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The Role of Shear-Wave Elastography of the Spleen in Ruling out the Presence of High-Risk Varices in Non-Alcoholic Fatty Liver Disease (NAFLD)

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Abstract: The progression of liver fibrosis and the presence of portal hypertension are two key points in the follow-up and severity assessment of patients with chronic liver disease. Objective evaluation of such aspects has proven to be difficult due to the lack of reproducible and standardized non-invasive methods. Therefore, the aim of this study was to evaluate whether spleen stiffness (SS) can rule out the presence of high-risk varices (HRVs) in patients with non-alcoholic fatty liver disease (NAFLD). We designed a prospective follow-up of a cohort of 48 consecutive patients diagnosed with compensated advanced chronic liver disease (cACLD) due to NAFLD, between January 2020 and January 2021. After clinical evaluation, laboratory testing, ultrasonography (US), and shear-wave elastography (2D-SWE.GE) of both the liver and the spleen, patients were endoscopically screened for esophageal varices, gastric varices, and portal hypertensive gastropathy. Correlations and predictors were assessed. After univariate, multivariate, and predictive analyses, SS could be referred to as an independent predictor for high-risk varices (AUROC 0.987, $p < 0.001$, OR 4.985, 95% CI: 1.57–15.73, $p = 0.006$), with a calculated cutoff value of 17.95 kPa. These results are consistent with those of other, similar studies using both 2D-SWE.GE and a similar module (2D-SWE.SSI) in patients with metabolic liver disease. When confirmed by subsequent larger studies, SS could potentially become a useful non-invasive tool in the assessment of clinically significant portal hypertension in patients with advanced fatty liver disease.

Keywords: esophageal varices; spleen stiffness; variceal bleeding; compensated advanced chronic liver disease

Citation: Olteanu, V.-A.; Sfarti, C.-V.; Balan, G.G.; Timofte, O.; Gologan, E.; Mitrică, D.E.; Gilca-Blanariu, G.-E.; Dascalu, C.G.; Sandu, I.; Ştefănescu, G. The Role of Shear-Wave Elastography of the Spleen in Ruling out the Presence of High-Risk Varices in Non-Alcoholic Fatty Liver Disease (NAFLD). *Appl. Sci.* **2023**, *13*, 5764. https://doi.org/10.3390/app13095764

Academic Editors: Jürgen W. Czarske, Richard Nauber and Lars Buettner

Received: 26 February 2023
Revised: 29 April 2023
Accepted: 4 May 2023
Published: 7 May 2023

1. Introduction

Non-alcoholic fatty liver disease (NAFLD) is defined by the accumulation of fat in the liver after the exclusion of secondary causes of fat accumulation, among which alcohol consumption, steatogenic medication, and genetic disorders play important roles. NAFLD is characterized by inflammation and progressive fibrosis, being a serious health issue not only in adults but also during childhood [1]. The progression of liver fibrosis, with a direct impact on the degree of portal hypertension (PHT) severity, represents a crucial element in the appearance of complications in cases of cirrhotic patients, influencing the mortality among these patients [2]. The quantification of this process has traditionally been performed by calculating the porto-suprahepatic pressure gradient with the threshold set at 10 mmHg, above which clinically significant portal hypertension (CSPH) can be defined [3,4]. Due to

its highly invasive character, the measurement of the porto-suprahepatic pressure gradient has become a marginal instrument that is mainly useful in the research procedures and characterized by low feasibility and reproducibility in usual practice [5].

The Baveno VI consensus has implemented transient elastography as a reproducible assessment tool for the risk of occurrence of CSPH, excluding the need for endoscopic screening in order to identify the presence of high-risk varices (HRVs) [6]. Adopting the Baveno VI principles, against the background of the development of more and more reliable and reproducible methods for the non-invasive evaluation of liver fibrosis, creates perspectives for research in order to identify other feasible methods for the non-invasive quantification of PH and of the risk of variceal bleeding in patients with compensated advanced liver disease (cALD). Taking into account that 2D-SWE elastography has attracted considerable interest among clinicians thus far, we can consider it to be a potentially useful and promising resource in assessing the severity of PH [7–13].

