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EUS-guided portal pressure measurement using a digital pressure wire with real-time remote display: a novel, minimally invasive technique for direct measurement in an animal model

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Abstract

Background and Aims—Hepatic venous pressure gradient (HVPG) currently serves as a surrogate for portal pressure measurement but has many limitations. We have developed a novel technique for rapid and direct portal pressure measurements using a digital pressure wire delivered through an EUS-guided 22-G FNA needle. Our aims were to evaluate (1) short term safety and technical feasibility; (2) procedural duration and subjective workload assessment; and (3) accuracy compared with a transjugular criterion standard approach.

Methods—The subjects were Yorkshire pigs, weighing 40 to 55 kg. The portal vein was identified using a linear-array echoendoscope and accessed with a commercially available 22-G FNA needle preloaded with a digital pressure wire. Access was confirmed by portal venography. Mean digital pressure measurements were recorded over 30 to 60 seconds and the NASA task load index (TLI) was scored. The control measurements were conventional transjugular catheterization with a balloon occlusion catheter to obtain free and wedged hepatic pressures, with subsequent HVPG calculation.

Results—The total time required for EUS identification and needle access of portal vein, venography, and digital pressure measurement was less than 5 minutes in 5 out of 5 pigs. The NASA TLI scores revealed a low subjective workload. Baseline portal pressure measurements via

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EUS ranged from 5 to 10 mm Hg (mean 6.4). HVPG measurements were consistently ± 1 mm Hg of portal pressure.

Conclusions—This study represents the first report of direct EUS-guided portal pressure measurements using a digital pressure wire. This method is routinely performed in minutes and provides real-time pressure tracings via wireless transmission. This novel approach for direct portal pressure measurement has the potential to supplant traditional indirect HVPG measurements.

Keywords

Portal hypertension; Endoscopic Ultrasound; EUS; Portal pressure; HVPG; Hepatic Venous Pressure Gradient; Chronic Liver Disease

INTRODUCTION

Portal hypertension, defined as a pathological increase in portal venous pressure, is an important adverse event of liver disease. It is necessary for the development of most clinical adverse events including variceal hemorrhage, jaundice, ascites, and encephalopathy, and should ideally be known in all patients[1–4]. However, direct measurement requires transcutaneous transhepatic portal vein puncture which is technically difficult and carries a high rate of adverse events, and therefore not routinely performed in clinical practice[5–8].

Rather, indirect pressure measurements, whereby a balloon catheter is advanced through the jugular or femoral vein and into the hepatic vein, are performed. The hepatic venous pressure gradient (HVPG) is derived from subtracting the free hepatic vein pressure from wedge hepatic vein pressure, and serves as a surrogate for portal pressure. This procedure is invasive, performed only in specialized centers, and may not always accurately reflect portal vein pressures[9].

As such, a straightforward minimally invasive technique for direct portal pressure measurements may be useful. We have developed a novel approach for rapid and direct portal pressure measurements using a digital pressure wire delivered through an EUS-guided 22-G FNA needle. The aim of the current study is to evaluate (1) short-term safety and technical feasibility; (2) procedural duration and subjective workload assessment; and (3) accuracy compared with the criterion standard approach.

METHODS

Preparation of animals

Five consecutive Yorkshire pigs weighing 40 to 55 kg were used in this study and housed at the Pine Acres Research Facility (Norton, Mass, USA).

Direct Portal Access Procedure

A linear-array echoendoscope (Pentax EG-387OUTK, Hitachi Preirus System) was used to identify the portal vein. With a commercially available 22-G FNA needle (Medtronic Beacon BNX system) preloaded with a digital pressure wire (PressureWire Aeris, St. Jude

Medical), the portal vein was punctured under Doppler imaging to ensure avoidance of other vasculature (Figure 1). Of note, this wire has a pressure sensor 3 cm from the tip, and therefore was extruded this distance after puncture. Furthermore, this wire features a transmitter with the potential to stream pressure data wirelessly to a remote vital signs display. Access was confirmed with portal venography under fluoroscopic and EUS guidance (Figure 2). Digital pressure measurements were recorded continuously over 30–60 seconds. Procedure times and video logs were maintained for subsequent review.

Control Measurements

Conventional transjugular catheterization was performed after cut-down to the right internal jugular vein. Per standard technique, needle aspiration confirmed venous entry. A 0.038 inch guidewire was inserted into the superior vena cava (SVC) and an 8F introducer sheath (Boston Scientific) was placed over the wire. Access to the right atrium and inferior vena cava was performed carefully to prevent coiling of the wire. A balloon occlusion catheter (Boston Scientific, Berenstein 8.5 mm/11.5 mm, 80 cm, 6F) was placed over the wire and advanced into the right hepatic vein under fluoroscopic guidance. Free and wedged hepatic pressures were transduced and recorded continuously over 30 to 60 seconds with subsequent HVPg calculation.

Post-Procedure

After euthanasia, necropsies were performed to evaluate for hemorrhage in both intraperitoneal and retroperitoneal spaces. Mean portal and HVPg pressure measurements ($\pm$ standard deviation) were calculated from the EUS-guided and transjugular approach, respectively.

After completion of each procedure, the endoscopist completed the National Aeronautics and Space Administration (NASA) Task Load Index (TLI) questionnaire[10], a reliable and validated multidimensional scale designed to obtain workload estimates through an assessment of seven parameters: mental demand, physical demand, temporal demand, performance, effort, and frustration in relation to a task (NASA Task Load Index v1.0, NASA Ames Research Center, Moffett Field, Calif, USA). Each procedure was assigned a level of difficulty score based on a visual analog scale.

