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Contents

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Contents

ABOUT COVER

Editorial board member of *World Journal of Gastrointestinal Oncology*, Dr. Cao is an Assistant Research Fellow at the Second Affiliated Hospital of Soochow University in Suzhou, China. Having received his Bachelor's degree from Soochow University in 2006, Dr. Cao undertook his postgraduate training at Soochow University, receiving his Master's degree in 2009 and his PhD in 2015. He works in the Department of Pathology, the Second Affiliated Hospital of Soochow University, Soochow University, where his ongoing research interests involve the molecular pathological mechanisms of malignant tumors, particularly in relation to oncogenesis, radiation resistance and cellular signal transduction involving tumors of the digestive system. To date, he has published 16 SCI papers as corresponding author or first author. (L-Editor: Filipodia)

AIMS AND SCOPE

The primary aim of *World Journal of Gastrointestinal Oncology* (*WJGO*, *World J Gastrointest Oncol*) is to provide scholars and readers from various fields of gastrointestinal oncology with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJGO mainly publishes articles reporting research results and findings obtained in the field of gastrointestinal oncology and covering a wide range of topics including liver cell adenoma, gastric neoplasms, appendiceal neoplasms, biliary tract neoplasms, hepatocellular carcinoma, pancreatic carcinoma, cecal neoplasms, colonic neoplasms, colorectal neoplasms, duodenal neoplasms, esophageal neoplasms, gallbladder neoplasms, *etc*.

INDEXING/ABSTRACTING

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ORIGINAL ARTICLE

Retrospective Study

Accurate ultrasonography-based portal pressure assessment in patients with hepatocellular carcinoma

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Author contributions: Zhang Y wrote the manuscript; Liu FQ conceived and designed the study and are the co-corresponding authors; Wang Z, Wu YF, and Fan ZH collected the data; Zhao HW, Yue ZD, and Wang L analyzed the data; all authors made critical revisions to the manuscript and approved the final version.

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Abstract

BACKGROUND

Portal pressure is of great significance in the treatment of hepatocellular carcinoma (HCC), but direct measurement is complicated and costly; thus, non-invasive measurement methods are urgently needed.

AIM

To investigate whether ultrasonography (US)-based portal pressure assessment could replace invasive transjugular measurement.

METHODS

A cohort of 102 patients with HCC was selected (mean age: 54 ± 13 years, male/female: 65/37). Pre-operative US parameters were assessed by two independent investigators, and multivariate logistic analysis and linear regression analysis were conducted to develop a predictive formula for the portal pressure gradient (PPG). The estimated PPG predictors were compared with the transjugular PPG measurements. Validation was conducted on another cohort of 20 non-surgical patients.

RESULTS

The mean PPG was 17.32 ± 1.97 mmHg. Univariate analysis identified the association of the following four parameters with PPG: Spleen volume, portal vein diameter, portal vein velocity (PVV), and portal blood flow (PBF). Multiple linear regression analysis was performed, and the predictive formula using the PVV and PBF was as follows: PPG score = 19.336 - 0.312 × PVV (cm/s) + 0.001 × PBF (mL/min). The PPG score was confirmed to have good accuracy with an area

available database in hospital.

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under the curve (AUC) of 0.75 (0.68-0.81) in training patients. The formula was also accurate in the validation patients with an AUC of 0.820 (0.53-0.83).

CONCLUSION
The formula based on ultrasonographic Doppler flow parameters shows a significant correlation with invasive PPG and, if further confirmed by prospective validation, may replace the invasive transjugular assessment.

Key words: Portal pressure gradient; Hepatic vein pressure gradient; Hepatocellular carcinoma; Transjugular; Portal pressure; Portal vein pressure

Core tip: The direct measurement of portal pressure is complicated; therefore, non-invasive measurement methods are urgently needed to guide the treatment of hepatocellular carcinoma. The combined measurements of portal vein velocity and portal blood flow could be clinically and economically useful in estimating portal pressure gradient.

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INTRODUCTION

Hepatocellular carcinoma (HCC) is a significant public health problem worldwide and is currently the main event leading to death in patients with cirrhosis[1]. The current treatment modalities for HCC include liver resection (LR) and liver transplantation. Portal pressure accurately predicts the risk of peri-operative morbidity and mortality[1,2]. The European Association for the Study of the Liver and American Association for the Study of Liver Diseases guidelines for the management of HCC consider a hepatic venous pressure gradient (HVPG) ≥ 10 mmHg to be a contraindication for LR[3,4].

