Title page

The propagation display method improves the reproducibility of pancreatic shear wave elastography

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ABSTRACT

Evaluation of the pancreatic elastic modulus (PEM) using shear wave elastography (SWE) requires at least 5 measurements to ensure reproducibility. The aim of this study was to evaluate improvement in reproducibility of SWE using the propagation display method in normal pancreas (NP) (phase 1) and to examine differences in PEM between NP and chronic pancreatitis (CP), intraductal papillary mucinous neoplasm (IPMN), and autoimmune pancreatitis (AIP) (phase 2).

In phase 1, the measurement success rate, median PEM in repeated measurements, and appropriate number of SWE measurements were determined in 109 cases with NP. In phase 2, PEM was measured in CP (n=10), IPMN (n=31), and AIP (n=5) using the required number of SWE measurements determined in phase 1.

In phase 1, the measurement success rate was 93.9% (92/109 cases). The median PEM for NP was 14.6 kPa and the appropriate number of SWE measurements was at least 3. In phase 2, the median PEMs in CP, IPMN, and AIP were 19.6, 18.1, and 17.2 kPa, respectively, with significant differences between NP and CP (P =0.0133), and NP and IPMN (P =0.0436).

Use of the propagation display method in SWE improves the reproducibility of measurement of PEM.

Keywords: shear wave elastography; pancreas; chronic pancreatitis; propagation display method

Introduction

Ultrasound elastography is a useful technique for measurement of tissue elasticity(Shiina 2013; Hirooka et al. 2015). Tissue is generally elastic and Young's modulus can be used for evaluating elasticity (Ferraioli et al, 2012). There are two types of ultrasound elastography: strain elastography and shear wave elastography (SWE). Strain elastography uses hand pressure and pulsation of the heart and aorta beat, and measures the target tissue elasticity with the strain generated, whereas SWE generates strain by a push pulse from a probe, measures the propagation velocity, and obtains the tissue elasticity. Strain elastography may be affected by the skill of the operator and the site chosen for measuring the tissue elasticity, whereas in SWE the difference between examiners is small, but the elastic modulus can change due to inflammation (Arena et al. 2008), jaundice (Millonig et al 2008), or blood congestion (Colli et al. 2010). Elastography can be performed using endoscopic ultrasonography (EUS), but transabdominal ultrasonography is superior to EUS in that it is a non-invasive and simple procedure (Hirooka et al. 2015).

The speed at which a shear wave propagates in a material has a positive correlation with the elastic modulus of the substance: the faster the propagation speed, the harder the material. This principle is used in SWE to determine the elastic modulus of tissue in a noninvasive and simple manner, including measurement of the pancreatic elastic modulus (PEM) (Hirooka et al. 2015).

SWE permits measurement of the PEM, but there are errors in the measurement. One problem is setting the correct region of interest (ROI). If the ROI contains tissues other than pancreatic parenchyma, such as the extended main pancreatic duct and blood vessels, or the aorta or intestinal tract is close to the ROI, it becomes difficult to evaluate the PEM (Ichikawa et al. 2012). Thus, we found that obtaining a reproducible median PEM from SWE performed at an arbitrary part of pancreatic parenchyma required at least 5 measurements (Kuwahara et al. 2016).

The “propagation display method” in SWE was developed in 2014 to confirm the tissue arrival time of the shear wave using contour lines (Iijima 2014). Using this indication of the timing of SWE, it is possible to visualize the shear wave propagating in the target tissue before measurement. That is, since the tissue elasticity can be measured within the range where the shear wave is well propagated (Iijima reported that in areas where the contour lines are parallel, the shear waves propagate properly and the reliability of the obtained data is high.), more reliable measurements can be made, which may lead to improvement of SWE reproducibility. In this study, SWE with propagation display method was applied to a normal pancreas and improvement of PEM reproducibility was evaluated. The relationship of PEM for the normal pancreas with PEMs for chronic pancreatitis (CP), intraductal papillary mucinous neoplasm (IPMN), and autoimmune pancreatitis (AIP) was then examined using the same SWE method.

Materials and methods

Phase 1

Phase 1: A total of 109 cases with a normal pancreas (NP) were included in this phase of the study. Cases with NP were defined as patients with no apparent pancreatic diseases such as tumors, cysts, or a dilated main pancreatic duct, no history of alcohol consumption >80 g per day, and normal serum levels of amylase and lipase. The mean age was 62.6 ± 13.8 years (range 29-85 years) and the male/female ratio was 46/63 (Table 1）(Kuwahara et al. 2016).