In this regard, the extension of the elastographic evaluation on the splenic parenchyma has also recently been discussed, with splenic fibrosis being potentially correlated with the degree of PH and the risk of bleeding [14–17]. Moreover, spleen volume is referred to as an important diagnostic feature in NAFLD [18]. The clinical basis of this research approach is the fact that, up to this point, the parameters relevant to spleen dynamics—such as the bipolar diameter of the spleen, the caliber of the splenic vein, the number of platelets, or combinations of the above—have been useful benchmarks in assessing the degree of PH, as well as in estimating the risk of variceal bleeding, thereby creating a possible link between spleen elastography and non-invasive evaluation of CSPH [17,19,20].

Given this state of knowledge, the aim of this study was to investigate the performance of shear-wave elastography of the spleen in the follow-up of patients with advanced chronic liver disease, and to prove its correlation with the presence of high-risk varices (HRVs).

2. Materials and Methods

2.1. Patients

The prospective study was carried out within the Institute of Gastroenterology and Hepatology, as well as Grigore T. Popa University of Medicine and Pharmacy of Iasi, Romania, between January 2020 and January 2021.

Initially, 59 patients diagnosed with compensated advanced liver disease (cALD) secondary to NAFLD were referred for inclusion. The inclusion criteria were as follows: (i) age > 18 years; (ii) positive diagnosis of compensated metabolic advanced liver disease (by clinical, paraclinical, and imaging criteria); (iii) LS evaluated by 2D-SWE.GE elastography > 10 kPa, in agreement with the Baveno VI consensus. The exclusion criteria throughout the prospective follow-up were as follows: (i) occurrence of decompensation (encephalopathy or ascites); (ii) acute or past variceal bleeding or endoscopic therapy (band ligation); (iii) current treatment with beta blockers; (iv) history of alcohol intake more than 2 units per day; (v) transjugular portosystemic shunt; (vi) the presence of portal vein thrombosis; (vii) the presence of hepatocarcinoma; (viii) the presence of viral infections (e.g., hepatitis B/C), or of other ongoing causes of liver disease (e.g., Wilson's disease, hemochromatosis, autoimmunity); (ix) the presence of acute liver injury; (x) the presence of biliary obstruction; (xi) the presence of heart failure.

Of the 59 patients initially evaluated, 5 patients were excluded from the study batch (1 patient presenting a liver nodule, 1 patient with portal vein thrombosis, 1 patient with a history of esophageal ligation, and 2 patients with grade 2 ascites). Subsequently, another 6 patients were excluded given that the quality criteria for the measurement of spleen fibrosis were not met. The final prospective cohort included 48 patients, who were evaluated clinically, biochemically, by ultrasound and elastography, and by esophagogastroduodenoscopy.

Sample size and power considerations were as follows: Considering the nature of the study, we did not pre-plan the sample size. We reasoned, however, that a sample of 59 patients would provide reasonable grounds for a comparison between the cohorts; indeed, assuming a ratio of patients' inclusion in control vs. study samples of 0.4, based

on previous studies that showed a 40% risk in patients with compensated advanced liver disease (cALD) to develop high-risk varices (HRVs) [21], and an average SS between 13.27 and 16.71 in the control sample and between 18.22 and 26.18 in the experimental sample, our sample provided 80% power at a two-sided 0.05 alpha level to conduct the proposed univariate and multivariate analyses.

In order to ensure the ethical compliance of the suggested study, in accordance with the norms of the Declaration of Helsinki, the consent of the Ethics Committee of Grigore T. Popa University of Medicine and Pharmacy of Iasi was obtained. Each patient included in the study signed their informed consent to participate in the evaluation and monitoring process, as well as regarding the data processing.

2.2. Study Protocol

After the complete clinical examination and the registration of the anthropometric data, biological samples were harvested from the patients, including complete blood counts and liver samples (SGOT, SGPT, GGT, FA, total bilirubin, INR, prothrombin time, albumin).

