Two-dimensional shear wave elastography utilized in patients with ascites: a more reliable method than transient elastography for noninvasively detecting the liver stiffness—an original study with 170 patients

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Background: Two dimensional shear wave elastography (2D-SWE) is an ultrasound elastography technique based on shear waves implemented on a diagnostic ultrasound system. Transient elastography (TE) uses an ultrasound displacement M-mode and A-mode image produced by the system. So, TE mechanically induced impulse at tissue surface and difficultly across water. This paper compared the reliability and reproducibility of 2D-SWE with that of TE in patients with chronic hepatic disease. Comparisons were made in terms of the success rate, reliability, reproducibility, operation time, and influence of operator experience.

Methods: A total of 170 patients were included in this study. Participants underwent 2D-SWE and TE performed by 2 different operators (a novice and veteran) on the same day. Nonparametric statistical tests were used to compare the technical success rate and reliable measurement rate, and inter-operator reproducibility was evaluated using intra-class correlation coefficients (ICCs).

Results: The 2D-SWE technique showed a higher technical success rate than TE. Either 2D-SWE or TE can be utilized in patients with ascites lamella of less than 10 mm or ascites lamella plus skin-capsular distance of less than 25 mm. However, although the reliability rate of liver stiffness measurement with 2D-SWE did not significantly differ between the novice and veteran operators, for TE, there was a significant difference when body mass index (BMI) ≤25 kg/m^2. When performed by the novice and veteran operators, 2D-SWE and TE both showed excellent inter-operator agreement, with ICCs of 0.968 and 0.973, respectively. Both 2D-SWE and TE displayed reliable measurement and excellent reproducibility in patients with chronic liver disease, were minimally influenced by operator experience.

Conclusions: 2D-SWE may be a more reliable method for clinical application in noninvasive detecting the liver stiffness.

Keywords: Transient elastography (TE); shear wave elastography (SWE); reliability; reproducibility; liver fibrosis

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Introduction

It has been reported that more than 550,000 million people worldwide have chronic viral hepatitis (1), including children (2), and it is particularly prevalent in developing countries where hepatitis B virus (HBV) infection is common (3). Globally, HBV and hepatitis C virus (HCV) have been identified as the major etiological factors for approximately 60% of cirrhosis cases and 80% of hepatocellular carcinoma (HCC) cases (4). Early diagnosis and the correct staging of hepatic fibrosis are pivotal to monitoring and early treatments, which prevent development into cirrhosis and HCC. The traditional "gold standard" diagnostic test is biopsy, which has disadvantages (5-7) including its invasive nature, association with hemorrhage, and limited specimen retrieval; additionally, biopsy is not the optimal method for the diagnosis of liver fibrosis in certain populations (6).

Ultrasound elastography is a noninvasive method that can detect the stiffness characteristics of tissue. Both 2-dimensional shear wave elastography (2D-SWE) and transient elastography (TE) are dynamic methods, with quantitative evaluations made by the measurement of shear-wave speed, which is converted into the elastic modulus or Young's modulus (kPa).

TE was the earliest discovered method of ultrasound-based elastography for the assessment of liver fibrosis with chronic hepatitis and has accumulated a large amount of clinical evidence (8-11). TE uses an ultrasound displacement M-mode and A-mode image produced by the system. The European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) has recommended (12) that TE can be used to assess the severity of liver fibrosis in patients with chronic viral hepatitis. In clinical practice, TE has inherent pitfalls, including unreliable results in patients with a body mass index (BMI) >30 kg/m^2, type 2 diabetes, and an age >52 years. Furthermore, it cannot be performed in patients with perihepatic ascites.

2D-SWE is a new SWE technique that works by detecting the speed of a shear wave, which offers a quantitative estimate of liver elasticity, basing on shear waves implemented on a diagnostic ultrasound system (12). 2D-SWE is guided by conventional B-mode imaging, which easily enables the avoidance of large vascular structures and masses in the liver. Published studies have demonstrated an equal or superior accuracy of 2D-SWE compared to TE in assessing significant fibrosis (F≥2) (13,14).

