Original Article

Reliability and Factor Effect Reliability Measurement of Liver Shear Wave Elastography Variant Method: 2D and Point Shear Wave Elastography

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Background: Chronic liver disease is a worldwide problem with many causes and varying degree of fibrosis that end up with cirrhosis. Several ultrasound elastography techniques have been introduced to assessment liver pathologic and fibrosis stage. New techniques and machines were developed for the last years.

Objective: To compare the reliability of method for evaluation the liver stiffness measurements head to head by three techniques of shear wave elastography: point shear wave (P-SWE: ElastPQ) and 2D shear wave elastography (2D-SWE: ElastQ and LOGIQ™ E9) and analyze the factor influence realiablity measurement.

Materials and Methods: The present study was a retrospective study of 801 patients with liver disease in Rajavithi Hospital between September 2017 and March 2018, evaluated measurement by point shear wave elastography and 2D shear wave elastography. Then compared percentage reliability measurement and performing time of three methods.

Results: Eight hundred and one patients with liver disease, mean age ± SD was 51.6±12.94 years (range 20 to 84), 56.1% were male. The percentage of success rate more than 60% of 2D LOGIQ™ E9, 2D ElastQ and P-SWE (Elast PQ) were 99,94.9 and 70.4 that show a significant difference (p<0.001). The IQR/median are 99.9, 99.3 and 97.9 that show the significant difference of 2D-SWE LOGIQ™ E9 and P-SWE (p<0.001). The measurement values and performing time were correlated with reliable measurement.

Conclusion: The reliable measurement difference between method and machine. 2D-SWE (LOGIQ™ E9, ElastQ) give reliability (IQR/mean) and reliable measurement better than P-SWE (ElastPQ), statistically significant. The reliable measurement is related to liver stiffness value and performing time. Other factors show no significant influence on reliable measurement.

Keywords: Liver stiffness, Shear wave elastography (SWE), Point shear wave elastography (P-SWE), 2D shear wave elastography (2D-SWE), Reliability, Reliability measurement, Liver stiffness measurement (LSM)

J Med Assoc Thai 2019;102(Suppl.4):94-103
Website: http://www.jmatonline.com

Chronic liver diseases are major worldwide public health with an estimated mortality of about 1.5 million per year due to cirrhosis and its complications[1]. There are many causes of chronic liver disease such as chronic viral hepatitis (hepatitis B, C), autoimmune, hereditary, metabolic, toxin mediated liver disease and cholestasis liver disease[2].

Liver fibrosis is a diffuse excessive deposition of extracellular matrix especially collagen material in the liver, which is repair response mechanism after chronic liver injury[3]. It is a clinically significant condition that results from many pathogenesis of life threatening condition cirrhosis. Mild to moderate fibrosis is reversible while liver cirrhosis, the end stage of fibrosis is irreversible[4]. The assessment of liver fibrosis is a key element to determine prognosis, to manage treatment, to monitor disease progression and to assess response to therapy in the patients with chronic liver disease. Histopathological assessment using liver biopsy remained the standard of reference to evaluate fibrosis. However the role of liver biopsy has been compromised because of the risk of complication and considerable probability of sampling error mostly linked to the very small area in the liver[5-9]. The non-invasive methods have been increased used to assessment liver stiffness and fibrosis. Non-invasive methods for evaluating liver fibrosis can be divided into two main groups: biomarker using blood serum[10,11] and physical parameter or imaging based method for evaluation of elastography using ultrasound[12-21] and MRI[20].

Many guidelines included The European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB), World Federation for Ultrasound in Medicine and Biology, Canadian Association for the study of the liver, National Institution for Health and Care Excellence, have mentioned elastography for assessment of liver fibrosis in clinical guidelines[22-26]. Transient Elastography (Fibroscan) is the most extensively used and validated method for fibrosis

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How to cite this article: Chitwiset S. Reliability and Factor Effect Reliability Measurement of Liver Shear Wave Elastography Variant Method: 2D and Point Shear Wave Elastography. J Med Assoc Thai 2019;102(Suppl.4):94-103.

staging. The recent guideline for management of hepatitis C infection of European Association for the study of the liver allows the use of TE instead of liver biopsy and Transient elastography still approved by French national Health Authority for the evaluation of fibrosis in the treatment of the patient with chronic hepatitis C with no comorbidity.

2D shear wave elastography was performed by LOGIQ E9 (GE Healthcare, Wauwatosa, WI, USA) using R5.1.0 software and the C1-6-D probe to obtained a quantitative elasticity map of the medium. Use ultrafast, ultrasonic scanner generated the mechanical shear wave by focusing ultrasound at given location and image the medium during wave propagation at level high frame rate and displaced in unit of velocity, meter per second (m/s) or converted into kilopascal. The region of interested (ROI) was placed at least 1cm below liver capsule and free of vessel. The circular measurement, approximately 1 cm in diameter, 10 measurement regions were placed on difference shear wave image. The system calculated the mean and median value and the IQR of the valid measurement. Measurement in homogenous area with IQR less than 30% was considered valid measurement.

