HOKKAIDO UNIVERSITY

Title	Significance of shear wave dispersion slope values before versus after biliary drainage in patients with obstructive jaundice : a single-center prospective observational cohort study
Author(s)	Sugiura, Ryo; Kuwatani, Masaki; Nishida, Mutsumi et al.
Citation	Ultrasound quarterly, 39(3), 152-157 https://doi.org/10.1097/RUQ.0000000000000644
Issue Date	2023-09
Doc URL	https://hdl.handle.net/2115/93392
Rights	This is a non-final version of an article published in final form in Significance of Shear Wave Dispersion Slope Values Before Versus After Biliary Drainage in Patients With Obstructive Jaundice A Single-Center Prospective Observational Cohort Study ; Sugiura, Ryo ; Kuwatani, Masaki ; Nishida, Mutsumi ; Satoh, Megumi ; Kawakubo, Kazumichi ; Kato, Shin ; Hirata, Koji ; Nakajima, Masahito ; Hirata, Hajime ; Takishin, Yunosuke ; Sakamoto, Naoya, Ultrasound Quarterly 39(3):p 152-157, September 2023
Type	journal article
File Information	UQ 39(3) 152-157.pdf

Hokkaido University Collection of Scholarly and Academic Papers : HUSCAP

Significance of shear wave dispersion slope values before *versus* after biliary drainage in patients with obstructive jaundice: a single-center prospective observational cohort study

Running title: Shear wave dispersion in obstructive jaundice

Ryo Sugiura, MD, PhD[1], Masaki Kuwatani, MD, PhD[2], Mutsumi Nishida, PhD[3], Megumi Satoh, PhD[3], Kazumichi Kawakubo, MD, PhD[1], Shin Kato, MD, PhD[1], Koji Hirata, MD, PhD[1], Masahito Nakajima, MD[1], Hajime Hirata, MD, PhD[1], Yunosuke Takishin, MD[1], Naoya Sakamoto, MD, PhD[1]

1. Department of Gastroenterology and Hepatology, Hokkaido University Faculty of Medicine and Graduate School of Medicine, Sapporo, Japan

2. Department of Gastroenterology and Hepatology, Hokkaido University Hospital, Sapporo, Japan

3. Division of Laboratory and Transfusion Medicine, Hokkaido University Hospital, Sapporo, Japan

Correspondence author: Masaki Kuwatani, MD, PhD

Department of Gastroenterology and Hepatology, Hokkaido University Hospital, North 14, West 5, Kita-ku, Sapporo, 060-8648, Japan.

Tel.: +81-11-716-1161

Fax: +81-11-706-7867

E-mail: mkuwatan@med.hokudai.ac.jp

Acknowledgements: Nil.

Funding statement: No funding was received for this article.

Conflict of interest disclosure: The authors declare no potential conflict of interest.

Ethics of approval statement: The study protocol was conducted in accordance with the ethical guidelines of the 1975 Declaration of Helsinki (revised in 2013) and it was approved by the Institutional Review Board of Hokkaido University Hospital (017-0278).

Patient consent statement: All patients provided written informed consent to participate in this prospective study.

Significance of shear wave dispersion slope values before *versus* after biliary drainage in patients with obstructive jaundice: a single-center prospective observational cohort study

Running title: Shear wave dispersion in obstructive jaundice

Abstract

The shear wave dispersion (SWD) slope has become available in the clinical practice and is related to tissue viscosity. However, clinical evaluation using SWD was not yet performed for obstructive jaundice. We aimed to evaluate the change of SWD values between before and after biliary drainage in patients with obstructive jaundice. This prospective observational cohort study evaluated twenty patients with obstructive jaundice who underwent biliary drainage. The SWD and liver elasticity values were measured before *versus* after biliary drainage, comparing between days −5 and 0 (Day 0), days 1 and 3 (Day 2), and days 6 and 8 (Day 7). The mean values of SWD (standard deviation) measured at Day 0, Day 2, and Day 7 were 15.3 ± 2.7, 14.2 ± 3.3, and 13.3 ± 2.4 m/s/kHz, respectively. Dispersion slope values were decreased significantly from Day 0 to Day 2, from Day 2 to Day 7, and from Day 0 to Day 7 ($P < 0.05$). Liver elasticity levels and serum hepatobiliary enzymes were additionally decreased significantly over time after biliary drainage. The correlations between SWD and

liver elasticity values were strong (r = 0.91, $P < 0.01$). In conclusion, **t**he SWD values decreased significantly over time after biliary drainage concomitant with liver elasticity.