The reproducibility of 2D-SWE in the livers of healthy volunteers has been reported as having an intra-operator intra-class correlation coefficient (ICC) of 0.91 and an inter-operator ICC of 0.78. By contrast, the intra- and inter-operator reproducibility of TE are excellent (ICC 0.98 for both) (15). Even so, the reproducibility of 2D-SWE in patients with chronic hepatitis and in comparison with TE has not previously been examined. Indeed, the technical success rates are difficult to compare across modalities because different samples show different success rates (16,17). It is also unknown whether operator experience influences the reproducibility and technical success rates for 2D-SWE and TE.

Further, TE is not recommended for patients with perihepatic ascites by guidelines (12); 2D-SWE is performed on patients with ascites, which may lead to the difference of technical success rate between 2D-SWE and TE.

The goal of this study was to evaluate whether 2D-SWE should be recommended for clinical generalized application, by comparing the technical success rate, reliability, reproducibility, operation time, and influence of operator experience of 2D-SWE with those of TE in the same group of patients with chronic hepatitis. We present the following article in accordance with the TREND reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-6454/rc).

Highlight box

Key findings

- 2D-SWE may be a more feasible method for clinical application in noninvasive detecting the liver stiffness.

What is known and what is new?

- TE was the earliest discovered method of ultrasound-based elastography for the assessment of liver fibrosis with chronic hepatitis and has accumulated a large amount of clinical evidence.
- The goal of this study was to evaluate that 2D-SWE should be recommended for clinical generalized application, by comparing the technical success rate, reliability, reproducibility, operation time and influence of experience by 2D-SWE and TE in the same group of patients with chronic hepatitis.

What is the implication, and what should change now?

- 2D-SWE would be another more feasible method for clinical application, with higher technical success rate and in patients with perihepatic ascites.

Methods

Patients

From August 2013 to November 2014, 171 consecutive patients were enrolled in this single-center prospective study in The Third Affiliated Hospital of Sun Yat-sen University. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by committee of The Third Affiliated Hospital of Sun Yat-sen University (No. [2018] 02-365-01) and informed consent was taken from all the patients. The inclusion criterion was patients with chronic hepatic disease based on clinical and laboratory examination. 2D-SWE and TE were performed on all patients on the same day. The exclusion criteria were the following: lack of consent for the 2D-SWE or TE examination, malignant liver tumor, and prior liver transplant.

Chronic hepatitis was assessed by clinical, biological, and blood viral markers (18). The following data were recorded for all patients: age, gender, weight, and height. Ascites lamella and skin-capsular distance were recorded for patients with perihepatic ascites. The BMI was calculated as the body weight (kg)/height (m^2). All data collection planned before 2D-SWE and TE were performed.

Procedures

All patients underwent 2D-SWE coupled with TE performed by 2 different operators (Novice and Veteran) (19,20) on the same day. The Novice operator had 1 year of experience in ultrasound examination and 3 months training in elastography examination and had performed fewer than 50 examinations prior to this study. The Veteran had more than 8 years' experience in ultrasound examination and more than 3 years' experience in elastography examination and had performed elastography on more than 500 patients.

The 2 machines used to perform 2D-SWE and TE were placed beside the bed at the same time. The novice or veteran was randomly selected to perform the TE examination, which was followed by the 2D-SWE examination.

Both operators who performed the 2D-SWE and TE measurements were blinded to each other's findings, findings from other noninvasive methods, and all clinical and biological data.

This study was not supported by any 2D-SWE or TE manufacturers.