Patients were subsequently examined by ultrasound, sitting in dorsal decubitus, after a minimum of 8 h of fasting, by a single operator, using the General Electric LOGIQ 9 (GE Healthcare, Chalfont St Giles, UK) ultrasound equipment, selecting the convex probe, abdominal protocol, and subcostal and intercostal approach. The morphology of the liver was evaluated, with the measurement of the craniocaudal diameter of the hepatic lobes, with the probe on the medioclavicular line, subcostal, in the sagittal plane. The measurement of the portal vein (PV) caliber was performed with the patient in the dorsal or left lateral decubitus, also using the Doppler module, positioning the transducer between the porto-splenic junction and the intrahepatic bifurcation of the PV. Subsequently, the spleen bipolar diameter (SBD) was measured. Another aspect of interest was the exclusion of focal liver injury, biliary obstruction, stasis liver, portal vein thrombosis, and ascites.

After ultrasonographic examination, the patients were examined by the same operator with the convex probe C1–6-D, in the Elasto 2D-SWE.GE mode; the patient was placed in the dorsal decubitus, with the right upper limb in complete abduction and the approach being intercostal, to obtain an optimal ultrasound window. The ROI was placed subcapsular, in an area without large vessels, for the acquisition of at least 10 shear-wave images. Measurements were then made by placing a circular area at the level of each previously saved image, excluding artifacts. The LS expressed using the Young's modulus (kPa) was saved in the system for each image, and we automatically calculated the median value and IQR. In order to validate the results, the IQR/median value ratio had to be less than 30%. We used a cutoff value of more than 10 kPa for the diagnosis of compensated advanced liver disease (cALD).

For the evaluation of SS, the patient was positioned in the dorsal or right lateral decubitus, with the upper left limb in abduction, and with the positioning of the probe in an intercostal space, to obtain an appropriate image of the splenic parenchyma—preferably in the middle area, avoiding the large vessels—and then following the same steps described previously in the LS evaluation. Figure 1 shows the acquisition of a measurement at the level of the splenic parenchyma by the 2D-SWE.GE method.

All patients were examined endoscopically during the same admissions; the standard evaluation was performed by a single operator, and the following endoscopic parameters were recorded for each patient: the presence of grade I, II, or III esophageal varices, the presence of gastric varices, the presence of portal hypertensive gastropathy, and the presence of variceal red marks. The criteria for classification and risk assessment of esophageal varices were established in agreement with the Baveno VI consensus, as follows: (i) grade I: varices that flatten on insufflation; (ii) grade II: non-confluent varices protruding into the lumen upon insufflation; (iii) grade III: confluent varices that do not flatten upon insufflation. Patients without esophageal varices or with grade I varices have no risk of variceal bleeding, while patients with grade II and III varices—or those with grade I varices and red marks—are at high risk of bleeding high-risk varices (HRVs).

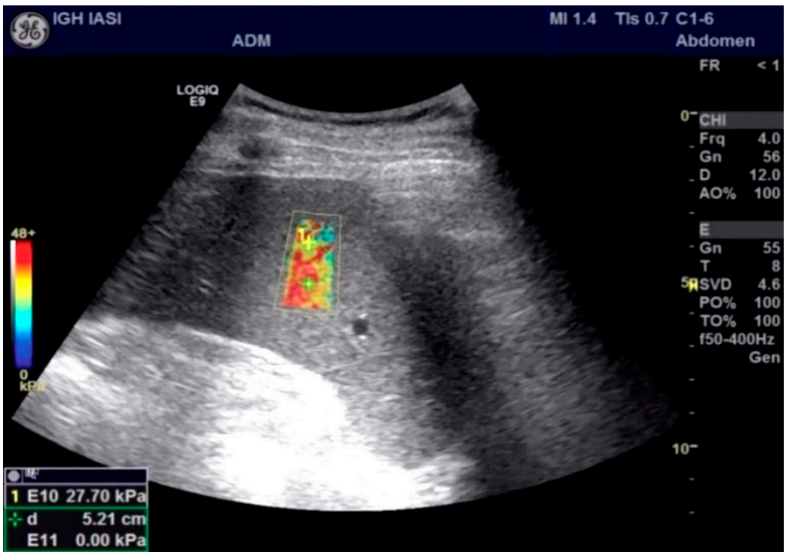

Figure 1. Splenic elastography via 2D-SWE.GE (measuring panel, color map, measurements).