Point shear wave elastography by EPIQ7, Elast PQ technique, this method generated shear wave inside the liver using radiation force from a focus ultrasound beam. The ultrasound machine monitor the shear wave propagation and measurement the velocity of shear wave. The shear wave velocity is displayed in meters per second (m/s) or in kilopascal (kPa). Using real time image selected the vessel free area, at least 1.5 cm from liver capsule, fixed region of interest of 0.5 cm x 1.5 cm was placed while patients hold their breath, 10 valid measurements were performed.

2D-shear wave elastography by EPIQ7, ElastQ technique this method using acoustic radiation force impulse(ARFI), the same as ElastPQ, but generated multiple pulse at many locations with parallel processing architecture with large field of view and color-coded quatitative assessment of tissue stiffness in real-time feedback. There is confidence map using intellegnet analysis to highlight area of optimum measurement area. The ultrasound machine monitor the shear wave propagation and measurement the velocity of shear wave. The shear wave velocity is displayed in meters per second (m/s) or in kilopascal (kPa). Using real time image selected the vessel free area, at least 1.5 cm from liver capsule, fixed region of interest of 0.5 cm x 1.5 cm was placed while patients hold their breath, 10 valid measurements were performed.

Transient elastrography: Fibroscan device (EchoSens, Paris, France), which incorporate 1.5-MHz ultrasound transducer probe vibrator for generated a complete painless vibration (50 Hz frequency and 2 mm amplitude) for induced and elastic shear wave propagation through skin and subcutaneous tissue to the liver. The wave velocity is tracked by coaxial ultrasound transducer and is calculated by the device and expressed in kilopascals.

In each patient 10 valid TE measurement were performed. Reliable measurement defined as success rate (SR = ratio of the number of successful acquisition devided but the total number of acquisitions) >60% and interquartile range interval (IQR = the difference between the 75th and 25th percentile, essential the range of the middle 50% of the data) <30%, then median value of the 10 valid measurement were calculated.

Shear wave elastography technique has been implemented in conventional real-time ultrasound systems. Several studies have shown their accuracy on the assessment of liver fibrosis. Compared with TE, this technique has the advantage of the B-mode image guidance to choose the best acoustic window for correctly performing the examination in real time.

The aim of study was to assess the reliability measurement of 2D-SWE, P-SWE and potentially effective factors.

Materials and Methods

Study population

Subjects and study design

This was a single center, cross-section study. The study was included in the patients in the hepatobiliary and Gastroenterology unit from Rajavithi Hospital who were investigated ultrasound upper abdomen in the Radiology department and add-on liver elastography by a radiologist with 1-year experience on liver elastography.

The patient in fasting condition was sent to radiology department for evaluation upper abdominal ultrasound. After finished B scan examination upper abdomen, the patient was performed evaluation liver stiffness in supine position with the right arm in maximum abduction, measurement in the right lobe of the liver through intercostal space. The measurements were performed in while holding their breath for a few seconds. The study had been performed by using the EPIQ7 ultrasound system (Philips Healthcare, Bothell, WA, USA) with convex broadbase probe 2D-SWE (ElastQ) technique before point shear wave elastography (ElastPQ) technique was performed at the same area. After finishing evaluation, the patient was moved to the room for evaluation with 2D shear wave elastography by GE LOGIQ™ E9 (GE Healthcare, Wauwatosa, WI, USA) at the same rib space in the same session. The system calculated the average (mean), median value, standard variation and the IQR and IQR/median of the valid measurement. The performing time was counted from the start time of evaluation of elastography till completed the last measurement.

2D shear wave elastography

2D-shear wave elastography by Philips EPIQ7 with ElastQ technique (2D-SWE ElastQ)

2D shear wave elastography by Philips EPIQ7, ElastQ technique was performed in the patient which provides a quantitative assessment of tissue stiffness, using ARFI to push multiple pulses at many locations causing it to move by a few micrometers. This movement generated a transverse (shear) wave that moved more slowly in the soft tissue. ElastQ imaging provided a large color-coded map in real time. The ROI represented a greater area to assess change in tissue stiffness. Then region of interest (ROI) was placed at least 1.5 to 2 cm below the liver capsule and free of vessel, 10 samples.

2D shear wave elastography by LOGIQ™ E9 (2D-SWE LOGIQ™ E9)

2D shear wave elastography was performed by LOGIQ™ E9 (GE Healthcare, Wauwatosa, WI, USA) using R5.1.0 software and the C1-6-D probe to obtain a quantitative elasticity map of the medium. Using ultrafast, ultrasonic scanner generated the mechanical shear wave by focusing ultrasound at a given location and imaged of the medium during wave propagation at the level of high frame rate and displayed in unit of velocity, meter per second (m/s) or converted into kilopascal. The region of interest (ROI) was placed at least 1 cm below the liver capsule and free of the vessel. The circular measurement, approximately 1 cm in diameter, 10 measurement regions were placed on different shear wave image.