Keywords: Ultrasound elastography; Shear wave dispersion; Shear wave elastography; Obstructive jaundice; Biliary drainage

Abbreviations:

ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; D-BIL, direct bilirubin; FOV, field of view; IQR, interquartile range; SWD, shear wave dispersion; SWE, shear wave elastography; T-BIL, total bilirubin; γ-GT, γ-glutamyltranspeptidase

Introduction

Assessing the grade of hepatic fibrosis is essential to determine the prognosis and indication for treatment in patients with chronic liver disease.[1] Liver biopsy plays an important role when pathological evaluation of fibrotic tissues was conducted.[2] However, the method occasionally causes various complications, such as life-threatening hemorrhagic shocks.[3] Ultrasound-based methods, including shear wave elastography (SWE), have been developed to quantify liver elasticity for the assessment of liver fibrosis.[4-6] Although the advantages of ultrasound elastography, such as its noninvasiveness and suitability for repeated use, are convenient, the method is influenced by several factors, including acute liver damage,[7, 8] congestive heart failure,[9, 10] and food intake.[11, 12] Obstructive jaundice is further associated with changes in liver elasticity, independent of liver fibrosis.[13-19] Nevertheless, the mechanisms underlying the development of high liver elasticity values due to obstructive jaundice remain unknown.

Most ultrasound elastography models measure not only tissue elasticity, but also the combination of tissue elasticity and viscosity. Recently, shear wave dispersion (SWD) imaging (Canon Medical Systems Corporation, Otawara, Tochigi, Japan) has become available in the clinical practice. The dispersion slope value measured using shear wave speed is related to the tissue viscosity, which notably reflects inflammation and necrosis.[20, 21] Both the dispersion slope and liver elasticity measurements are calculated in parallel using

the shear wave speed. Clinical application of SWD has been reported in the liver.[22, 23] However, a clinical evaluation of SWD for obstructive jaundice. We conducted this prospective study to evaluate the change of dispersion slope values between before and after biliary drainage in patients with obstructive jaundice.

Material and methods

The protocol of this study was conducted in accord with the Declaration of Helsinki (revised in 2013). The hospital's Institutional Review Board approved this study (017-0278). This study was registered at UMIN-CTR (UMIN000031034). Informed consent was obtained from all patients before SWD and SWE as well as biliary drainage were measured.

Study design

This was a prospective observational cohort study conducted at the study institution. Between February 2018 and June 2019, patients with obstructive jaundice (serum total bilirubin [T-BIL] with levels ≥ 2 mg/dL) who planned to undergo biliary drainage at our hospital were examined and enrolled. The exclusion criteria were the following: (1) chronic hepatic disease, (2) diffuse liver tumors, (3) acute cholangitis, (4) lack of expected jaundice improvement, (5) evanescent jaundice, (6) contraindication for abdominal ultrasonography, (7) pregnancy or suspected pregnancy, and (8) difficulty measuring SWD and SWE.

The SWD and SWE values were measured before and after biliary drainage, comparing between days −5 and 0 (Day 0), day 1 and 3 (Day 2), and days 6 and 8 (Day 7). The SWD and SWE measurements were calculated in parallel using the shear wave speed. Patients who did not obtain clinical success of biliary drainage or could not undergo SWD and SWE measurements for all three sessions were considered as a deviation. Clinical success of biliary drainage was defined as (a) a decrease in serum T-BIL to ≤ 2.0 mg/dL or (b) a decrease in serum T-BIL by half within 14 days after biliary drainage. Blood samples were obtained from all the patients on the days when SWD and SWE measurements were performed.

Measurements of SWD and SWE

Two experienced operators (R.S. and M.N.) measured SWD and SWE values using shear wave speed, with the Aplio^{TM} i800 (Canon Medical Systems Corporation) with a i8CX1 ultrasound probe. Patients fasted for at least 5 hours before the SWD and SWE measurement. The SWD and SWE values were measured from the right lobe of the liver using the intercostal scan. The right arm was raised above the head. The measurements were made while the patients were in the supine position and slightly held their breath, for only a few seconds to avoid deep inspiration. A field of view (FOV) (3 × 3 cm) was placed at a depth greater than 1 cm from the liver surface to avoid reverberation artifacts resulting from blood vessels, tumors, and dilated bile ducts. Within the FOV, a single circular region of interest (1-

cm diameter) was placed manually to avoid disturbance propagation and perform measurement referencing to a propagation map (Fig. 1). Measurements of SWD and SWE were completed during the same ultrasonography session. Each patient was measured by the same operator across all three sessions.

The SWD and SWE values were expressed in m/s/kHz and kPa, respectively. The results were calculated as a median of 10 reliable measurements. An interquartile range (IQR)/median ratio within 30% was defined as the criterion for a reliable measurement

Outcome measures

The primary outcome was the changes of SWD values measured before *versus* after biliary drainage. The secondary outcomes were the changes of liver SWE values and serum hepatobiliary enzymes before *versus* after biliary drainage, and the coefficients of correlation among the SWD value, SWE value, and serum hepatobiliary enzymes. Inter-observer differences were also analyzed for the SWD values.

Statistical analysis

Statistical analyses were performed using the freeware EZR (Saitama Medical Center, Jichi Medical University, Saitama, Saitama, Japan).[24] Results are shown as means +/− standard deviation for quantitative variables and medians (IQR) for nonparametric variables.