2.3. Statistical Analysis

Statistical analysis was performed using the IBM SPSS software, version 20.0. The categorical variables were reported as percentages, and the numerical variables were reported as averages and standard deviations. Group comparisons of categorical variables were performed using Pearson's chi-squared test. The Kolmogorov–Smirnov test was used to check the normality of the distribution in the case of numerical variables. Student's *t*-test was used for group comparisons of the numerical variables with normal distribution. The nonparametric Mann–Whitney U test was applied for numerical variables with non-normal distribution; the value $p < 0.05$ was considered statistically significant, and the value $p < 0.01$ was considered highly statistically significant. The ROC curves were calculated for the 2D-SWE.GE elastographic method, as well as for other significant parameters correlated with the risk of HREV, in order to identify their potential to predict HREV. The optimal cutoff values were determined from the analysis of the area under the ROC curve (AUROC) and the corresponding sensibility and specificity, according to the Youden criterion. A binary logistic regression model based on the forward LR method was used for the multivariate analysis of the studied predictors of HREV.

3. Results

3.1. Univariate Analysis

Patient distribution showed that 37.5% of patients with compensated advanced liver disease (cALD) did not have esophageal varices (EVs), 25% had grade I EVs, and 37.5% had HRVs (grade II–12.5%; grade III–25%). We found that patients with grade I and II EVs tended to be older that those with grade III EVs (62.3 and 59.5 years old, respectively, vs. 46.08 years old; $p = 0.019$). Furthermore, patients with GOVs were younger than those without GOVs (44.08 years old vs. 57.05 years old; $p = 0.047$).

Table 1 shows the results for the univariate analysis of parameters related to HRVs. Patients with an increased risk of bleeding had a significantly larger caliber of the PV compared to those without risk of bleeding (14.117 mm vs. 12.927 mm; $p = 0.007$). Similar findings were described regarding the SBD; in patients with an increased risk of bleeding the spleen, the bipolar diameter was significantly larger than in patients without risk of bleeding (142.56 mm vs. 129.27 mm; $p = 0.005$). For the laboratory findings, patients with HRVs had significantly lower albumin values (3.13 g/L vs. 3.77 g/L; $p < 0.001$) and platelet counts (94,720/cmm vs. 149,600/cmm; $p < 0.001$) when compared with those without HRVs. Moreover, patients with HRVs had significantly higher INR values (1.44 vs. 1.24; $p = 0.022$) and total bilirubin concentrations (2.10 mg/dL vs. 1.44 mg/dL; $p = 0.007$) when compared to those without HRVs. Consequently, we assessed the correlation be-

tween elastographic parameters and the overall risk of bleeding. Both LS and SS were directly correlated with HRVs. Patients with HRVs had significantly higher values for LS (16.05 kPa vs. 13.06 kPa; $p = 0.004$) and SS (22.2 kPa vs. 14.94 kPa; $p < 0.001$) when compared to patients without HRVs.

Table 1. Baseline characteristics of the studied sample and the univariate analysis of parameters related to the presence of HREVs.