Point shear wave elastography (P-SWE) by Philips EPIQ7 technique (P-SWE ElastPQ)

Point shear wave elastography by Philips EPIQ7 technique, this method generated shear wave inside the liver using radiation force from a focus ultrasound beam.

The ultrasound machine monitored the shear wave propagation and measured the velocity of the shear wave. The shear wave velocity was displayed in meters per second (m/s) or in kilopascal (kPa). Using real time image selected the vessel free area, at least 1.5 cm from the liver capsule, fixed region of interest of 0.5 cm x 1.5 cm was placed while the patients hold their breath till 10 valid measurements in each patient were performed.

We calculated the sample size based on the previous study of Castera L et al, with the success rate of about 60 percent. The calculated sample size was.

The study was approved by the local ethics Committee and was performed in accordance with the Helsinki Declaration of 1975.

Statistical analysis

The demographic, clinical history was summarized as descriptive statistics. All analyses were performed with IBM SPSS Statistic version 22.0. The categorical variables were reported as number of patients (percentage). Student's t-test and paired t-test were used for group comparison of a continuous variable (the results of the liver stiffness) with normal distribution. The Pearson's Chi-square-test correlation coefficient(r) was used to assess the correlation of measurement result and patient's factors with three techniques (point shear wave elastography: P-SWE ElastPQ, 2D shear wave elastography by Phillips:2D-SWE ElastQ and 2D shear wave elastography by GE: 2D-SWE LOGIQ™ E9).

Results

Abdominal ultrasound and elastography wer performed in 810 patients were performed ultrasound abdomen and elastography. Nine patients were excluded (hearing problem, respiration problem in respiratory holding). Shear wave elastography both 2D-SWE (LOGIQ™ E9 and ElastQ) and point shear wave elastography P-SWE in 801 patients, 449 (56.0%) women, 352 (44%) men. Mean age was 51.60±12.94 (16 to 84) years. Mean body weight was 64.15±13.43 (24 to 137) kg, mean height 162.35±8.43 (140 to 190) cm and mean BMI was 24.27±4.37 kg/m^2. Based on the Asian BMI criteria, 62.3% was normal (BMI 18.5 to 25 kg/m^2), 28.1% was over weight (BMI 25 to 30 kg/m^2), 9.6% was obese (BMI >30 kg/m^2). The causes of chronic liver disease were hepatitis B 49.7%, hepatitis C 23.4%, alcoholic hepatitis 7.7%, fatty liver (fatty liver, NASH and NAFLD) 9.9%.

Patient's characteristics were presented on Table 1.

Liver stiffness value for different techniques

Elastography was performed by 3 techniques 2D-SWE by LOGIQ™ E9, 2D-SWE ElastQ by Philips, point shear wave elastography (ElastPQ) by Philips. Mean of the liver stiffness evaluated by 2D-SWE by LOGIQ™ E9, 2D-SWE ElastQ, P-SWE (ElastPQ) were 7.88±4.31, 6.57±3.54 and 10.79±25.27 respectively. The median of liver stiffness

Table 1. The characteristic of the subjects (n = 801)

Characteristic	n (%)
Age (years)	51.60±12.94
Gender	
Male	449 (56.1)
Female	352 (43.9)
Weight (mean ± SD)	64.15±13.43
Height (mean ± SD)	162.35±8.43
BMI	24.27±4.37
Normal <25	499 (62.3)
Overweight 25 to 30	225 (28.1)
Obese >30	77 (9.6)
Depth (mean ± SD)	
Skin-liver capsule	16.32±5.33
Subcutaneous fat at epigastrium (skin-linear alba)	13.94±5.04
Intra-abdominal fat thickness (skin-posterior wall aorta)	62.06±19.50
Underlying	
Hepatitis B infection	398 (49.7)
Hepatitis C infection	187 (23.4)
Alcoholic	62 (7.7)
Fatty liver (fatty, NASH, NAFLD)	80 (9.9)
HIV infection	32 (3.9)

BMI = Body mass index; NASH = Nonalcoholic steatohepatitis; NAFLD = Nonalcoholic Fatty Liver Disease; HIV = Human immunodeficiency virus
Values are represented as n (%) and mean ± SD

of 2D-SWE LOGIQ™ E9, 2D-SWE ElastQ, P-SWE (ElastPQ) were 6.43 (2.22 to 27.69), 5.28 (2.42 to 99.44) and 5.16 (1.69 to 19.75) respectively. The average of IQR/median of LOGIQ™ E9, 2D-SWE ElastQ and P-SWE (ElastPQ) were 0.15±0.65, 0.22±0.63 and 0.23±0.11 respectively (Table 2).