Continuous variables were compared using paired Student's t-tests. The median values of nonparametric variables were compared using the Wilcoxon signed rank test. Correlation coefficients were calculated using the Spearman's rank correlation coefficient. The classification of correlation coefficients (r) was as follows: almost none, $r < 0.2$; mild, $r = 0.2–0.4$; moderate, $r = 0.4–0.7$; and strong, $r \geq 0.7$. Inter-observer differences of SWD values were evaluated using the intra-class correlation coefficient. The intra-class correlation coefficients were classified as follows: poor, 0.00–0.40; fair to good, 0.40–0.75; and excellent, > 0.75 as previously reported.[22, 25] A *P* value of < 0.05 was considered as statistically significant.

Results

22 patients with obstructive jaundice and serum T-BIL levels ≥ 2 mg/dL who met the clinical criteria were enrolled in this study. Of these, one patient did not obtain clinical success of biliary drainage and another did not undergo SWD and SWE measurements in all three sessions. Therefore, the remaining 20 patients were analyzed.

Baseline characteristics of the patients and biliary drainage methods

Table 1 shows the baseline characteristics of the patients. The patients comprised 17 males and 3 females with a mean age of 66.2 ± 8.4 years. The mean body mass index was 22.3 ±

3.1 kg/m^2. The baseline diseases were nine pancreatic cancer, six cholangiocarcinoma, three autoimmune pancreatitis, and two lymph node metastasis (one esophageal cancer and one sigmoid colon cancer). There was no patient with chronic hepatitis and ascites. The site of biliary obstruction was the distal bile duct in all patients; therefore, a single drainage tube/stent could be used to decompress all the hepatic bile ducts.

The biliary drainage methods were endoscopic biliary stenting using a plastic stent in 13 patients, endoscopic nasobiliary drainage using a nasobiliary tube in four patients, percutaneous transhepatic biliary drainage in two patients, and endoscopic ultrasound-guided choledochoduodenostomy using a 10-mm diameter self-expandable metallic stent in one patient. All patients obtained clinical success of the first biliary drainage and did not undergo additional drainage procedure. There was no patient with drainage-related adverse event.

Changes of SWD values before *versus* after biliary drainage

All patients underwent SWD and SWE measurements in the three sessions. The median values with IQR were considered to be reliable in all patients. The median duration days between Day 0 and biliary drainage, biliary drainage and Day 2, and biliary drainage and Day 7 (IQR) were 0 (0–1), 2 (2–3), and 7 (6–7) days, respectively. The mean values of SWD at Days 0, 2, and 7 were 15.3 ± 2.7, 14.2 ± 3.3, and 13.3 ± 2.4 m/s/kHz, respectively (Table 2).

The SWD values decreased significantly from Day 0 to 2 ($P < 0.01$), Day 2 to 7 ($P = 0.04$), and Day 0 to 7 ($P < 0.01$) (Fig. 2).

Changes of liver SWE values and serum hepatobiliary enzymes before *versus* after biliary drainage

The mean values of SWE at Days 0, 2, and 7 were 9.43 ± 2.56, 7.92 ± 2.26, and 7.34 ± 2.35 kPa, respectively. The SWE values decreased significantly from Day 0 to 2 ($P < 0.01$), Day 2 to 7 ($P = 0.02$), and Day 0 to 7 ($P < 0.01$). The changes of serum hepatobiliary enzymes (aspartate aminotransferase [AST], alanine aminotransferase [ALT], alkaline phosphatase [ALP], γ-glutamyltranspeptidase [γ-GT], T-BIL, and direct bilirubin [D-BIL]) are shown in Table 2. The median values of all serum hepatobiliary enzymes decreased significantly from Day 0 to 2, Day 2 to 7, and Day 0 to 7 ($P < 0.05$).

Correlation analysis among the SWD, SWE, and serum hepatobiliary enzymes

The correlations between SWD and SWE values were strong (r = 0.91, $P < 0.01$) (Fig. 3). Correlations between SWD values and serum hepatobiliary enzymes were tested. Mild correlations were found between SWD and D-BIL values (r = 0.26, $P = 0.04$) and between SWD and ALP values (r = 0.28, $P = 0.03$). Correlations between SWE values and serum

hepatobiliary enzymes were also tested. Mild correlations were found between SWE and D-BIL values (r = 0.26, $P = 0.04$) and between SWE and ALP values (r = 0.30, $P = 0.02$).

Inter-observer repeatability of SWD

Inter-observer differences in SWD measurement between two blinded operators were evaluated in 11 consecutive images during the study period. The intra-class correlation coefficient was 0.794 (95% confidence interval: 0.422–0.939), which indicates an excellent reliability.

Discussions

The current study revealed that the SWD values but also SWE values decreased significantly over time after biliary drainage.