Parameter	Total (n = 48) M ± SD/n(%)	HREVs (n = 18) M ± SD/n(%)	Without HREVs (n = 30) M ± SD/n(%)	p
Gender				
M	35 (72.9%)	17 (94.4%)	18 (60.0%)	0.017
F	13 (27.1%)	1 (5.6%)	12 (40.0%)	
Age (y.o.)	55.77 ± 13.09	51.50 ± 13.50	58.33 ± 12.36	0.08
Portal vein caliber (mm)	13.37 ± 1.51	14.11 ± 1.63	12.92 ± 1.27	0.007
SBD (mm)	134.25 ± 16.26	142.56 ± 13.92	129.27 ± 15.702	0.005
Albumin (g/L)	3.53 ± 0.59	3.13 ± 0.54	3.77 ± 0.50	<0.001
Platelets (n/cmm)	129.02 ± 45.74	94.72 ± 23.71	149.60 ± 43.51	<0.001
Total bilirubin (mg/dL)	1.69 ± 0.84	2.1072 ± 0.80	1.44 ± 0.77	0.007
INR	1.32 ± 0.26	1.44 ± 0.34	1.24 ± 0.15	0.022
TGO	69.33 ± 54.81	91.94 ± 63.76	55.77 ± 44.47	0.067
TGP	49.17 ± 39.02	57.67 ± 43.60	44.07 ± 35.80	0.160
LS (kPa)	14.18 ± 3.04	16.05± 3.76	13.06 ± 1.81	0.004
SS (kPa)	17.67 ± 4.48	22.20 ± 3.98	14.94 ± 1.67	<0.001
GOV				
Present	5 (10.4%)	5 (27.8%)	-	0.005
Absent	43 (89.6%)	13 (72.2%)	30 (100.0%)	
GPH				
Present	7 (14.6%)	7 (38.9%)	-	<0.001
Absent	41 (85.4%)	11 (61.1%)	30 (100.0%)	
CHILD				
A	26 (54.2%)	3 (16.7%)	23 (76.7%)	<0.001
B	22 (45.8%)	15 (83.3%)	7 (23.3%)	
FIB-4	1.02 ± 0.51	1.03 ± 0.50	1.37 ± 0.82	

Subsequently, ROC curve analyses were performed for all of the study variables, and they are presented in Figure 2. The results of the AUROC analysis are presented in Table 2. In all cases, the area under the curve was statistically significant, certifying the predictive value of the parameters in question. However, both sensitivity and specificity were poor and, thus, did not allow the setting of cutoff parameter values.

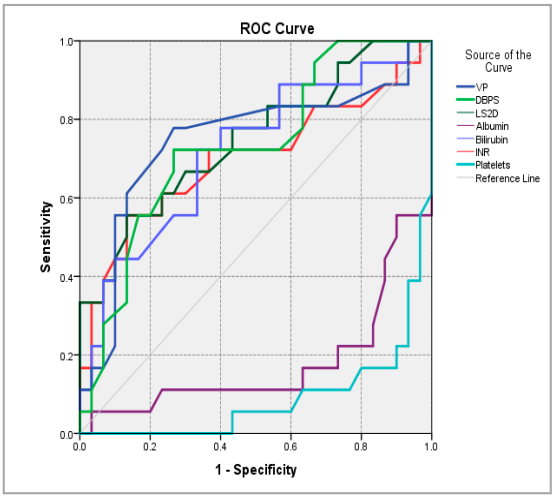

Figure 2. ROC curve analyses for the investigated parameters.

Table 2. Comparative analysis of ROC curves for the investigated parameters.

Parameter	AUC	AUC 95% CI	*p*-Value	Cutoff Value	Sensitivity (%)	Specificity (%)
PV caliber	0.746	0.586 ÷ 0.907	0.005	13.45	77.80%	73.30%
SBD	0.731	0.583 ÷ 0.878	0.008	137	72.20%	73.30%
LS	0.747	0.600 ÷ 0.895	0.004	15.16	55.60%	86.70%
Albumin	0.178	0.041 ÷ 0.315	0.000	4.555	5.60%	96.70%
BT	0.719	0.565 ÷ 0.872	0.012	1.82	72.20%	66.70%
INR	0.699	0.531 ÷ 0.867	0.022	1.375	55.60%	86.70%
Platelets	0.088	0.003 ÷ 0.172	0	265.5	-	96.70%
SS	0.987	0.964 ÷ 1.000	0.000	17.95	94.40%	96.70%

The ROC curve for SS values is presented in Figure 3. SS seems to be a significant predictor for the presence of HRVs (SS AUROC 0.987; $p < 0.001$), with an appropriate cutoff value of 17.95 kPa given the ratio between a sensitivity of 94.4% and specificity of 96.7%, calculated according to Youden's coefficient.