Portal pressure gradient (PPG), ranges between 1 mmHg and 5 mmHg in normal conditions, which represents the hepatic perfusion pressure of portal blood[5]. HVPG measurement has the advantages of simple measurement techniques and low risk, which is widely used to estimate PPG and is regarded as the gold standard for the diagnosis of portal hypertension. Based on HVPG, clinically significant portal hypertension (CSPH) is defined as an HVPG of at least 10 mmHg[6-8]. The limitations of HVPG measurement are that it is invasive and impractical for routine clinical practice. Many non-invasive portal pressure assessment techniques have been introduced in recent years[9-13]. Doppler sonography offers real-time observation of blood flow with qualitative and quantitative assessments, and the application of microbubble-based contrast agents has improved the detectability of peripheral blood flow. In addition, elastography of the liver and spleen covers a wider field beyond the original purpose of fibrosis assessment. These developments enhance the practical use of ultrasonography (US) in the evaluation of portal hemodynamic abnormalities[12,14]. However, none of these methods have gained extensive clinical acceptance, as a consequence of small sample size, lack of external validation, and/or their low accuracy in the prediction of CSPH.

The aim of this study was to clarify whether simple, non-invasive US parameters correlate with the invasive transjugular PPG measurement and to develop a formula to estimate PPG.

MATERIALS AND METHODS

The present study was based on a retrospective analysis of prospectively collected data in our department. This study was compliant with the Health Insurance

Portability and Accountability Act. Due to the retrospective nature of the study, informed consent was waived. This study was approved by the hospital ethics committee.

Inclusion and exclusion criteria

All consecutive patients who underwent transjugular PPG measurement from January 2016 to June 2018 were included.

The inclusion criteria were as follows: (1) Patients aged 18-70 years; (2) Patients who were diagnosed with HCC; (3) Patients who underwent transjugular portal pressure measurement, abdominal computed tomography (CT) angiography, and Doppler US; (4) Patients received no treatment for HCC at the time of PPG measurement, and underwent US examination at the same time as PPG measurement; and (5) Patients with a follow-up period of minimum 12 mo.

The exclusion criteria were: (1) Patients with portal vein thrombosis or hepatic vein thrombosis; (2) Those with massive ascites in which accurate measurements by Doppler US were not possible; and (3) Pregnant or lactating women.

Clinical assessment

Baseline demographic, clinical, and laboratory characteristics were retrieved from clinical records. All patients underwent hematological tests including complete blood counts, routine coagulation examination, and kidney and liver function tests at admission. Details pertaining to the use of alcohol and hepatotoxic drugs were recorded. Patient sera were tested for hepatitis B surface antigen and antibody to hepatitis C virus. Other appropriate tests for determining etiology were also performed, if required. The Child-Pugh and Model for End-stage Liver Disease (MELD) scores were calculated on the basis of clinical data. The severity of liver disease at inclusion and during follow-up was assessed by the Child–Pugh grade and MELD score. The ALBI grade was calculated using the following equation: Linear predictor = ($\log_{10}$ bilirubin μmol/L × 0.66) + (albumin g/L × -0.085).

Ultrasound examination

US was performed before the hemodynamic investigation in patients fasted for 8 h. US examination was performed using a 3.5-MHz sector transducer (iU22 Ultrasound System; Philips Healthcare, Reedsville, PA, United States). The diameter of the portal vein was measured using B-mode US. In each patient, all measurements were carried out on a longitudinal section of the vessel and were repeated by one radiologist who had no knowledge of the hemodynamic values. These measurements included the diameter of the portal vein and portal blood velocity. All measurements were performed in triplicate and then averaged.

The portal blood flow was calculated as portal vein velocity (PVV, cm/s) × portal vein cross-sectional area × 0.57, and the congestion index (CI) of the portal vein was calculated as previously reported[15]: The "congestion index" is used to mean the ratio between the cross-sectional area (cm^2) and the blood flow velocity (cm/s) of the portal vein, as determined by a duplex Doppler system.

Transjugular PPG and HVPG measurements

Transjugular PPG and HVPG measurements were performed under general anesthesia in the angiography suite by an experienced radiologist. Pressure measurements were conducted using a balloon catheter (Edwards Lifesciences, Irvine, CA, United States) with a pressure transducer at the tip. A zero measurement with the transducer open to air was needed before transjugular catheterization. All measurements were performed in triplicate and then averaged.