2D-SWE

SWE was performed on an Aixplorer™ ultrasound system (SuperSonic Imagine S.A., Aix-en-Provence, France), with a broadband SC6-1 convex probe (9 cm × 4 cm). This machine is based on conventional B-mode ultrasound and is equipped with 2D-SWE. The machine scanner generates acoustic pulses and tissue displacement in the liver, followed by propagation of a shear wave. An ultrafast echo image (>4,000 frames/sec) is required to capture the shear wave, and the shear wave speed is assessed and translated into liver stiffness [measured as Young's modulus in kilopascals (kPa)] according to the following formula: $E=3\ pv_s^2$, where E is tissue elasticity (kPa), p is the tissue density (kg/m^3), and v_s is the shear wave velocity (m/s). The ultrasound system then creates real-time SWE imaging with a color-coded mapping in the form of a box superimposed on the standard B-mode. The standard grayscale B-mode image and the SWE image are displayed on the monitor side by side or on the top and bottom.

All patients were requested to fast for at least 8 hours prior to the SWE examination. Following the fast, the patients were examined in a supine position with the right arm in maximal abduction above their head to widen the intercostal sonic window. Liver stiffness measurements (LSMs) were performed in the right lobe of the liver through the intercostal space. The operator then changed to SWE mode after the conventional abdominal B-mode ultrasound examination and placed a color-coded mapping box in an area of liver parenchyma that was free of large vascular structures. The image was defined to be in a range of 10–50 mm below the liver capsule, with homogeneous signal fulfilling >90% of the mapping and timed with patient apnea. A circular region of interest (ROI) approximately 2 cm in diameter was chosen inside the image box, and the mean, minimum, maximum, and standard deviation of the elasticity were shown on the monitor. We used the mean value of the elasticity for statistical analyses. The size and position of the box and ROI could be changed by the operator. The measurements were repeated on each participant 5 times with a goal to achieve 5 valid LSMs, with their median value was recorded as the liver stiffness. The duration of each examination was recorded.

Failure of SWE measurements was defined (16) if no or little signal filled the target area (less than 50%) of the elastogram, which could not ensure an effective ROI within at least 5 attempts. Reliable measurement of SWE was defined (13,16,21) as a median value of 5 valid

Table 1 Clinical characteristics of the 170 patients

Characteristics	Values
Age (years), mean ± SD, range	40.09±12.87, 3–71
Gender, n (%)	
Male	98 (57.6)
Female	72 (42.4)
BMI (kg/m^2), mean ± SD, range	22.57±3.94, 14.58–39.73
Etiology, n (%)	
Chronic hepatitis B	89 (52.4)
Chronic hepatitis C	31 (18.2)
Chronic hepatitis B+ NAFLD	23 (13.5)
Chronic hepatitis C+ NAFLD	14 (8.2)
NAFLD	13 (7.6)
Ascites	26 (15.3)

SD, standard deviation; BMI, body mass index; NAFLD, non-alcoholic fatty liver disease.

measurements with a success rate (equal to the ratio of valid measurements to the total number of valid measurements) ≥60% and/or an interquartile range interval (IQR; the difference between the 75th percentile and the 25th percentile) that essentially spanned the middle 50% of the data range (<30%).

The skin-capsular distance and ascites lamella in anterior axillar were vertically measured in the presence of surrounding liver-ascites, meanwhile TE was performed in the same position.

TE

TE examination was performed with a FibroScan device (EchoSens, Paris, France), using a standard M probe. A 5 MHz ultrasound transducer fixed on a vibrator produced a low-frequency pulse at the surface of the body, and pulse-echo acquisitions captured the propagation of the shear wave and the shear wave speed inside the liver tissue. The LSMs were taken in a volume approximately 1 cm wide and 4 cm long, computed to be 25 to 65 mm below the skin surface. Then, Young's modulus was calculated to represent the tissue elasticity.

TE was performed on all patients, who had been fasting for at least 8 hours. Patients were placed in a supine position, with the right arm in maximal abduction above the head to enhance the size of the intercostal space. The exam was performed using an M probe, and the median value of 10 valid LSMs was recorded for statistical analyses. The duration of the procedure for each patient was recorded.