The result of measurement of each technique was quite different. The mean and median of liver stiffness measurement (LSM) by 2D-SWE ElastQ is lowest and LSM by P-SWE ElastPQ is highest. There were correlation between LSM-mean and median between 2D-SWE LOGIQ™ E9 and 2D-SWE ElastQ (r = 0.69, p<0.001). The liver stiffness measurement-means by P-SWE ElastPQ has correlation with 2D-SWE LOGIQ™ E9 but not correlated with 2D-SWE ElastQ and liver stiffness measurement-median by P-SWE had no correlation with both techniques (Table 4).

The time of performed elastography by 2D-SWE LOGIQ™ E9 was less than 2D-SWE ElastQ and P-SWE ElastPQ (77.40±37.34, 97.10±63.31 and 160.80±98.10 second, respectively) (Table 2).

Reliability of three techniques

The reliable measurement was defined as the measurement which IQR/median less than 0.3 and success rate more than 60 percent. There was statistical significance when compared between three techniques except IQR/median of 2D-SWE Logic9E and 2D-SWE ElastQ. The percentage of reliable measurements of 2D-SWE LOGIQ™ E9 was higher than 2D-SWE ElastQ and P-SWE ElastPQ (98.9, 93.9 and 70.4 respectively). The percentage of IQR/median less than 0.3 of 2D-SWE by LOGIQ™ E9 were higher than 2D-SWE ElastQ and P-SWE ElastPQ (98.9, 91.1 and 92.1 respectively). Percentage of success rate more than 60% of 2D-SWE by LOGIQ™ E9 was higher than 2D-SWE ElastQ and P-SWE ElastPQ (99.0, 94.6 and 70.4 respectively).

2D shear wave elastography(LOGIQ™ E9 and ElastQ) had higher reliable measurement (98.9% and 93.9%) than point shear wave elastography P-SWE ElastPQ (70.5%). In the same machine, Philips different technique (2d-SWE elastQ and P-SWE ElastPQ) were given different reliability (Table 3).

Table 2. Liver stiffness measurement (kPa), success rate for different techniques (n = 801)

Liver stiffness measurement (kPa)	2D-SWE LOGIQ™ E9	2D-SWE (ElastQ)	P-SWE (ElastPQ)
Mean	7.88±4.31	6.57±3.54	10.79±25.27
Median	6.43 (2.22 to 27.69)	5.28 (2.42 to 99.4)	5.16 (1.69 to 19.75)
Standard deviation (SD)	0.81 (0.11 to 7.6)	0.96 (0.19 to 5.24)	0.95 (0.12 to 38.97)
IQR	1.27±1.06	1.47±0.96	2.72±8.36
IQR/median	0.15±0.65	0.22±0.63	0.23±0.11
IQR/median <0.3	800 (99.9)	795 (99.3)	784 (97.9)
IQR/median >0.3	1 (0.1)	6 (0.7)	17 (2.1)
Success rate			
Success rate <60%	8 (1.0)	43 (5.4)	237 (29.6)
Success rate >60%	793 (99.0)	758 (94.6)	564 (70.4)
Operation time (second)	77.40±37.34	97.10±63.31	160.80±98.10

2D-SWE LOGIQTM E9 = 2D shear wave elastography with GE LOGIQ E9; 2D-SWE (ElastQ) = 2D shear wave elastography by Philips with ElastQ technique; P-SWE (ElastPQ) = Point shear wave elastography by Philips with ElastQ technique; IQR = Interquartile range
Values are represented as n (%), mean ± SD and minimum-maximum

Table 3. Comparison reliable measurements, percent of success, IQR/median, between three techniques (n = 801)

	2D-SWE LOGIQ™ E9 vs. 2D-SWE (ElastQ)		2D-SWE LOGIQ™ E9 vs. P-SWE (ElastPQ)		2D-SWE (ElastQ) vs. P-SWE (ElastPQ)	
	%: %	p-value	%: %	p-value	%: %	p-value
Success rate >60%	99.0:94.6	<0.001*	99.0:70.4	<0.001*	94.6:70.4	<0.001*
IQR/median <0.3	98.9:91.1	0.125	98.9:91.1	<0.001*	99.3:97.9	0.035*
Reliable measurement	98.9:93.9	<0.001*	98.9:70.4	<0.001*	93.9:70.4	<0.001*

2D-SWE LOGIQTM E9 = 2D shear wave elastography with GE LOGIQ E9; 2D-SWE (ElastQ) = 2D shear wave elastography by Philips with ElastQ technique; P-SWE (ElastPQ) = Point shear wave elastography by Philips with ElastQ technique; IQR = Interquartile range
* Statistical significance at p<0.05, values are represented as (%)

Table 4. Comparison of liver stiffness measurement results (mean, median, IQR, IQE/median), performing time between three techniques (n = 801)