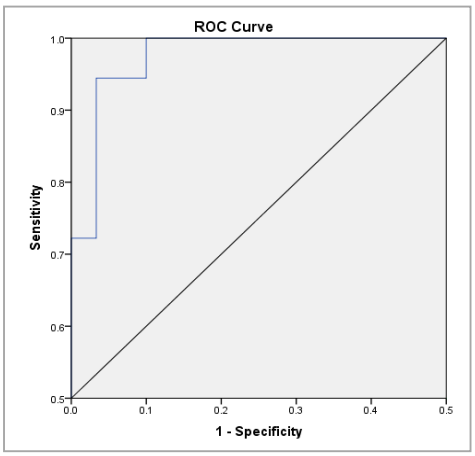

Figure 3. ROC curve analysis for SS values.

3.2. Multivariate Analysis

For the multivariate analysis, a binary logistic regression model based on the forward LR method was also used, as shown in Table 3. The overall prediction accuracy for the diagnosis of HRVs was initially 62.5%, and all predictors introduced in the model were identified as significant, except for the SGPT concentrations. The SS was demonstrated to be the most important independent predictor for HRVs, followed by platelet count, child class, albumin levels, and LS values; although other predictors were also initially found to be significant, they were not included in the final model.

Table 3. Multivariate analysis.

Variable	Score	df	Sig.
VP	7.044	1	0.008
DBPS	7.669	1	0.006
LS 2D	11.087	1	0.001
SS	30.169	1	0.000
Albumin	12.917	1	0.000
BT	7.148	1	0.008
INR	7.241	1	0.007
SGOT	5.005	1	0.025
SGPT	1.395	1	0.237
Platelets	16.535	1	0.000
Child(1)	16.313	1	0.000

The Hosmer–Lemeshow fit test indicated that the built model is viable, with its results being statistically insignificant (p = 1.00); the identified predictors increased the overall prediction accuracy for the diagnosis of HRVs up to 95.8%. Subsequently, the Wald test and odds ratio Exp(B) were calculated for the SS. As shown in Table 4, SS was significantly directly correlated with the risk of bleeding (OR 4.985, 95% CI: 1.57–15.73, p = 0.006).

Table 4. Wald test and OR for SS.

Variable	B	Standard Error	Wald	df	p Value	OR Exp(B)	95% CI for EXP(B) Lower	Upper
SS	1.606	0.587	7.5	1	0.006	4.985	1.579	15.736

4. Discussion

Numerous studies have reported a good correlation between the size of the spleen and the presence of esophageal varices [17,22]. In a study from 2019, Karagiannakis et al. [17] evaluated whether SS measurement could rule out the presence of HRVs in patients with cirrhosis, avoiding an upper gastrointestinal endoscopy, and concluded that 2D-SWE of the spleen is a reliable method for ruling out the presence of HRVs in cirrhotic patients.

Yan et al. [11] investigated whether liver stiffness (LS) measured by two-dimensional shear-wave elastography (2D-SWE) and platelet count (PLT) could rule out high-risk varices in patients with compensated advanced chronic liver disease (cACLD). They concluded that the Baveno VI criteria can be applied to LS measurement by 2D-SWE, because LS measured by 2D-SWE is a reliable predictive factor for all-size varices and high-risk varices in patients with compensated advanced chronic liver disease. The new criteria of LS < 16 kPa and PLT > 100 × 10^9/L could be a potential model to avoid further endoscopic screening, with a <5% miss rate for high-risk varices.

However, it has been shown that, although splenomegaly is commonly present in patients with advanced liver disease, a significant percentage of patients with hepatic cirrhosis do not have HRVs [23].

In our study, univariate and multivariate analyses confirmed several significant correlations between clinical, laboratory, ultrasonographic, and elastographic parameters and the presence of HRVs. Hence, the PV caliber, SBD, albumin levels, total bilirubin levels, INR, platelet count, LS, and SS were qualified as significant predictors of HRVs. Furthermore, SS was proven to be an independent predictor of HRVs (AUROC 0.987, p < 0.001, OR 4.985, 95% CI: 1.57–15.73, p = 0.006), with a calculated cutoff value of 17.95 kPa.