Transjugular PPG measurement

Using an established technique to measure PPG[16], the portal vein was punctured with a modified transjugular liver biopsy needle under ultrasonographic and radiological guidance, and was aimed at the right portal vein branch 1-3 cm above the portal vein bifurcation. After successful puncture, the portal vein was catheterized using a 5F catheter, and baseline measurements of portal venous pressure, inferior vena cava pressure, and the PPG were obtained.

Transjugular HVPG measurement

Transjugular HVPG measurement was conducted according to the standard protocol[17]. The free HVPG was measured in the right hepatic vein (approximately 1-3 cm from the IVC). Then, as the balloon was inflated for total occlusion of the right

hepatic vein, the wedged hepatic venous pressure was measured. Continuous recording was necessary until the pressure reached a plateau. HVPG was calculated by subtracting the free venous hepatic pressure from the wedged hepatic pressure.

CT-based HVPG

The CT-based portal pressure score was calculated as follows: 17.37-4.91 × ln (liver-to-spleen volume ratio) + 3.8 (if perihepatic ascites is present)[18].

Statistical analysis

Quantitative variables are expressed as the mean ± SD and qualitative data are expressed as percentages. The independent *t* test or analysis of variance was applied for comparisons of normally distributed variables. For non-normally distributed data, the Kruskal-Wallis test or Wilcoxon's rank-sum (Mann-Whitney) test was used to analyze the statistical significance of intergroup differences. Pearson's correlation for normally distributed variables and Spearman's rank-correlation coefficient for non-normally distributed data were used, as appropriate. Linear regression analyses were performed according to the least-squares method. Spearman correlation coefficient analysis (R^2 value) and the Bland-Altman plot were used to assess the correlation and the agreement between transjugular PPG and HVPG, and between estimated PPG and transjugular PPG, respectively. The proposed PPG predictive models were subsequently tested on a validation cohort, which included 20 patients (none of these patients underwent surgery or transplantation). The performance of the estimated PPG in predicting transjugular PPG was assessed using receiver operator characteristic curves and the area under the curve (AUC) was calculated. Two-sided $P < 0.05$ was considered statistically significant. Statistical analyses were performed with the SPSS 20.0 package (SPSS, Chicago, IL, United States) and Graphpad Prism 8.0 (Graphpad Software Inc., United States).

RESULTS

Demographics

A total of 102 patients with HCC were included, and their demographics and clinicopathological parameters are shown in Table 1. The baseline liver function of these patients was as follows: Alanine aminotransferase, 24.4 ± 18.0 IU/L; aspartate aminotransferase, 35.0 ± 24.4 IU/L; and total bilirubin, 2.20 ± 3.61 mg/dL. No complications during the measurement of direct PPG were recorded in the present series.

US Doppler parameters

Doppler liver and abdominal vascular scans were performed for all patients. These US Doppler parameters are summarized in Table 2. The preoperative US Doppler parameters were as follows: Portal vein diameter, 1.20 cm ± 0.37 cm; portal vein velocity, 25.1 cm/s ± 11.4 cm/s; portal blood flow, 1729.9 mL/min ± 1003.1 mL/min; and CI, 0.11 ± 0.07.

Correlation between HVPG and PPG

HVPG was 17.07 ± 4.78 mmHg and PPG was 17.32 ± 1.97 mmHg. The paired *t* test showed no significant difference between HVPG and PPG (Figure 1A). Correlation analysis showed that the correlation coefficient between HVPG and PPG was 0.51, and the R^2 was 0.46 ($P = 0.13$, Figure 1B). The Bland-Altman plot showed a difference between HVPG and PPG (Figure 1C). These results indicated that the PPG had a good correlation with HVPG.

Development of a predictive formula of PPG

Table 3 shows the correlations between the PPG and other comparable parameters. The correlation analysis identified four variables as significantly negatively correlated with PPG: SV, PVD, PVV, and PBF ($P < 0.05$). Other parameters were not correlated with the PPG in these patients.

The four selected US parameters were examined for correlations with PPG using multiple linear regression analysis by the stepwise method (Table 4). Based on this result, the following regression equation was established: PPG score = 19.336 - 0.312 × PVV (cm/s) + 0.001 × PBF (mL/min).