Liver stiffness measurement	2D-SWE LOGIQ™ E9 vs. 2D-SWE (ElastQ)		2D-SWE LOGIQ™ E9 vs. P-SWE (ElastPQ)		2D-SWE ElastQ vs. P-SWE Elast PQ	
	r	*p*-value	r	*p*-value	r	*p*-value
Mean	0.698	<0.001*	0.055	<0.001*	0.050	0.156
Median	0.699	<0.001*	0.051	0.151	0.042	0.235
SD	0.522	<0.001*	0.007	0.843	0.041	0.247
IQR	0.463	<0.001*	-0.019	0.600	0.017	0.627
IQR/median	0.061	0.084	0.011	0.745	-0.059	0.093
Operation time	0.023	0.052	0.057	0.107	0.026	0.467

2D-SWE LOGIQTM E9 = 2D shear wave elastography with GE LOGIQ E9; 2D-SWE (ElastQ) = 2D shear wave elastography by Philips with ElastQ technique; P-SWE (ElastPQ) = Point shear wave elastography by Philips with ElastQ technique; IQR = Interquartile range; SD = Standard deviation

* Statistical significance at $p<0.05$

Correlation of reliability measurement, percentage of IQR/median and success with gender, liver stiffness measurement (LSM) value, depth

The reliable mesurement were defined as the measurement which IQR/median <0.3, success rate >60%. The liver stiffness measurement (LSM) value (mean, median, SD, IQR), performing time were significantly correlated to percentage of reliable measurement of the three techniques. The distance between the probe and liver capsule was significantly correlated with reliable measurement by P-SWE ElastPQ, but not significant when correlated with 2D-SWE Logic 9E, 2D-SWE ElastQ. The age was significantly related with the reliable measurement of 2D-SWE ElastQ but not significantly related in reliable measurement by 2D-SWE Logic 9E, 2D-SWE ElastPQ (Table 5).

The liver stiffness measurement (LSM) value (mean, median, IQR/median and SD) were significant correlation but low correlation with success percentage of measurement of 2D-SWE LOGIQ™ E9 and P-SWE ElastPQ. The operation times were performed by technique 2D-SWE ElastQ and P-SWE ElastPQ correlated significantly but medium correlation with success percentage but reversely correlated by the technique 2D SWE LOGIQ™ E9 (Table 6). Factors correlated to the percentage of IQR/median of 2D-SWE by Logic 9E were age, thicken intraabdominal fat but factors correlated with IQR/median of P-SWE ElastPQ was skin-liver capsule distance (Table 7).

Gender had no correlated with LSM value (mean, median), percentage of success by 2D-SWE by LOGIQ™ E9 and P-SWE ElastPQ but correlated with LSM value by 2D-SWE ElastQ.

Correlation operation time with gender, LSM value, depth

For the measurement of 2D SWE LOGIQ™ E9 found significant but low correlation with age, skin-liver capsule distance, intra-abdominal fat and liver stiffness measurement value (mean, median, IQR, IQR/median, SD). For the measurement of P-SWE by ElastPQ found significant correlation but poor reverse correlation with skin-liver capsule distance but significant but low correlation with liver stiffness measurement value (mean, median, IQR, IQR/median, SD). The operation time of 2D-SWE ElastQ have no correlation with age, depth of skin-liver capsule, subcutaneous fat, intra-abdominal fat and liver stiffness measurement (mean, median, IQR, SD) (Table 8).

Discussion

Elastography is a noninvasive imaging technique that aims to assess tissue elasticity in several organ. Shear wave elastrography (SWE) of the liver is accurate in assessing liver fibrosis with chronic liver disease[5]. SWE has been an important add-on to the existing diagnosis and monitoring the patient with chronic liver disease. In the last years, several manufacturers have introduced new elastography methods. Shear wave elastography was integrated or installed in high-end ultrasound machine or additional optional software for other ultrasound machines.

In the present study, we evaluated three different shear wave elastography techniques, compare head to head with 2D-SWE GE LOGIQ™ E9, 2D-SWE Philips (ElastQ), point SWE (ElastPQ) for evaluation the precision of each methods. There is no standard direct measurement criterion of its reliability for 2D-SWE. The liver stiffness measurement is usually considered as reliable or valid measurement when fulfills all the following criteria: 10 measurements with success rate ≥60%, interquatile range/median (IQR/M) ≤0.3[27-29]. The IQR/median ratio is the method for measuring data variability and is recommended as reliable indicator for transient elastography by the manufacturer (Echosens, Paris, France)[27]. The IQR-to-median ratio is also important as a quality control measure for P-SWE and was observed in several studies[30,31]. Anesa M et al evaluated five different systems of shear wave elastography in phantom and found

Table 5. Pearson correlation coefficients of reliable measurement with factor effects (n = 801)