Failed TE measurements were defined (22-24) as when no value was obtained after 10 attempts. Reliable measurement of TE was defined as a median value of 10 valid measurements with a success rate (equal to the ratio of the number of successful acquisitions divided by the total number of acquisitions) ≥60% and/or an IQR interval (IQR, the difference between the 75th and 25th percentiles) that essentially spanned the middle 50% of the data range (<30%).

Statistical analyses

Some statistical analyses were performed using the software SPSS 20.0 (IBM Corp., Armonk, NY, USA). Nonparametric statistical tests (Pearson's chi-square test or Fisher's exact test when the minimal expected value <5) were used to compare the technical success rate and reliable measurement rate of 2D-SWE and TE. A paired-samples *t*-test was used to compare the mean operation time by the novice and veteran, and an independent-samples *t*-test was used to compare the whole mean operation time. Two-way mixed effects model ICCs for continuous variables were used to assess the inter-operator reproducibility with 2D-SWE or TE between the novice and veteran. The ICC ranged from 0 to 1 in value, with 0 indicating differences in measurement between operators and 1 indicating 100% agreement. Operator agreement was classified as excellent (ICC >0.75), fair-to-good (ICC =0.40–0.75), or poor (ICC <0.40).

The results were displayed as the mean ± SD with 95% confidence intervals (95% CIs). A 2-sided P value of <0.05 was deemed significant.

Results

Patient characteristics

A total of 171 patients met the study inclusion criteria and enrolled in our study from August 2013 to November 2014, among whom 1 patient was excluded for due to HCC in the liver. Thus, the final cohort consisted of 170 patients. The patients' characteristics are displayed in *Table 1*. The patients enrolled in our study had liver disease of various causes, including chronic HBV, chronic HCV, chronic HBV plus NAFLD (non-alcoholic fatty liver disease), chronic HCV plus NAFLD, and NAFLD alone. All the etiologies for 26 patients with ascites were decompensated cirrhosis.

Table 2 Technical success rate for the patients with or without ascites undergoing 2D-SWE and TE

Success rate	2D-SWE, %	TE, %	P value
All patients (n=170)			
Novice	94.1 (160/170)	87.6 (149/170)	0.038
Veteran	97.1 (165/170)	90.6 (154/170)	0.013
P value	0.187	0.384	
Patients excluding ascites (n=144)			
Novice*	93.8 (135/144)	92.4 (133/144)	0.643
Veteran*	96.5 (139/144)	95.8 (138/144)	0.759
P value*	0.273	0.211	

*, data of patients excluding ascites. 2D-SWE, 2-dimensional shear wave elastography; TE, transient elastography.

Table 3 Causes of technical failure in all 170 patients

Reasons	2D-SWE		TE	
	Novice	Veteran	Novice	Veteran
Thickness of the thoracic wall	6	3	7	4
Hepatic atrophy	1	0	0	0
Inefficient breath hold	1	1	3	1
Small intercostal space	1	1	1	1
Ascites	1	0	10	10

2D-SWE, 2-dimensional shear wave elastography; TE, transient elastography.

Table 4 Comparison of technical success rate for 26 patients with liver-ascites undergoing 2D-SWE and TE conducted by the veteran operator

Distance	2D-SWE, %	TE, %	P value
Ascites lamella			
≤10 mm	100 (7/7)	100 (7/7)	
>10 mm	94.7 (18/19)	47.4 (9/19)	0.001
Skin-capsular distance			
≤15 mm	100 (16/16)	75.0 (12/16)	0.109
>15 mm	90.0 (9/10)	40.0 (4/10)	0.061
Ascites lamella plus skin-capsular distance			
≤25 mm	100 (12/12)	100 (12/12)	
>25 mm	92.9 (13/14)	28.6 (4/14)	0.000

2D-SWE, 2-dimensional shear wave elastography; TE, transient elastography.