Table 1 Characteristics of the included patients, *n* = 102

Index		Index	
Age (yr)	54 ± 13	Globulin (g/dL)	30.5 ± 8.9
Gender (male/female)	65/37	Albumin (g/dL)	34.9 ± 5.9
Etiology, *n*	102	Total protein (g/dL)	65.5 ± 10.0
Virus	48	ALP (U/L)	120.6 ± 86.7
Alcohol	20	GGT (U/L)	67.7 ± 82.3
Cryptogenic	5	BUN (mmol/L)	6.8 ± 5.4
Multifactorial	20	Creatinine (μmol/L)	88.7 ± 138.6
Others	9	LDH (UL)	194.3 ± 59.8
GB history, *n* (%)	76 (74.51)	K (mmol/L)	4.0 ± 0.7
Refractory ascites, *n* (%)	78 (76.47)	Na (mmol/L)	138.4 ± 14.5
Encephalopathy, *n* (%)	4 (3.92)	Cl (mmol/L)	106.4 ± 5.1
Red blood cells (10^{12}/L)	3.3 ± 1.6	Ca (mmol/L)	2.15 ± 0.15
Hemoglobin (g/L)	91.6 ± 25.3	Blood ammonia (μmol/L)	51.2 ± 30.0
White blood cells (10^{12}/L)	4.1 ± 4.0	FIB (n/L)	2.3 ± 1.5
Platelet count (10^{9}/L)	106.7 ± 95.7	APTT (s)	34.5 ± 6.3
ALT (U/L)	24.4 ± 18.0	TT (s)	17.7 ± 5.4
AST (U/L)	35.0 ± 24.4	D dimer level (μg/L)	809 ± 1009
TBIL (mg/dL)	2.20 ± 3.61	Child–Pugh class, *n* (A/B/C)	26/58/18
DBIL (mg/dL)	1.41 ± 3.14	ALBI score	-2.06 ± 0.47
IBIL (mg/dL	0.67 ± 0.43	MELD score	7.66 ± 5.46
PT(s)	14.6 ± 3.6	HVPG (mmHg)	17.07 ± 4.78
PT (%)	61.1 ± 16.6	PVP (mmHg)	34.40 ± 5.95
INR	1.4 ± 0.3	PPG (mmHg)	17.32 ± 1.97

GB: Gastrointestinal bleeding; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; PT: Prothrombin time; TBIL: Total bilirubin; INR: International normalized ratio; ALP: Alkaline phosphatase; GGT: Glutamyl transpeptidase; BUN: Blood urea nitrogen; LDH: Lactate dehydrogenase; APTT: Activated partial thromboplastin time; TT: Thrombin time; HVPG: Hepatic venous pressure gradient; PVP: Portal vein pressure; PPG: Portal pressure gradient.

Correlation between estimated PPG score and actual PPG

The mean estimated PPG using the predictive formula was 17.16 ± 1.92 mmHg (11.51-21.14 mmHg). There was a statistically significant correlation between the PPG score and PPG in overall participants (n = 102, R = 0.884, P < 0.001, Figure 2A). A similar result was achieved using the Bland-Altman plot (Figure 2B). The proposed PPG score was applied to the training patients, which confirmed its good accuracy with an AUC of 0.75 (0.68-0.81).

Validation of the model for prediction of PPG

In addition, 20 patients were enrolled as the validation cohort, which included 12 with hepatic virus infection, 6 with alcoholic liver diseases, and 1 each with non-alcoholic liver disease and primary biliary cholangitis. The proposed PPG score was applied to the validation group and the results confirmed its good accuracy with an AUC of 0.68 (0.53-0.83, Figure 3A).

Comparison between HVPG- and CT-based HVPG scores

The CT-based HVPG score was applied to estimate HVPG, which confirmed its good accuracy with an AUC of 0.63 (0.55-0.71, Figure 3B). Compared with the estimated PPG formula proposed in this study, the power of the test was equivalent, but the ultrasound data in this study were relatively easy to obtain and there was no radiation

Table 2 Results of ultrasonography examination

Parameter	Result
Portal vein diameter (cm)	1.20 ± 0.37
Portal vein velocity (cm/s)	25.1 ± 11.4
Portal blood flow (mL/min)	1729.9 ± 1003.1
Congestion index	0.11 ± 0.07
IVC diameter (cm)	8.7 ± 2.9
IVC blood velocity (cm/s)	62.2 ± 31.0
Spleen vein diameter (cm)	1.12 ± 0.23
Spleen vein velocity (cm/s)	11.51 ± 3.23

IVC: Inferior vena cava.