Factor	2D-SWE LOGIQ™ E9			2D-SWE (ElastQ)			P-SWE (ElastPQ)		
	Unreliable (n = 9)	Reliable (n = 792)	*p*-value	Unreliable (n = 49)	Reliable (n = 752)	*p*-value	Unreliable (n = 237)	Reliable (n = 564)	*p*-value
Age	58.43±12.79	51.52±12.93	0.112	53.57±11.43	51.47±13.03	0.222	52.17±12.61	51.36±13.08	0.423
Height	167.22±11.40	162.29±8.38	0.081	161.49±7.64	162.40±8.48	0.464	161.71±8.67	162.61±8.32	1.169
Weight	71.77±7.99	64.07±13.46	0.087	65.34±12.87	64.07±13.47	0.524	62.12±14.16	65.01±13.03	0.005*
BMI	25.86±3.80	24.26±4.37	0.275	24.99±4.33	24.23±4.37	0.239	23.66±4.52	24.53±4.29	0.010*
Depth									
Skin-capsule	21.77±6.73	16.25±5.28	0.002*	15.18±4.20	16.39±5.38	0.123	18.39±5.11	15.44±5.17	<0.001*
Subcutaneous fat at epigastrium (skin-linear alba)	13.96±6.36	13.94±5.03	0.991	14.01±5.58	13.94±5.01	0.927	13.65±4.83	14.07±5.13	0.283
Intra-abdominal fat thickness (skin-posterior wall aorta)	73.90±16.68	61.87±19.50	0.066	64.95±19.73	61.81±19.48	0.275	61.08±20.25	62.39±19.18	0.383
Operation time (second)	210.67±84.43	75.89±33.64	<0.001*	203.65±80.60	90.16±55.37	<0.001	271.89±102.60	114.12±43.41	<0.001*

2D-SWE LOGIQTM E9 = 2D shear wave elastography with GE LOGIQ E9; 2D-SWE (ElastQ) = 2D shear wave elastography by Philips with ElastQ technique; P-SWE (ElastPQ) = Point shear wave elastography by Philips with ElastQ technique; IQR = Interquartile range; SD = Standard deviation; BMI = body mass index

* Statistical significance at $p<0.05$, values are represented as mean ± SD

low variance and high repeatability, coefficient of variation in the range of 0.00 to 0.21. All systems had reliable measurement, when applied reliable measurement IQR/median <30%, GE 2D-SWE and Samsung RS80A (P-SWE) showed the lowest variation for all phantom while Hitachi (SWM) and Philips demonstrated slightly higher variation for all

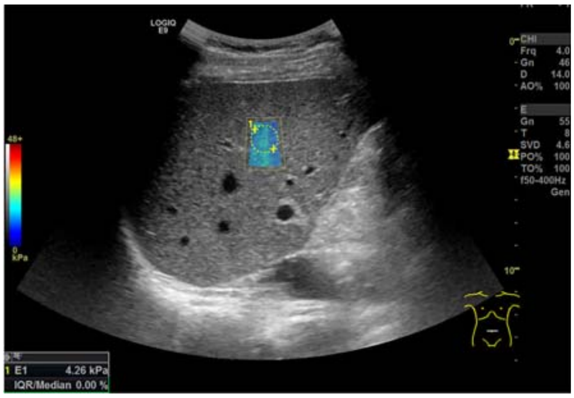

Figure 1. 2D-SWE by LOGIQ™ E9. The figure illustrated the method of 2D-SWE by GE. The color box(center) represent the elastogram and the circle represent the ROI where the elastic modulus (LSM, liver stiffness measurement) of the liver is acquire, The blue color indicates soft liver tissue, as semi-quatatively presented by the colour scale to the left.

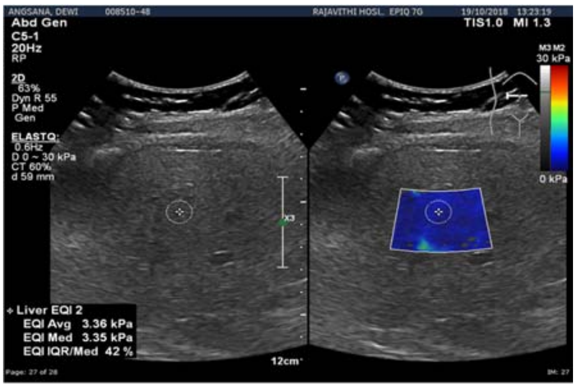

Figure 2. 2D-SWE by ElastQ. The figure illustrated the method of 2D-SWE by Phillips. The color box(center) represented the elastogram and the circle represented the ROI where the elastic modulus (LSM, liver stiffness measurement) of the liver was acquired, The blue color indicated soft liver tissue, as semi-quatatively presented by the colour scale to the right.

phantoms[32].