Currently, the performance improvement of the methods of measuring spleen stiffness is being pursued, given that two recent meta-analyses have shown the superiority of this technique for the risk of variceal bleeding, compared to the measurement of liver stiffness [24]. It is emphasized that the use of spleen stiffness values could be more efficient than the Baveno VI or LS criteria in assessing the risk of bleeding in these patients, according to such literature data.

Liu et al. [12] assessed the diagnostic performance of liver stiffness and SS measured by point shear-wave elastography (pSWE) and 2D-SWE in the detection of high-risk esophageal varices and compared their diagnostic accuracy, and they concluded that LS and SS measured by pSWE and 2D-SWE have good accuracy in predicting HREVs.

However, Fernandes et al. [13] evaluated the agreement/accuracy of p-SWE and 2D-SWE for liver fibrosis staging using TE as the reference, in a retrospective study that analyzed data from people with chronic liver diseases subjected to TE, p-SWE, and 2D-SWE, and they concluded that LSM by p-SWE and 2D-SWE techniques was correlated with TE, but LSM by p-SWE seemed to be more accurate than 2D-SWE for identifying patients with more advanced fibrosis.

In a study from 2018, Colecchia et al. [24] suggested a model of combined assessment of spleen and liver stiffness by transient elastography, which could represent an initial screening strategy for patients with advanced chronic liver disease, with the purpose of

detecting esophageal varices with increased risk of bleeding, as well as the appropriate therapeutic approach [24]. Applying the cutoff value identified for SS (≤46 kPa) would have led to the avoidance of endoscopic evaluation for 35.8% of patients, while the use of the Baveno VI criteria would have led to the avoidance of EDS for 21.7% of patients. The combination of SS with the Baveno VI criteria would have led to the avoidance of endoscopy for an additional 22.5% of patients (43.8%), with a false negative diagnosis rate < 5% [24].

The results of our study are consistent with the data from the literature, proving that there were statistically significant differences between the SS values measured by 2D-SWE.GE elastography in the two subplots. The cutoff value calculated for SS relative to the risk of bleeding was 17.95 kPa. As a result, this method can be successfully used for assessing the severity of portal hypertension in patients with advanced chronic liver disease. The cutoff threshold of SS measured by the 2D-SWE.GE elastography reported here was significantly lower compared to the one presented by the data reported in studies that used 2D-SWE.SSI elastography (25.6 kPa) [25]. This difference can be explained by the fact that, although using the same principle, the device used for the 2D-SWE.SSI elastography (Aixplorer® ultrasound system, SuperSonic Image) is based on different software than the one used for 2D-SWE.GE (LOGIQ E9, GE Healthcare). In support of this assertion, there are also data from the literature showing that although both 2D-SWE elastography techniques have good feasibility and a very good correlation with the evaluation by transient elastography (validated method), the values obtained by 2D-SW.GE are significantly smaller than those obtained by 2D-SWE.SSI [26–28].

Several studies have investigated the role of 2D.SWE.SSI elastography—an elastographic method similar to the 2D-SWE.GE method used in our study. Jansen et al. [10] used 2D-SWE.SSI elastography to determine the cutoff values of SS (26.33 kPa) for clinically significant portal hypertension in a batch of 158 patients with liver cirrhosis. The cutoff value of 26.33 kPa was associated with a sensitivity of 79.7% and specificity of 84.2%, with a value of 0.84 of the ROC curve for diagnostic accuracy. Cutoff values < 21.7 kPa have been reported for the exclusion of risk for clinically significant portal hypertension, while 35.6 kPa was the cutoff for the inclusion of patients in the risk category [10].

Procopet et al. [8] used 2D-SWE.SSI elastography to determine the threshold value (of risk for the installation of clinically significant hepatic portal hypertension) of SS in a batch of 55 patients with compensated liver cirrhosis. The authors of the study reported a cutoff value of exclusion below 22.7 kPa and a cutoff value of inclusion of 40 kPa for patients from the risk category, with values of 90% sensitivity and specificity, along with a value of 0.725 for the ROC curve's diagnostic accuracy [8].