Table 3 Correlations between portal pressure gradient and clinicopathologic parameters and parameters of Doppler ultrasound

Index	Correlation with PPG (γ)	*P* value
Age (yr)	0.345	0.632
Peri-hepatic ascites (yes *vs* no)	0.753	0.233
Platelet count (× 10^9/L)	-0.341	0.061
Total bilirubin (mg/dL)	-0.231	0.487
Serum albumin (g/dL)	0.542	0.683
AST (IU/L)	0.452	0.712
ALT (IU/L)	0.028	0.652
NH_3 (μg/dL)	0.126	0.515
MELD score	0.025	0.523
Portal vein diameter (cm)	0.102	0.019
Portal vein velocity (cm/s)	-0.321	0.034
Portal blood flow (mL/min)	-0.032	0.048
PV-CI	0.285	0.021
IVC diameter (cm)	0.129	0.496
IVC blood velocity (cm/s)	0.163	0.389
Spleen vein diameter (cm)	0.142	0.248
Spleen vein velocity (cm/s)	-0.062	0.654

AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; MELD: Model for End-stage Liver Disease; PVV: Portal vein velocity; PV-CI: Portal vein congestion index.

damage during CT examination.

DISCUSSION

Currently, the golden standard for measuring portal hypertension and its severity is usually HVPG measurement[19,20]. Measuring this gradient is safe and relatively simple to perform, but it is invasive and costly. In this study, the PVV and PBF showed independent positive correlations with the PPG. Thus, we developed an US-based estimated PPG formula and further validated its performance in the non-invasive diagnosis of portal pressure in patients with HCC. As expected, the estimated PPG

Table 4 Multiple linear regression stepwise method output using ultrasonography Doppler data for correlations with portal pressure gradient

Model	Unstandardized coefficients		Standardized coefficient	*T* value	*P* value	95% Confidence Interval
	β	Standard error	β			
1 (Constant)	19.432	2.785		8.538	0.000	15.133-21.482
SV (cm^3)	-0.212	0.214	-0.265	-1.432	0.654	-0.378-0.431
PVD (cm)	0.322	0.254	0.331	0.085	0.723	0.134-0.564
PVV (cm/s)	-0.323	0.187	-0.353	-1.572	0.157	-0.623-0.113
PBF (mL/min)	0.001	0.056	0.274	1.431	0.197	0.023-0.422
2 (Constant)	19.345	2.634		8.634	0.000	15.268-21.372
PVD (cm)	0.312	0.262	0.232	0.079	0.654	0.211-0.592
PVV (cm/s)	-0.343	0.232	-0.412	-1.548	0.132	-0.451-0.065
PBF (mL/min)	0.001	0.067	0.283			
3 (Constant)	19.336	2.543		8.634	0.000	16.235-22.354
PVV (cm/s)	-0.312	0.134	-0.532	-2.645	0.032	-0.454 – 0.001
PBF (mL/min)	0.001	0.078	0.276	2,143	0.025	0.034-0.462

SV: Spleen volume; PVD: Portal vein diameter; PVV: Portal vein velocity; PBF: Portal vein flow.

showed significant agreement with invasive PPG measurement.

Hepatic hemodynamic changes in patients with portal hypertension are often complicated. As a non-invasive method for assessing portal hypertension, Doppler US is economical, simple, and easy to repeat. Its development prospects are considerable. It is expected to become one of the development directions in the non-invasive diagnosis of portal hypertension. Some Doppler parameters have been proposed as candidate surrogates of the HVPG[21,22]. However, in validation studies, none of these parameters have proved to be accurate. A possible reason for this is that Doppler measurements can be influenced by many factors, such as respiration and vasoactive drugs, as well as by inter-observer and inter-equipment variability. However, measuring liver stiffness by ultrasound and dynamically detecting hemodynamic parameters can be used as non-invasive indicators for evaluating portal pressure and the presence or absence of portal hypertension[14]. Indeed, portal vein hemodynamics are predictive markers and lower velocity in the portal trunk in compensated cirrhosis is an indicator of decompensation[23]. As with any other vascular system, portal pressure is the product of two independent factors, namely, resistance to blood flow and amount of flow, as stated by Ohm's law: Pressure = Resistance × Flow[24]. Liver stiffness measurement accurately reflects liver fibrosis in chronic liver diseases. However, the exact HVPG value cannot be reliably estimated by LSM (correlation *R* ranges from 0.59 to 0.70)[25].