The percentage of reliable measurement of 2D-SWE LOGIQ™ E9 is better than 2D-SWE ElastQ and P-SWE ElastPQ (98.9%, 93.9% and 70.4% respectively). For only IQR/median criteria (IQR/median ≤0.3), 2D-SWE LOGIQ™ E9 is better than 2D-SWE ElastQ and P-SWE ElastPQ (98.9%, 91.9% and 92.1%). The percentage of success rate >60% of 2D-SWE LOGIQ™ E9 was better than 2D-SWE ElastQ and P-SWE ElastPQ (99.0, 94.6 and 70.4%). Measurement of 2D SWE LOGIQ™ E9 gave the highest reliability measurement with IQR/median and success rate of more than 60%.

Figure 3. Point shear wave elastography (P-SWE) by Phillips (ElastPQ). The figure illustrated point swear wave elastography performed on the patient. The box (center) represented the shear wave measurement area and is expressed below the obtained elasticity measurement of 6.15 kPa.

Different techniques gave different percentage of reliable measurement. 2D shear wave elastography technique included 2D-SWE LOGIQ™ E9 and 2D-SWE ElastQ has higher reliability measurement (98.9%, 93.9%) than point shear wave elastography: P-SWE ElastPQ (70.4%). The result measurement value by 2D technique (2D SWE GE and 2D SWE ElastQ) also gave higher correlation than the same machine but different techniques (2D-SWE ElastQ and P-SWE Elast PQ). Possible explanation may be that 2D shear wave elastography allowed the examinater place the analysis box or measurement ROI within the most homogeneous color elastogram, stable elastogram for a few seconds with complete filling during breath holding resulted in high accuracy, high reliability and low variance of measurement with supersonic shear wave imaging[33,34]. 2D-SWE Philips ElastQ had a confidence map guidance for the operator to perform measurement in the areas when the signal-to-noise ratio of SWS assessment was high. For P-SWE, IQR/mean ratio can only be calculated retrospectively, no indicator is available at time of acquired measurement.

Factor effect percentage of reliable measurement

All three methods of measurement did not demonstrate statistical significance of difference reliability rate between males and females.

The effect of gender on LSM has shown inconsistent results in the previous study[35,36]. Using P-SWE, no significant difference between genders in 137 patients[37] but Ling et al demonstrated that male has 8% higher LSM than female[38]. No significant correlation in percentage of reliability measurement between male and female was found in the present study.

The LSM value (mean and median, IQR, IQR/median, SD) correlated with percentage of reliable

Table 6. Pearson correlation coefficients of percent success with factor effects (n = 801)

Factor	2D-SWE LOGIQ™ E9		2D-SWE (ElastQ)		P-SWE (ElastPQ)	
	r	*p*-value	r	*p*-value	r	*p*-value
Age	-0.050	0.161	-0.048	0.173	-0.038	0.284
Height	-0.027	0.438	0.039	0.275	0.057	0.108
Weight	0.006	0.860	0.044	0.215	0.063	0.075
BMI	0.020	0.576	0.027	0.453	0.045	0.207
Operation time (second)	-0.602	<0.001*	0.725	<0.001*	0.801	<0.001*
Depth						
Skin-liver capsule	-0.120	<0.001*	0.042	0.230	-0.298	<0.001*
Subcutaneous fat at epigastrium (skin-linear alba)	-0.001	0.975	0.004	0.908	0.016	0.644
Intra-abdominal fat thickness (skin-posterior wall aorta)	-0.035	0.319	0.012	0.736	0.017	0.639

2D-SWE LOGIQTM E9 = 2D shear wave elastography with GE LOGIQ E9; 2D-SWE (ElastQ) = 2D shear wave elastography by Philips with ElastQ technique; P-SWE (ElastPQ) = Point shear wave elastography by Philips with ElastQ technique; IQR = Interquartile range; SD = Standard deviation; BMI = body mass index

* Statistical significance at $p<0.05$

Table 7. Pearson correlation coefficients of IQR/median with factor effects (n = 801)

Factor	2D-SWE LOGIQ™ E9		2D-SWE (ElastQ)		P-SWE (ElastPQ)	
	r	*p*-value	r	*p*-value	r	*p*-value
Age	0.118	<0.001*	0.060	0.090	0.002	0.953
Height	-0.053	0.137	-0.001	0.972	0.003	0.929
Weight	0.036	0.306	0.047	0.185	-0.033	0.356
BMI	0.071	0.044	0.059	0.093	-0.035	0.316
Performing time (sec)	0.221	<0.001*	0.004	0.908	0.024	0.460
Depth						
Skin-liver capsule	0.039	0.276	-0.041	0.243	0.183	<0.001*
Subcutenous fat at epigastrium (skin-linear alba)	0.012	0.725	0.050	0.155	0.005	0.890
Intra-abdominal fat thickness (skin-posterior wall aorta)	0.085	0.016*	0.044	0.213	-0.031	0.385

2D-SWE LOGIQTM E9 = 2D shear wave elastography with GE LOGIQ E9; 2D-SWE (ElastQ) = 2D shear wave elastography by Philips with ElastQ technique; P-SWE (ElastPQ) = Point shear wave elastography by Philips with ElastQ technique; IQR = Interquartile range; SD = Standard deviation; BMI = Body mass index
* Statistical significance at $p<0.05$