Elkrief et al. [7] used 2D-SWE.SSI elastography to determine the cutoff values of SS (regarding the risk of installation of clinically significant hepatic portal hypertension) in a batch of 79 patients with hepatic cirrhosis (compensated in most patients). The authors of the study reported a cutoff value of 34.7 kPa, with values of 40% for sensitivity and 100% for specificity, along with a value of 0.630 for the ROC curve's diagnostic accuracy [7].

The results of our study are similar to those reported by recent studies of 2D-SWE and pSWE elastography, the results of which recommend incorporating SS measurement into non-invasive algorithms by using validated software and optimized measurement scales to increase accuracy in the diagnosis of portal hypertension in patients diagnosed with compensated liver cirrhosis [28–30].

We did not include body mass index and waist circumference in our analysis, although they are correlated with steatosis and fibrosis, taking into consideration the data published by Latinga et al. [31] and Giuffrè et al. [32] stating that anthropometric measurements are not associated with SS.

The main limitations for the evaluation of SS by transient elastography are represented by the necessity of the initial evaluation by abdominal ultrasound and by the fact that, in most cases, diagnostic values cannot be obtained if the spleen is of normal size. All of these issues can be eliminated by the evaluation of SS using other methods, with 2D-SWE

elastography being suggested by Colecchia et al. [16] and Singh et al. [15], along with other non-invasive tests (ARFI, MRE).

This study can be considered to be one of the few investigating the performance of the 2D-SWE.GE elastographic method in the evaluation of SS in patients with advanced chronic liver disease, in order to identify patients with increased risk of variceal bleeding. As a result, SS measurement by 2D-SWE.GE elastography and the use of the regression equation could allow us to reduce the percentage of patients who need to undergo superior digestive endoscopy, which is an invasive examination that requires the allocation of significantly greater financial resources [24]. The main limitation of the 2D-SWE elastographic method is the lack of uniform testing on batches of patients with portal hypertension. The lack of sufficient evidence-based medical information is the main factor limiting the use of 2D-SWE elastography on a large scale in the evaluation of splenic rigidity in patients with portal hypertension.

5. Conclusions

Our study showed that platelet count and child class could be regarded as predictors of an increased risk of variceal bleeding, whereas liver and SS values were correlated with the presence of esophageal varices and could be used as predictors for variceal bleeding. Transient elastography (TE) is a validated method and, therefore, is the most widely used for the evaluation of liver stiffness, but major limitations for the evaluation of SS by transient elastography are represented by the necessity of the initial evaluation by abdominal ultrasound and by the fact that, in most cases, diagnostic values cannot be obtained if the spleen is of normal size. All of these issues can be eliminated by the evaluation of SS using 2D-SWE elastography.

In this context, the results obtained in our research demonstrate that SS values are correlated with CSPH and can be used as predictors of variceal bleeding, with a 2D-SWE.GE cutoff value for SS of 17.95 kPa.

In summary, SS measurement by 2D-SWE.GE elastography and the use of the regression equation could allow us to reduce the percentage of patients who need to undergo superior digestive endoscopy, which is an invasive examination that requires the allocation of significantly greater financial resources.

Thus, elastography of the spleen could be regarded as a useful method for ruling out the presence of HRVs in patients diagnosed with compensated advanced liver disease (cALD).

Author Contributions: Conceptualization, V.-A.O. and G.Ş.; methodology, E.G. and D.E.M.; software, C.G.D.; validation, C.-V.S.; formal analysis, G.G.B. and G.Ş.; investigation, V.-A.O., D.E.M. and O.T.; resources, G.Ş. and C.-V.S.; data curation, E.G. and G.-E.G.-B.; writing—original draft preparation, G.G.B. and V.-A.O.; writing—review and editing, O.T. and G.-E.G.-B.; visualization, I.S. and G.Ş.; supervision, I.S. and G.Ş.; project administration, C.-V.S. and V.-A.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of 'Grigore T. Popa' University of Medicine and Pharmacy Iasi. Approval code: 9293. Date: 10 May 2017.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Previous data from this study have not been published.

Conflicts of Interest: The authors declare no conflict of interest.

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