The SWD is related to the tissue viscosity, which notably reflects inflammation and necrosis.[20, 21] A previous animal experiment showed that inflammatory infiltrates are found pathologically in the liver after bile duct ligation, but with uncertainty after biliary decompression.[26] Another previous animal experiment showed that the expression of the several inflammatory markers were upregulated following bile duct ligation and significantly downregulated following biliary decompression.[27] These previous studies indicated that inflammation of the liver is caused by biliary obstruction and is reduced by subsequent biliary

decompression. Although there is no clinical symptom of cholangitis, the SWD value is considered to reflect the liver inflammation transition between before and after biliary drainage in patients with obstructive jaundice. Additionally, in an animal experiment,[27] peribiliary and liver fibrosis were found to progress at 14 days and 28 days after bile duct ligation, and decrease due to biliary decompression after 14 days in the pathological and immunohistological analyses. In addition, measuring messenger ribonucleic acid expression showed fibrosis resolution and reduced portal fibroblasts activation after the release of biliary obstruction.[27] These findings reveal that not only liver inflammation but also peribiliary and liver fibrosis can result from biliary obstruction in the short-term. Future investigation is required to evaluate the relation between SWD/SWE and pathological changes of the liver including liver inflammation and fibrosis over time before and after biliary drainage.

In the current study, both the SWD and SWE values were calculated using shear wave speeds, which naturally leads to strong correlations between SWD and SWE values. Our results indicate that the SWD values correlated with the SWE values, but also mildly with D-BIL and ALP values. The results were similar to those of previous studies showing that liver elasticities measured using various ultrasound elastography models correlated with serum bilirubin and ALP values.[18, 19]

A previous study showed that the inter-class correlation coefficient of SWD values in 19 healthy volunteers was 0.800 (95% confidence interval: 0.572–0.916),[22] in accordance with

the results of the current study. Altogether, these findings indicate that SWD for liver assessment has an excellent inter-observer repeatability regardless of the absence or presence of liver disease.

In the clinical practice, hepatectomy is the most effective method for the radical cure of primary malignant hepatobiliary tumors.[28, 29] Before hepatectomy, evaluating liver functional reserve is needed to avoid postoperative liver failure. Previous studies have shown that the liver elasticity values measured using Virtual Touch Quantification were moderately to strongly correlated with liver functional reserve, using the indocyanine green excretion test and Technetium-99m-diethylenetria-minepentaacetic acid-galactosyl-human serum albumin (^{99}mTc-GSA) scintigraphy.[30, 31] However, the relationship between SWD values and liver functional reserve remains unknown, making it important to investigate these associations in future studies. Consequently, SWD may not only allow for a differential diagnosis between obstructive jaundice and other liver dysfunctional conditions, but also predict whether liver function can be reserved by biliary drainage before drainage procedure.

There are some limitations to this study. First, this was a single-center study. Furthermore, long-term evaluation was not performed. Finally, there was no comparison between SWD/SWE and pathological evaluation of the liver.

Conclusion

The SWD and SWE values decreased significantly over time after biliary drainage. Our results indicate that the SWD values correlated with the SWE values.

References

1. Castera L. Invasive and non-invasive methods for the assessment of fibrosis and disease progression in chronic liver disease. *Best Pract Res Clin Gastroenterol.* 2011;25:291-303.

2. Bravo AA, Sheth SG, Chopra S. Liver biopsy. *N Engl J Med.* 2001;344:495-500.

3. Gilmore IT, Burroughs A, Murray-Lyon IM, et al. Indications, methods, and outcomes of percutaneous liver biopsy in England and Wales: an audit by the British Society of Gastroenterology and the Royal College of Physicians of London. *Gut.* 1995;36:437-441.

4. Fung J, Lai CL, Fong DY, et al. Correlation of liver biochemistry with liver stiffness in chronic hepatitis B and development of a predictive model for liver fibrosis. *Liver Int.* 2008;28:1408-1416.

5. Fung J, Lai CL, Seto WK, et al. Prognostic significance of liver stiffness for hepatocellular carcinoma and mortality in HBeAg-negative chronic hepatitis B. *J Viral Hepat.* 2011;18:738-744.

6. De Robertis R, D'Onofrio M, Demozzi E, et al. Noninvasive diagnosis of cirrhosis: a review of different imaging modalities. *World J Gastroenterol.* 2014;20:7231-7241.

7. Arena U, Vizzutti F, Corti G, et al. Acute viral hepatitis increases liver stiffness values measured by transient elastography. *Hepatology.* 2008;47:380-384.

8. Sagir A, Erhardt A, Schmitt M, et al. Transient elastography is unreliable for detection of cirrhosis in patients with acute liver damage. *Hepatology.* 2008;47:592-595.

9. Colli A, Pozzoni P, Berzuini A, et al. Decompensated chronic heart failure: increased liver stiffness measured by means of transient elastography. *Radiology.* 2010;257:872-878.

10. Millonig G, Friedrich S, Adolf S, et al. Liver stiffness is directly influenced by central venous pressure. *J Hepatol.* 2010;52:206-210.

11. Mederacke I, Wursthorn K, Kirschner J, et al. Food intake increases liver stiffness in patients with chronic or resolved hepatitis C virus infection. *Liver Int.* 2009;29:1500-1506.