Table 5 Comparison of the reliability rate of LSM with 2D-SWE and TE by both the novice and veteran

Operator	2D-SWE, %	TE, %	P value
BMI ≤25 kg/m^2			
Novice	91.9 (102/111)	83.7 (87/104)	0.064
Veteran	96.4 (107/111)	93.3 (97/104)	0.298
P value	0.153	0.030	
BMI >25 kg/m^2			
Novice	78.8 (26/33)	65.5 (19/29)	0.243
Veteran	93.9 (31/33)	82.8 (24/29)	0.324
P value	0.151	0.134	

LSM, liver stiffness measurement; 2D-SWE, 2-dimensional shear wave elastography; TE, transient elastography; BMI, body mass index.

Comparison of the feasibility and reproducibility of 2D-SWE and TE

Technical success rate and causes of failure

A total of 10 patients experienced technical failure of 2D-SWE; 21 patients experienced technical failure of TE.

A comparison of the technical success rates of 2D-SWE and TE with or without ascites is shown in *Table 2*. The success rates did not differ between the novice and veteran operators for TE and 2D-SWE. However, 2D-SWE showed a higher technical success rate than TE in all patients. The reasons for the failed measurements are presented in *Table 3*. The technical success rates of 26 patients with ascites are shown in groupings in *Table 4*. Technical success rate displayed significant differences between 2D-SWE and TE when ascites lamella was more than 10 mm and ascites lamella plus skin-capsular distance was more than 25 mm.

Reliability rate of LSMs

When evaluated by the novice, 10 patients had excluded values for 2D-SWE and 21 patients had excluded values for TE, including 10 patients with ascites. Another 16 patients with ascites were excluded for further analysis. Therefore, 144 2D-SWE measurements and 133 TE measurements were used for further comparison of the reliability of measurements with both 2D-SWE and TE, as shown in *Table 5* and *Table 6*, which were divided into 2 groups according to BMI.

The reliability rate of LSM with 2D-SWE did not

Table 6 Comparison of inter-operator reproducibility with 2D-SWE and TE

Methods	Operators (mean ± SD)		ICC (95% CI)
	Novice	Veteran	
2D-SWE (kPa)	10.90±8.98	10.51±8.56	0.968 (0.954–0.978)
TE (kPa)	11.75±12.19	11.63±12.04	0.973 (0.940–0.988)

2D-SWE, 2-dimensional shear wave elastography; TE, transient elastography; SD, standard deviation; ICC, intraclass correlation coefficient; CI, confidence interval.

Table 7 Procedure time for 2D-SWE and TE when performed by the novice and veteran

Operator	2D-SWE (min)	TE (min)	P value
Novice	2.54±0.95	1.99±1.21	0.000
Veteran	1.86±0.82	1.90±0.97	0.612
P value	0.000	0.270	

Data are presented as the mean ± SD. 2D-SWE, 2-dimensional shear wave elastography; TE, transient elastography; SD, standard deviation.

significantly differ between the operators (novice and veteran), either BMI ≤25 or >25 kg/m^2. A total of 16 patients were excluded due to unreliable measurements with 2D-SWE. However, for TE, there was a significant difference between the novice and veteran when BMI ≤25 kg/m^2. A further 28 patients were excluded for unreliable measurements for TE. Among these patients, 15 patients also experienced unreliable 2D-SWE measurements. No significant difference was revealed in the comparison of 2D-SWE with TE by novice and veteran for either BMI ≤25 or >25 kg/m^2. Therefore, a total of 29 patients were excluded and 104 patients were included in further statistical analyses.

Inter-operator reproducibility

Reproducibility is defined as the variation in repeated measurements made on the same participant under identical conditions (25). We used ICCs to assess the inter-operator measurement reproducibility between the novice and veteran with 2D-SWE and TE, as shown in *Table 6*. When performed by the novice and the veteran, both 2D-SWE and TE showed excellent inter-operator agreement, with ICCs of 0.968 and 0.973, respectively. The results of a paired *t*-test on the liver stiffness values obtained by the different operators with 2D-SWE or TE showed no significant differences, with P values of 0.076 and 0.757, respectively.