In the present study, the combined measurements of the PVV and PBF were clinically and economically useful in distinguishing those patients who truly required further assessment for portal hypertension using more invasive and expensive procedures such as PPG determination. By comparing the calculated PPG with the actual PPG, a strong correlation was observed even though both the calculated PPG and the actual PPG were not always the same in each patient, and the calculated PPG was extremely accurate in the prediction of PPG (AUC = 0.75) in the training cohort. During the validation study, based on a cohort of 20 patients, the calculated score was slightly lower, but still showed good accuracy with an AUC of 0.68. In another study, the diagnostic accuracy of HVPG reached 0.83, but the non-invasive HVPG interpretation is relatively time-consuming (approximately 2.5 h per case)[26]. The formula can save time in each patient and may be used as a preliminary choice before the virtual evaluation of HVPG. However, based on the research conditions of this study, there may be the following restrictions when using this formula. The sample of this study is mainly the Chinese population. The cause of cirrhosis is mainly viral cirrhosis, which is different from the alcoholic cirrhosis in Western countries. When using this formula, we should consider the differences caused by different etiology.

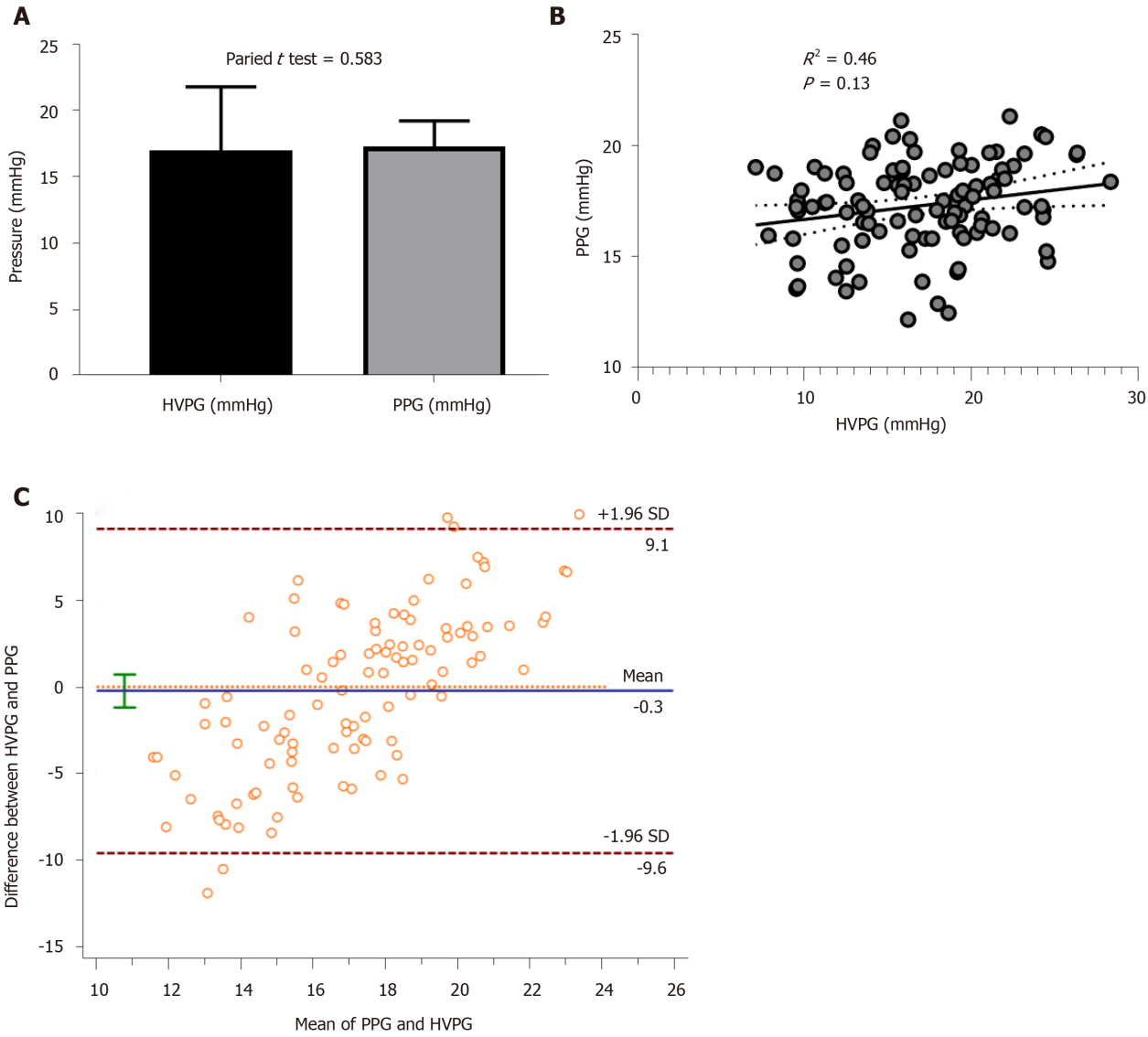

Figure 1 Correlation between portal pressure gradient and hepatic venous pressure gradient in the overall group. A: Paired *t*-test showed that there was no significant difference between hepatic venous pressure gradient (HVPG) and portal pressure gradient (PPG); B: Scatterplot shows agreement between PPG and HVPG; C: Bland-Altman plot shows the difference between PPG and HVPG.