12. Goertz RS, Egger C, Neurath MF, et al. Impact of food intake, ultrasound transducer, breathing maneuvers and body position on acoustic radiation force impulse (ARFI) elastometry of the liver. *Ultraschall Med.* 2012;33:380-385.

13. Millonig G, Reimann FM, Friedrich S, et al. Extrahepatic cholestasis increases liver stiffness (FibroScan) irrespective of fibrosis. *Hepatology.* 2008;48:1718-1723.

14. Yashima Y, Tsujino T, Masuzaki R, et al. Increased liver elasticity in patients with biliary obstruction. *J Gastroenterol.* 2011;46:86-91.

15. Trifan A, Sfarti C, Cojocariu C, et al. Increased liver stiffness in extrahepatic cholestasis caused by choledocholithiasis. *Hepat Mon.* 2011;11:372-375.

16. Harata M, Hashimoto S, Kawabe N, et al. Liver stiffness in extrahepatic cholestasis correlates positively with bilirubin and negatively with alanine aminotransferase. *Hepatol Res.* 2011;41:423-429.

17. Pfeifer L, Strobel D, Neurath MF, et al. Liver stiffness assessed by acoustic radiation force impulse (ARFI) technology is considerably increased in patients with cholestasis. *Ultraschall Med.* 2014;35:364-367.

18. Attia D, Pischke S, Negm AA, et al. Changes in liver stiffness using acoustic radiation force impulse imaging in patients with obstructive cholestasis and cholangitis. *Dig Liver Dis.* 2014;46:625-631.

19. Kubo K, Kawakami H, Kuwatani M, et al. Liver elasticity measurement before and after biliary drainage in patients with obstructive jaundice: a prospective cohort studya prospective cohort study. *BMC Gastroenterol.* 2016;16:65.

20. Barry CT, Mills B, Hah Z, et al. Shear wave dispersion measures liver steatosis. *Ultrasound Med Biol.* 2012;38:175-182.

21. Sugimoto K, Moriyasu F, Oshiro H, et al. Viscoelasticity measurement in rat livers using shear-wave US elastography. *Ultrasound Med Biol.* 2018;44:2018-2024.

22. Yoo J, Lee JM, Joo I, et al. Prospective validation of repeatability of shear wave dispersion imaging for evaluation of non-alcoholic fatty liver disease. *Ultrasound Med Biol.* 2019;45:2688-2696.

23. Schulz M, Wilde AB, Demir M, et al. Shear wave elastography and shear wave dispersion imaging in primary biliary cholangitis—a pilot study. *Quant Imaging Med Surg.* 2022;12:1235-1242.

24. Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. *Bone Marrow Transplant.* 2013;48:452-458.

25. Büsing KA, Kilian AK, Schaible T, et al. Reliability and validity of MR image lung volume measurement in fetuses with congenital diaphragmatic hernia and in vitro lung models. *Radiology.* 2008;246:553-561.

26. Kirkland JG, Godfrey CB, Garrett R, et al. Reversible surgical model of biliary inflammation and obstructive jaundice in mice. *J Surg Res.* 2010;164:221-227.

27. Yoshino K, Taura K, Iwaisako K, et al. Novel mouse model for cholestasis-induced liver fibrosis resolution by cholecystojejunostomy. *J Gastroenterol Hepatol.* 2021;36:2493-2500.

28. Hirano S, Kondo S, Tanaka E, et al. Outcome of surgical treatment of hilar cholangiocarcinoma: a special reference to postoperative morbidity and mortality. *J Hepatobiliary Pancreat Sci.* 2010;17:455-462.

29. Miyazaki M, Kimura F, Shimizu H, et al. Surgical treatment for liver cancer. Current issues. *Dig Surg.* 2007;24:120-125.

30. Sun XL, Liang LW, Cao H, et al. Liver reserve function assessment by acoustic

radiation force impulse imaging. *World J Gastroenterol.* 2015;21:9648-9655.

31. Sugiura R, Kuwatani M, Nishida M, et al. Correlation between Liver Elasticity by Ultrasound Elastography and Liver Functional Reserve. *Ultrasound Med Biol.* 2019;45:2704-2712.

Figure legends

Figure 1. Measurement example of share wave elastography/shear wave dispersion imaging. Left, elasticity map; right, propagation map

Figure 2. Changes in shear wave dispersion (SWD) slope values before *versus* after biliary drainage.

SWD values decreased significantly from Day 0 to 2 ($P < 0.01$), Day 2 to 7 ($P = 0.04$), and Day 0 to 7 ($P < 0.01$).

Figure 3. Correlation among the shear wave dispersion (SWD) values, shear wave elasticity (SWE) values, and serum hepatobiliary enzymes.

(a) SWD and SWE values (r = 0.91, $P < 0.01$).

(b) SWD and direct bilirubin (D-BIL) values (r = 0.26, $P = 0.04$).

