Endosc Ultrasound* 2018; 7: 257–262.
19. Rockey DC, Caldwell SH, Goodman ZD, et al. Liver biopsy. *Hepatology* 2009; 49: 1017–1044.
20. Boyd A, Cain O, Chauhan A, et al. Medical liver biopsy: background, indications, procedure and histopathology. *Frontline Gastroenterol* 2020; 11: 40–47.
21. Intraobserver and interobserver variations in liver biopsy interpretation in patients with chronic hepatitis C. The French METAVIR Cooperative Study Group. *Hepatology* 1994; 20: 15–20.
22. Bedossa P and Poynard T. An algorithm for the grading of activity in chronic hepatitis C. The METAVIR Cooperative Study Group. *Hepatology* 1996; 24: 289–293.
23. Harris R, Harman DJ, Card TR, et al. Prevalence of clinically significant liver disease within the general population, as defined by non-invasive markers of liver fibrosis: a systematic review. *Lancet Gastroenterol Hepatol* 2017; 2: 288–297.
24. Kirk GD, Astemborski J, Mehta SH, et al. Assessment of liver fibrosis by transient elastography in persons with hepatitis C virus infection or HIV-hepatitis C virus coinfection. *Clin Infect Dis* 2009; 48: 963–972.
25. Almpanis Z, Demonakou M and Tiniakos D. Evaluation of liver fibrosis: "Something old, something new. . .". *Ann Gastroenterol* 2016; 29: 445–453.
26. Schmid P, Bregenzer A, Huber M, et al. Progression of liver fibrosis in HIV/HCV co-infection: a comparison between non-invasive assessment methods and liver biopsy. *PLoS One* 2015; 10: e0138838.

27. Lin Z-H, Xin Y-N, Dong Q-J, et al. Performance of the aspartate aminotransferase-to-platelet ratio index for the staging of hepatitis C-related fibrosis: an updated meta-analysis. *Hepatology* 2011; 53: 726–736.

28. Dulai PS, Singh S, Patel J, et al. Increased risk of mortality by fibrosis stage in nonalcoholic fatty liver disease: systematic review and meta-analysis. *Hepatology* 2017; 65: 1557–1565.

29. Younossi ZM, Stepanova M, Rafiq N, et al. Pathologic criteria for nonalcoholic steatohepatitis: interprotocol agreement and ability to predict liver-related mortality. *Hepatology* 2011; 53: 1874–1882.

30. Ekstedt M, Hagström H, Nasr P, et al. Fibrosis stage is the strongest predictor for disease-specific mortality in NAFLD after up to 33 years of follow-up. *Hepatology* 2015; 61: 1547–1554.

31. Monachese M, Kolb JM, Chang KJ, et al. EUS guided porto-systemic pressure gradient evaluation predicts liver histology and clinical parameters of liver disease: a large multi-center endohepatology study. *Gastrointest Endosc* 2022; 95: AB237.

32. Fujii-Lau LL, Leise MD, Kamath PS, et al. Endoscopic ultrasound-guided portal-systemic pressure gradient measurement. *Endoscopy* 2014; 46(Suppl. 1): E654–E656.

33. Huang JY, Samarasena JB, Tsujino T, et al. EUS-guided portal pressure gradient measurement with a simple novel device: a human pilot study. *Gastrointest Endosc* 2017; 85: 996–1001.

34. Zhang W, Peng C, Zhang S, et al. EUS-guided portal pressure gradient measurement in patients with acute or subacute portal hypertension. *Gastrointest Endosc* 2021; 93: 565–572.

35. Bureau C, Metivier S, Peron JM, et al. Transient elastography accurately predicts presence of significant portal hypertension in patients with chronic liver disease. *Aliment Pharmacol Ther* 2008; 27: 1261–1268.

36. Reiberger T, Ferlitsch A, Payer BA, et al. Noninvasive screening for liver fibrosis and portal hypertension by transient elastography—a large single center experience. *Wien Klin Wochenschr* 2012; 124: 395–402.

37. Vizzutti F, Arena U, Romanelli RG, et al. Liver stiffness measurement predicts severe portal hypertension in patients with HCV-related cirrhosis. *Hepatology* 2007; 45: 1290–1297.

38. Malik A, Yousaf MN and Hammoud GM. The safety and efficacy of endoscopic ultrasound-guided portal pressure gradient measurement with concomitant endoscopic ultrasound-guided liver biopsy: a systematic review. *Front Gastroenterol* 2023; 2:1209539.

39. Del Valle R, Cunto D, Puga-Tejada M, et al. Comparative analysis of vibration-controlled transient elastography and EUS-shear wave elastography for liver stiffness measurement in cirrhosis. *Endosc Ultrasound* 2025; 14: 57–64.

40. Kohli DR, Mettman D, Andraws N, et al. Comparative accuracy of endosonographic shear wave elastography and transcutaneous liver stiffness measurement: a pilot study. *Gastrointest Endosc* 2023; 97: 35–41.e1.