There are several limitations to this study. Due to the limited sample size in this study, the detection index was also small, which affected the accuracy of the results to some extent. In future studies, prospective studies with a large sample size are required to increase the test indicators and identify indicators that can objectively and accurately reflect PPG. Despite the very good accuracies of the proposed model including PVV and PBF, a larger sample size may further improve the study power. A further external validation appears mandatory prior to potential wider clinical use.

In conclusion, PVV and PBF are independently and positively correlated with PPG, suggesting the usefulness of these parameters as non-invasive predictors of PPG. Monitoring of PVV and PBF may be clinically useful for the early detection and management of portal hypertension to distinguish those patients who require further invasive and expensive procedures such as PPG determination.

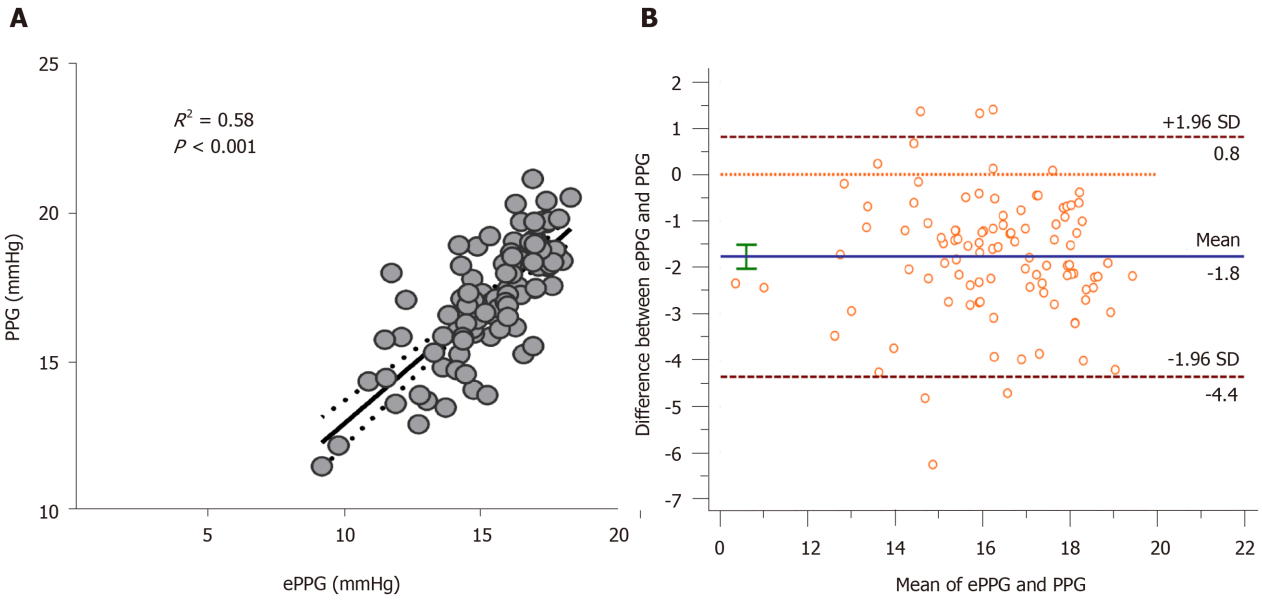

Figure 2 Correlation between portal pressure gradient and estimated portal pressure gradient in the overall group. A: Scatterplot shows agreement between portal pressure gradient (PPG) and estimated PPG (ePPG); B: Bland-Altman plot shows the difference between PPG and ePPG.