RESULTS

Puncture of the portal vein with a 22-G FNA needle was successfully performed in all pigs. The mean diameter of the portal vein was 1.04 cm. The pressure wire was consistently advanced through the FNA needle until the floppy tip extruded from the needle under sonographic visualization. However, in many cases, pressure readings occurred immediately after needle puncture before wire extrusion. Direct pressure measurements were successfully performed in 5 out of 5 pigs (Figure 1). The total time required for EUS identification and needle access of portal vein, venography, and digital pressure measurement was routinely less than 5 minutes (range 2.3–4.7 minutes). Baseline portal pressure measurements via EUS ranged from 5 to 10 mm Hg, with a mean of 6.4 mm Hg (Table 1). In 4 of the 5 animals, portal pressure measurements were considered normal, ranging from 3 to 6. One animal had

elevated portal pressures of 10. No intravascular thrombosis was noted on EUS. NASA TLI and technical difficulty visual analog scale scores were consistent with overall low subjective workload (Table 2).

Transjugular catheterization was successfully performed in 5 out of 5 animals (Figure 3). HVPg measurements were consistently ± 1 mm Hg of portal pressure for all animals (Table 1). There was no intraprocedural hemodynamic instability and no evidence of intraabdominal or retroperitoneal bleeding on necropsy.

DISCUSSION

The presence of portal hypertension is responsible for many of the clinical adverse events of liver disease[1–3, 11]. Measurement of HVPg is currently used in practice, but it is invasive, indirect, and may be falsely normal in pre-hepatic and post-hepatic etiologies of portal hypertension[8, 9, 12].

The current study presents a novel EUS-based technique for obtaining direct digital pressure measurements of the portal vein in a reproducible and efficient manner. This approach is advantageous in providing a direct measurement of portal vein pressure, and also diagnostic in non-cirrhotic etiologies of portal hypertension.

Few studies to date have investigated EUS-guided portal vein catheterization. Giday et al [13, 14]. evaluated the feasibility and safety of EUS-guided PV angiography in a porcine model with an FNA needle using carbon dioxide (CO₂) as a contrast agent, and found this approach to be feasible, technically simple, and safe. Lai et al[7] investigated the feasibility of EUS-guided portal vein catheterization in animals in both a normal and portal hypertension-induced state, and correlated these measurements with those obtained via a transhepatic approach. Pressures were measured using an analog system, where the proximal end of the needle was connected to a fluid-filled manometer and pressure recorder.

The approach we describe has several advantages. First, it represents the first report of direct EUS-guided portal pressure measurements using a digital pressure wire. With the transducer located at the needle tip, this technique eliminates pressure variation known to occur in analog systems, where positional changes can alter the pressures transduced. Moreover, it reduces the contribution of operator variability. Second, this method is rapid and routinely performed in minutes, as the pressure wire is preloaded in the 22-G needle. Further reduction in procedure time could be accomplished if a modified wire with a single pressure transducer could be engineered. Third, from a technical standpoint, the procedure is straightforward, as reflected by consistently low NASA TLI scores. The portal vein is easy to identify in human anatomy given its proximity to the duodenal bulb. For clinical application, a transhepatic approach to target a portal venule may make more sense from a safety standpoint, and even that is technically straightforward. Fourth, this technique provides real-time pressure tracings via wireless transmission that are featured on vitals display and can eventually be archived. The values obtained reflect direct portal pressure measurements, unlike HVPg measurements, which provide only a surrogate.

Limitations of this study include the small sample size and inclusion of animals without underlying portal hypertension. Furthermore, although there was no evidence of bleeding on necropsy, further studies are needed to determine its safety in portal hypertensive coagulopathic states.

This study presents a novel EUS-based technique for obtaining direct digital pressure measurements of the portal vein in a reproducible and efficient manner, and has the potential to supplant traditional HVPg measurements. Ongoing survival animal studies and early human protocols are currently underway.

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Abbreviations

HVPg	Hepatic venous pressure gradient
SVC	superior vena cava
NASA	National Aeronautics and Space Administration
TLI	Task Load Index
CO₂	carbon dioxide
VAS	visual analog scale

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Figure 1.
Location of portal vein confirmed under Doppler imaging.

Figure 2.
Passage of EUS-guided needle (A) into portal vein (B) confirmed under EUS guidance.

Figure 3.
Transjugular catheterization with balloon occlusion catheter performed under fluoroscopy.

Table 1

Comparison of HVPG measurements (mm Hg) and EUS-guided portal pressure measurements (mm Hg) in each animal.

Pig number	HVPG measurement (mm Hg)	EUS-guided portal pressure measurement (mm Hg)
1	5	5
2	4	5
3	7	7
4	6	5
5	11	10

Table 2

NASA Task Load Index for endoscopist's effort in EUS-guided portal pressure measurement based on a 10-cm visual analog scale (VAS). The endoscopist specified his score by indicating a position along a continuous line between 2 endpoints from 0 (disagree) to 10 (strongly agree).

Category	Animals (n = 5)					Mean
	1	2	3	4	5	
Mental demand	4	3	2	1	2	2.4
Physical demand	3	2	2	3	2	2.4
Temporal demand	2	1	2	2	1	1.6
Performance	3	2	1	2	1	1.8
Effort	3	2	1	2	2	2.0
Frustration	2	1	2	2	1	1.6
Technical difficulty	3	3	1	2	2	2.2