Table 8. Pearson correlation coefficients of operation with factor effects (n = 801)

Factor	2D-SWE LOGIQ™ E9		2D-SWE (ElastQ)		P-SWE (ElastPQ)	
	r	*p*-value	r	*p*-value	r	*p*-value
Age	0.195	<0.001*	0.024	0.502	0.001	0.981
Height	-0.024	0.503	-0.038	0.287	-0.047	0.179
Weight	0.043	0.223	-0.043	0.223	-0.048	0.172
BMI	0.066	0.062	-0.021	0.549	-0.034	0.332
Depth						
Skin-liver capsule	-0.120	<0.001*	0.042	0.230	-0.298	<0.001*
Subcutenous fat at epigastrium (skin-linear alba)	0.018	0.612	0.020	0.565	-0.040	0.256
Intra-abdominal fat thickness (skin-posterior wall aorta)	0.142	<0.001*	-0.037	0.298	-0.011	0.748

2D-SWE LOGIQTM E9 = 2D shear wave elastography with GE LOGIQ E9; 2D-SWE (ElastQ) = 2D shear wave elastography by Philips with ElastQ technique; P-SWE (ElastPQ) = Point shear wave elastography by Philips with ElastQ technique; IQR = interquartile range; SD = Standard deviation; BMI = Body mass index
* Statistical significance at $p<0.05$

measurement by 2D-SWE LOGIQ™ E9 and P-SWE ElastPQ but did not correlate with mean and median of LSM value by 2D-SWE ElastQ. High stiffness, high grade fibrosis gave more variation, use more time for evaluation, less reliable measurement, less success rate. The significant fibrosis was the independent predictor for an unreliable result[39], unlike cirrhosis did not influence the rate of reliable P-SWE measurement[40]. No correlation of percentage of reliable measurement with age, weight, BMI, subcutaneous depth, and abdominal fat, as same as the previous study by Bota et al, age and sex were not independent predictors for unreliable result[39]. The proportion of non reliable measurement was low in 2D measurement technique (1.1% and 6.1%), causing poor measurement effect factor correlated with reliable measurement.

The shear wave elastography vary in technologies, the systems from different manufactures, different setting might result in a difference in value. The liver stiffness measurement value was higher in P-SWE. There was a correlation of value of liver stiffness measurement in the same technique of 2D shear wave elastography (2D-SWE LOGIQ™ E9 and 2D-SWE ElastQ) but less correlation even in the same machine but different technique (2D-ElastQ and P-SWE ElastPQ).

The shear wave elastrography was appilicable in view of both patient friendly, user-friendly. Shear wave elastography has been add-on to existing diagnostic ultrasound liver. Mostly examinations were completed within a few minutes. The duration of time add-on about 77.4, 97.10 and 160.80 seconds (2D-SWE LOGIQ™ E9, 2D-SWE ElastQ, P-SWE ElastPQ). The median performing time for add-on shear wave elastography for 2D-SWE GE was shortest, about 77.4 seconds. Instruction of the patient position and breathing, looking for optimal windows, seeking optimum place for area of interests were not included in the performing time.

Conclusion

Shear wave elastography is a reliable technique and applicable, user-friendly. Obesity, BMI, subcutaneous fat, intra-abdominal fat have influence on reliability. Different methods have an effect on reliability and rate of reliable measurement. 2D-SWE LOGIQ™ E9 is highest reliability rate and shortest time. Further investigations for the value of this examination are still expected to assure the results of this study.

What is already known on this topic?

Shear wave elastrography (SWE) of the liver is accurate in assessing liver fibrosis with chronic liver disease.

The IQR/median ratio is the method for measuring data variability and is recommended as reliability indicator for transient elastography by the manufacture (Echosens, Paris, France) Liver stiffness is usually considered as reliable when is fulfills all the following criteria $\geq$10 valid measurement, success rate $\geq$60%, LSE interquatile range/median (IQR/M) $\leq$0.3.

Anesa et al evaluated five difference system of shear wave elastography in phantom found low variance and high repeatability, coefficient of variation in the range 0.00 to 0.21.

What this study adds?

Measurement of 2D-SWE LOGIQ™ E9 gives the highest reliability measurement, IQR/median and success rate of more than 2D-SWE ElastQ and P-SWE ElastPQ.

Reliable measurement by means of ARFI elastography in this study (70.4%) is slightly different to the previous study (64.7 to 93.9%).

No significant correlation of percentage of the reliability measurement between males and females in this study.

High stiffness, high grade fibrosis give more variation, use more time for evaluation, less reliable measurement, less success rate.

Acknowledgements

The author wishes to thank everyone in Rajavithi Hospital who gave their support throughout this study, especially radiologic department.

Potential conflicts of interest

The authors no declare conflicts of interest.

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