(c) SWD and alkaline phosphatase (ALP) values (r = 0.28, $P = 0.03$).

(d) SWE and D-BIL values (r = 0.26, $P = 0.04$).

(e) SWE and ALP values (r = 0.30, $P = 0.02$).

Table 1. Baseline characteristics of the patients and biliary drainage methods

Sex (male: female), n	17: 3
Age, mean (SD), year	66.2 (±8.4)
Body mass index, mean, (SD), kg/m^2	22.3 (±3.1)
Baseline diagnosis, n	
Pancreatic cancer	9
Cholangiocarcinoma	6
Autoimmune pancreatitis	3
Lymph node metastasis	2
Biliary drainage method, n	
EBS	13
ENBD	4
PTBD	2
ESU-CDS	1

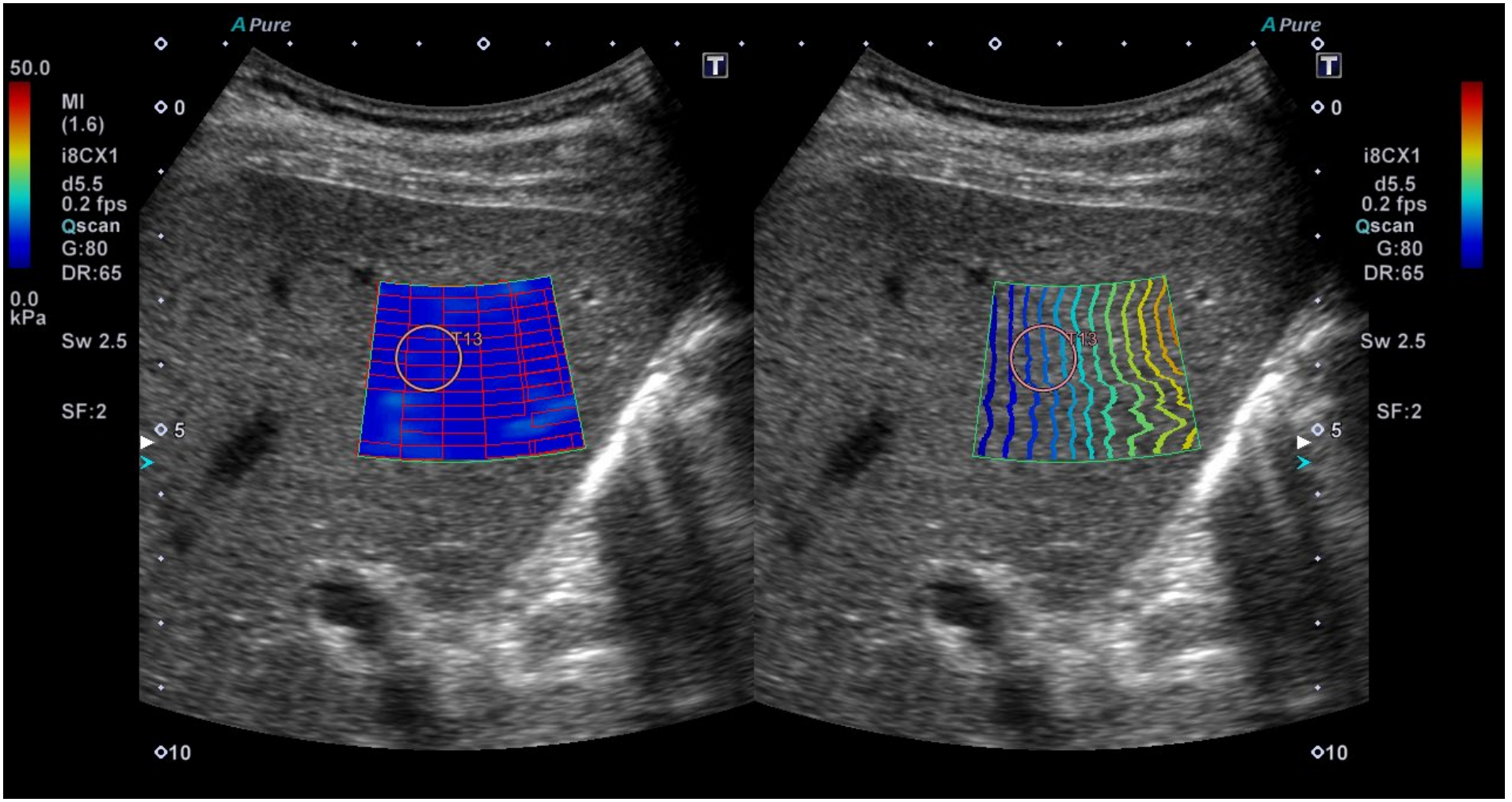
EBS, endoscopic biliary stenting; ENBD, endoscopic nasobiliary drainage; EUS-CDS, endoscopic ultrasound-guided choledochoduodenostomy; SD, standard deviation; PTBD, percutaneous transhepatic biliary drainage