Procedure time

We compared the mean procedure time for each patient with both 2D-SWE and TE when performed by the different operators, as shown in *Table 7*. The mean procedure time for TE was 1.93±1.09 minutes, and the mean procedure time for 2D-SWE was 2.18±1.05 minutes. Levene's test indicated homogeneity of variance (F=0.126, P=0.722), with t=−2.35 and P=0.019 for these measurements. The mean procedure times for TE and SWE showed a significant difference.

Discussion

TE detects shear wave speed and then converts this value into a Young's modulus value, using a surface impulse. A low-frequency pulse is generated at the surface of the abdominal wall, and the shear wave propagates from the surface inside the liver tissue. TE provides no conventional anatomical ultrasound images, as it is performed without an ultrasound scanner and lacks 2D image guidance. In obese patients, TE does not obtain sufficient signal with a standard probe (M probe, 3.5 MHz, 2 mm vibration amplitude). 2D-SWE is another type of dynamic quantitative elastography that detects shear wave speed. The 2D-SWE scanner generates an acoustic pulse in the liver, which generates and propagates the shear wave in the liver tissue. The tissue displacement is captured, and the shear wave speed is converted into Young's modulus. The technical differences between TE and 2D-SWE may be a cause of the disparities in their clinical application.

For TE, 149 of the 170 patients experienced technical success, and for 2D-SWE, 160 of the 170 patients had successful measurements. Although the TE and 2D-SWE success rates did not differ between the novice and veteran operators, 2D-SWE showed a higher technical success rate than TE in all patients. After excluding 26 patients with ascites, 2D-SWE and TE showed no significant differences in success rate. This result indicates that the main reason for the technical failure of TE was the presence of ascites.

When we separately analyzed the technical success rate for 26 patients with perihepatic ascites, it was shown that 2D-SWE and TE both acquired valid measurement successfully when the ascites lamella was less than 10 mm or the ascites lamella plus skin-capsular distance was less than 25 mm. In contrast, 2D-SWE showed a higher success rate than TE when the ascites lamella was more than 10 mm or the ascites lamella plus skin-capsular distance was more than 25 mm. These results are in accordance with the guidebook of FibroScan device, that the valid measurement depth is between 25 and 65 mm (M probe) below the skin surface. Kohlhaas *et al.* (26) also confirmed that shear wave generated by TE is not altered in a copolymer phantom by surrounding water; ascites and increased intra-abdominal pressure do not affect liver stiffness according to the use of an animal ascites model and patients with ascites. Kohlhaas's study showed that 23 of the 24 patients with ascites could be measured using the XL probe and 11 patients using the M probe. We supposed that frequency pulse and shear wave do not vanish through a water-filled plastic bag or ascites *in vivo*. Our study also indicates that TE should not be regarded as an exclusion criterion when patients present with perihepatic ascites. The principle of 2D-SWE is that shear wave generates and propagates in liver tissue, and is not affected by ascites, which is in agreement with the EFSUMB guidelines (12) stating that 2D-SWE can be utilized in patients with ascites.

The reliability rate of LSM with 2D-SWE did not significantly differ between the operators (novice and veteran), for either BMI ≤25 or >25 kg/m^2. However, for TE, there was a significant difference between the novice and veteran when BMI ≤25 kg/m^2. 2D-SWE is guided by a conventional B-mode image, making it easy to avoid large vascular structures and masses in the body, all of which reduce the learning curve (16). This may be the reason behind the more reliable measurements with 2D-SWE and may have reduced the effect of experience. By avoiding these complicating factors of LSM, operator experience showed no influence on 2D-SWE measurements. By contrast, operator experience did play a role in obtaining reliable measurements with TE. Castéra *et al.* (27) previously analyzed 13,369 examinations of LSMs made with TE, and operator experience (>500 examinations) was found to influence the measurement reliability. This result was also confirmed by Lucidarme *et al.* (28), who showed that operator experience was critical for reliable LSM results. In this study, the novice recorded a total of 17 patients with unreliable TE measurements, whereas only 7 unreliable measurements were made by the veteran, when BMI ≤25 kg/m^2. The reliability rate is not affected by operator experience when BMI >25 kg/m^2. We supposed that BMI may be the independent factor in unreliable measurement. Our results are in agreement with the study results from Yoon *et al.* (16,21,29), who reported that a BMI of 25 kg/m^2 or greater was an important factor associated with unreliable measurements. The findings are further supported by the results of Pang *et al.* (19), who determined that obesity, increased liver stiffness, and operator experience were important determinants of unreliable TE measurements.