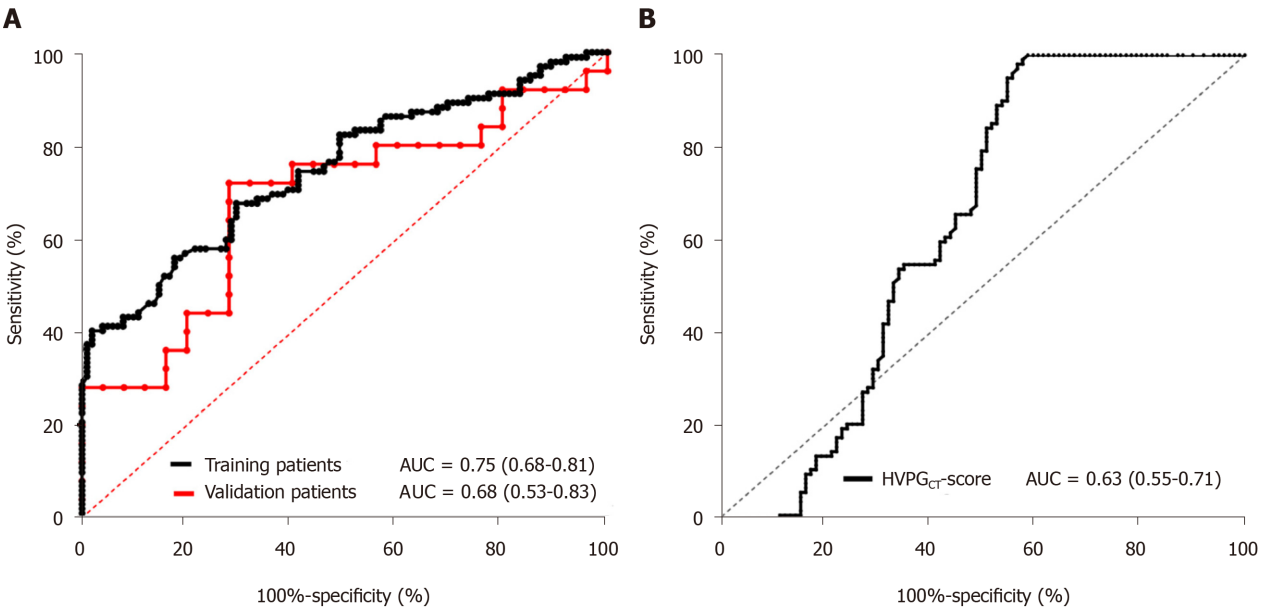

Figure 3 Diagnostic performance of estimated portal pressure gradient for portal pressure gradient. A: Receiver operating characteristic curves of estimated portal pressure gradient (PPG) for predicting PPG in the training and validation cohorts (n = 102 and n = 20, respectively); B: Receiver operating characteristic curves of the HVPG$_{CT}$ score. AUC: Area under curve; HVPG$_{CT}$ score: CT-based portal pressure score.

ARTICLE HIGHLIGHTS

Research background

Portal pressure accurately predicts the risk of peri-operative morbidity and mortality in liver carcinoma. The limitations of HVPG measurement are that it is invasive and impractical for routine clinical practice. Thus, non-invasive measurement methods are urgently needed.

Research motivation

Doppler sonography offers real-time observation of blood flow with qualitative and quantitative assessments, and the application of microbubble-based contrast agents has improved the detectability of peripheral blood flow. The aim of this study was to clarify whether simple, non-invasive US parameters correlate with the invasive

transjugular PPG measurement and to develop a formula to estimate PPG.

Research objectives

To investigate whether ultrasonography (US)-based portal pressure assessment could replace invasive transjugular measurement.

Research methods

A cohort of 102 patients with HCC was selected (mean age: 54 ± 13 years, male/female: 65/37). Pre-operative US parameters were assessed by two independent investigators, and multivariate logistic analysis and linear regression analysis were conducted to develop a predictive formula for the portal pressure gradient (PPG). The estimated PPG predictors were compared with the transjugular PPG measurements. Validation was conducted on another cohort of 20 non-surgical patients.

Research results

The mean PPG was 17.32 ± 1.97 mmHg. Univariate analysis identified the association of the following four parameters with PPG: Spleen volume, portal vein diameter, portal vein velocity (PVV), and portal blood flow (PBF). Multiple linear regression analysis was performed, and the predictive formula using the PVV and PBF was as follows: PPG score = 19.336-0.312 x PVV (cm/s) + 0.001x PBF (mL/min). The PPG score was confirmed to have good accuracy with an area under the curve (AUC) of 0.75 (0.68-0.81) in training patients. The formula was also accurate in the validation patients with an AUC of 0.820 (0.53–0.83).

Research conclusions

The formula based on ultrasonographic Doppler flow parameters shows a significant correlation with invasive PPG and, if further confirmed by prospective validation, may replace the invasive transjugular assessment.

Research perspectives

The formula for the prediction of PPG should be verified on a larger and external validation cohort for widespread acceptance.

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