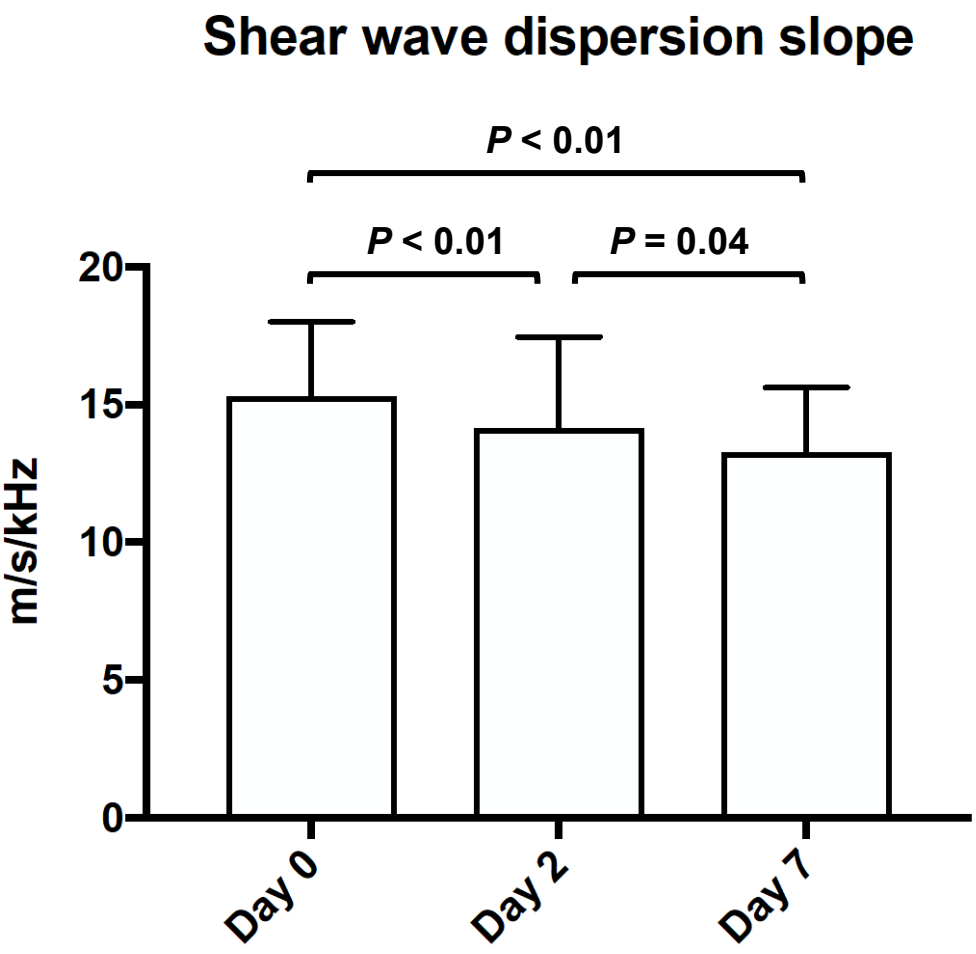
Table 2. Shear wave dispersion, shear wave elasticity values, and serum hepatobiliary enzymes before and after biliary drainage