In this study, the novice and veteran showed excellent agreement in the measurement of liver stiffness values by TE and 2D-SWE. For TE, the ICC was 0.973 (0.940–0.988), and for 2D-SWE, the ICC was 0.968 (0.954–0.978). Ferraioli *et al.* (30) reported that 2D-SWE is a reproducible method for the assessment of liver elasticity, with excellent inter-observer agreement between 2 different operators (one with 4 years of 2D-SWE experience, and the other with 3 months of training). We conclude that, for 2D-SWE, experience has minimal influence on the measurement of liver elasticity in patients with chronic liver disease. Our results also suggest an excellent correlation for TE, a result that is in agreement with a study by Gatos *et al.* (31).

To compare the convenience of and procedure time for TE and 2D-SWE, we recorded and compared procedure times for both modalities by both operators. The mean procedure times for TE performed by the novice and veteran were 1.99±1.21 and 1.90±0.97 minutes, respectively. For 2D-SWE, the mean procedure times were 2.54±0.95 and 1.86±0.82 minutes, respectively. To acquire an optimal image and ROI, the novice required more time on 2D-SWE than TE. Although the entire mean procedure times for TE and SWE significantly differed, all mean times were less than 3 minutes. Whether using TE or 2D-SWE, this is a time-saving procedure that is easy for operators.

We conclude with points of comparison of 2D-SWE and TE in a clinical context. First, 2D-SWE showed a higher technical success rate than TE. Either 2D-SWE or TE can be utilized in patients with ascites lamella less than 10 mm or ascites lamella plus skin-capsular distance less than 25 mm, yet 2D-SWE may be a preferable choice. Second, experience plays a role in obtaining reliable TE measurements when BMI ≤25 kg/m^2, whereas this is not the case for 2D-SWE, which is guided by conventional B-mode imaging. Third, the reproducibility of liver stiffness values measured by TE and 2D-SWE showed no difference when performed by the novice and veteran. Reliable measurement and excellent reproducibility of 2D-SWE results are important for following and monitoring patients in clinical practice (32,33). Finally, from a technical perspective, the

2D-SWE probe contains an external vibrator equipped with broadband (60–600 Hz) pulse that generates the shear wave, whereas TE uses a 50 Hz signal (34). Therefore, 2D-SWE acquires more quantitative information than TE.

This study has certain limitations. First, most cases enrolled in our study did not undergo a gold standard diagnostic test (liver biopsy). This fact does not influence the results of this study, as we did not analyze the stage of liver fibrosis. Second, no comparison of diagnostic performance was made between 2D-SWE and TE, as the aim of this study was to compare the reliability and reproducibility of 2D-SWE and TE.

Conclusions

Compared with TE, 2D-SWE would be a more reliable method for clinical application, with higher technical success rate and in patients with perihepatic ascites, especially when the ascites lamella is more than 10 mm or ascites lamella plus skin-capsular distance is more than 25 mm, with the added value of measurement reliability not being affected by operator experience.

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Footnote

Reporting Checklist: The authors have completed the TREND reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-6454/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-6454/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-6454/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by committee of The Third Affiliated Hospital of Sun Yat-sen University (No. [2018] 02-365-01) and informed consent was taken from all the patients.

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