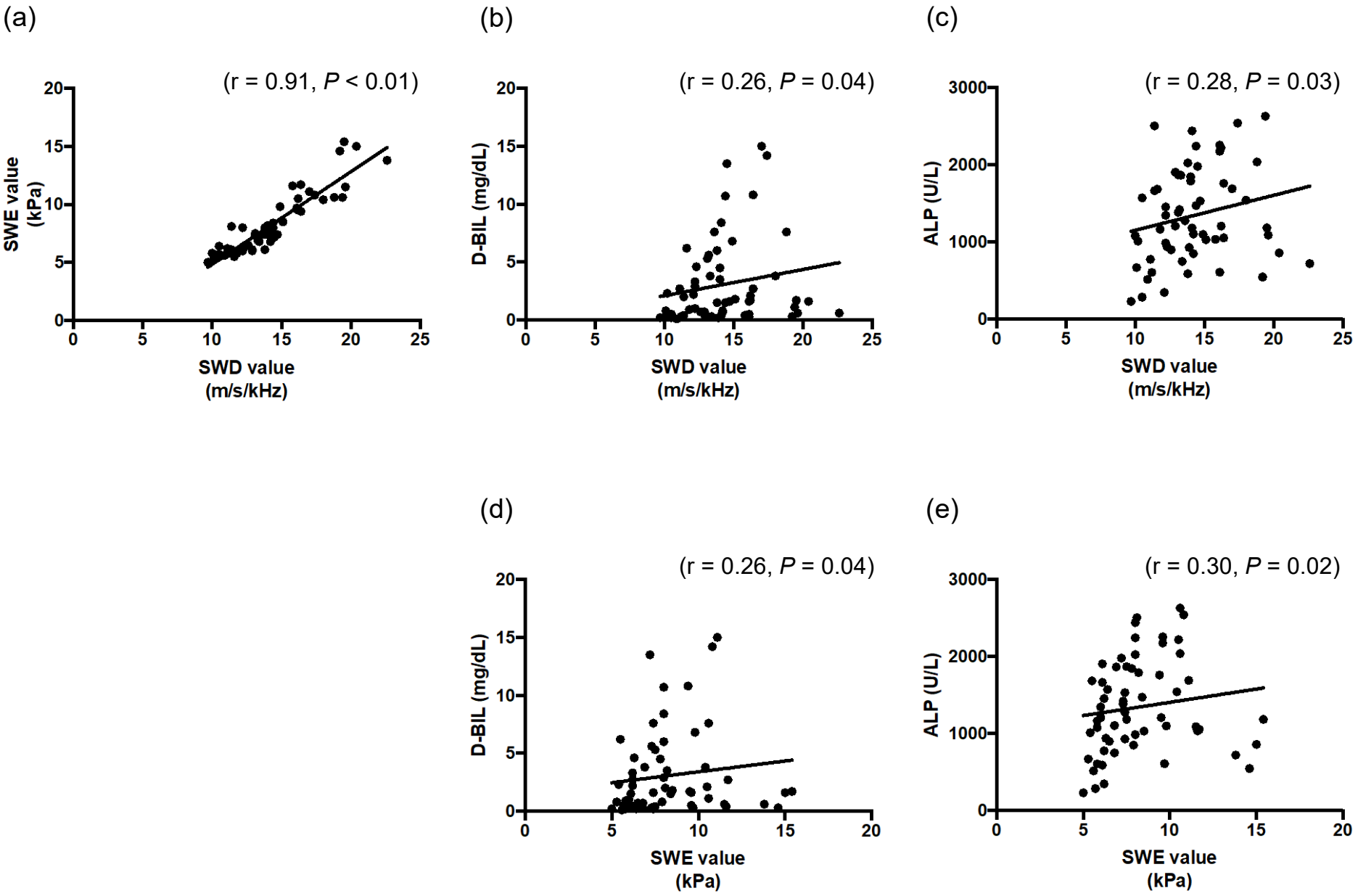
	Day 0	Day 2	Day 7	*P**	*P***	*P****
SWD values, mean (SD), m/s/kHz						
	15.3 (±2.7)	14.2 (±3.3)	13.3 (±2.4)	< 0.01	0.04	< 0.01
SWE values, mean (SD), kPa						
	9.43 (±2.56)	7.92 (±2.26)	7.34 (±2.35)	< 0.01	0.02	< 0.01
Serum hepatobiliary enzyme, median (IQR)						
AST, U/L	110 (79–192)	67 (53–113)	52 (42–100)	< 0.01	0.04	0.04
ALT, U/L	136 (–316)	115 (65–225)	102 (50–186)	0.01	0.02	< 0.01
ALP, U/L	1582 (1068–2238)	1500 (929–1824)	1035 (609–1313)	< 0.01	< 0.01	< 0.01
γ-GT, U/L	839 (502–1390)	672 (369–1096)	375 (243–598)	< 0.01	< 0.01	< 0.01
T-BIL, mg/dL	6.2 (3.6–10.9)	3.4 (1.7–6.9)	1.9 (1.3–3.0)	< 0.01	< 0.01	< 0.01
D-BIL, mg/dL	4.1 (2.0–8.2)	1.7 (0.5–3.8)	0.6 (0.3–1.0)	< 0.01	< 0.01	< 0.01

ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; D-BIL, direct bilirubin; SD, standard deviation; SWD, shear wave dispersion; SWE, shear wave elasticity; T-BIL, total bilirubin; γ-GT, γ-glutamyltranspeptidase

* ‘‘Day 0’’ verses ‘‘Day 2’’; ** ‘‘Day 2’’ verses ‘‘Day 7’’; *** ‘‘Day 0’’ verses ‘‘Day 7’’


A Pure
50.0
MI
(1.6)
i8CX1
d5.5
0.2 fps
Qscan
G:80
DR:65
0.0
kPa
Sw 2.5
SF:2
T13
0
5
10
A Pure
i8CX1
d5.5
0.2 fps
Qscan
G:80
DR:65
Sw 2.5
SF:2
T13
0
5
10


Shear wave dispersion slope
P < 0.01
P < 0.01
P = 0.04
20
15
10
5
0
m/s/kHz
Day 0
Day 2
Day 7


(a)
(r = 0.91, P < 0.01)
SWE value (kPa)
SWD value (m/s/kHz)
(b)
(r = 0.26, P = 0.04)
D-BIL (mg/dL)
SWD value (m/s/kHz)
(c)
(r = 0.28, P = 0.03)
ALP (U/L)
SWD value (m/s/kHz)
(d)
(r = 0.26, P = 0.04)
D-BIL (mg/dL)
SWE value (kPa)
(e)
(r = 0.30, P = 0.02)
ALP (U/L)
SWE value (kPa)