Phase 2

Phase 2: Cases with CP (n=10), IPMN (n=31), and AIP (n=5) that underwent SWE with propagation display method were included in this phase of the study (Table 1). In the CP, IPMN, and AIP cases, the mean ages were 53.7 ± 18.2 (30-79), 67.6 ± 7.4 (51-81), and 71.8 ± 8.3 (61-82) years, respectively, and the male/female ratios were 6/4, 11/20, and 4/1,

77 respectively (Table 1). CP, IPMN, and AIP were diagnosed using Japanese Clinical
78 Diagnostic Criteria for Chronic Pancreatitis 2009 (Shimosegawa et al. 2010), International
79 Consensus Guidelines 2012 for Management of IPMN and MCN of the Pancreas (Tanaka et
80 al. 2012), and Clinical Diagnostic Criteria for Autoimmune Pancreatitis 2011 (The Japan
81 Pancreas Society 2012), respectively.
82 In both phases, consecutive patients were recruited from March 2015 to May 2016 at
83 Nagoya University Hospital and all provided informed consent before the examination.
84 Patients for whom it was difficult to perform an examination because of severe complications
85 or mental disorder were excluded. The study was approved by the Institutional Review Board
86 of Nagoya University Hospital, performed according to the Declaration of Helsinki, and
87 registered in UMIN-CTR (registration ID 000016497).
88
89 *Shear wave elastography*
90 In all cases, SWE was performed using an Aplio 500 ultrasound system (Toshiba Medical
91 Systems, Otawara, Japan) with a 5-MHz convex probe (PVT-375BT). SWE detects the speed
92 at which the shear wave caused by a push pulse from the probe propagates through the tissue
93 and evaluates the tissue elasticity. The shear wave has constant velocity in the same elastic
94 materials, and is fast in hard material and slow in soft material. In soft tissues such as in vivo,
95 it is possible to assume that the difference in tissue density is small, so it is possible to
96 estimate Young's modulus(E) from shear wave velocity(vS). From this fact, the shear wave
97 velocity is expressed in kilopascals(kPa) or m/s through E = 3(vS2p), where p is the tissue
98 density (Ferraioli et al, 2012).
99
100 *Propagation display method*
101 A feature of the Aplio 500 used in this study is the propagation display method mounted on
102 the shear wave. The propagation display method allows the arrival site of the shear wave to

be visualized by contour lines at regular time intervals by utilizing the difference in propagation speed of the shear wave. The intervals between the displayed contour lines are wider in hard tissues and narrower in soft tissues. In a homogeneous elastic tissue, since the velocity of the shear wave is constant, the widths of the contour lines are equal and parallel. Parallel contour lines mean that the shear wave has propagated properly and the data are highly reliable, whereas distorted or non-parallel contour lines indicate that the reliability of the data is low(Iijima 2014) (Fig. 1).

Elastography

SWE measurements were performed from the epigastric fossa in the supine position and the measurement site was defined as the parenchyma of the pancreatic body. The transducer was repositioned for each acquisition. In the measurement of PEM by SWE, a so-called "evaluation ROI" was first established as the target and the "measurement ROI" was set as wide as possible for the part where the width of the contour line was equal and parallel. The ROI is the recommended measurement range up to 5 cm from the probe. Measurements were evaluated by a doctor and an ultrasonic specialist.

In the phase 1 study, SWE using the propagation display method was performed 5 times for NP cases (Kuwahara et al. 2016). Contour lines from the propagation display method that were visually recognized were defined as a valid measurement. It was defined as invalid measurement when the ROI did not reach, when the patients could not hold their breath, and when it was difficult to visualize the pancreas due to the influence of intestinal gas. Valid measurements were judged to be successful when the contour lines were equal in width and equilibrium (Fig. 1). The measurement success rate was calculated as the average of the number of valid measurements/total measurements × 100 in each case (Castera et al. 2012). ICC(1,1) was obtained from valid measured values, and the appropriate number of measurements (k) was obtained from the equation $k = \rho2(1-\rho1)/\rho1(1-\rho2)$, where $\rho1$ is

ICC(1,1) and ρ2 is the target coefficient value (0.9).

In the phase 2 study, PEM measurements for CP, IPMN, and AIP were performed using the required number of measurements (k) found in phase 1, and PEM for each disorder was compared with PEM for NP. For cases of IPMN, the measurement ROI did not cover the cystic lesion or extended main pancreatic duct. In CP, a case in which the pancreas was thinned and the pancreas itself was difficult to visualize was excluded as unmeasurable.

Statistical analysis

Statistical analyses of recorded data were performed using an Excel-based program (BellCurve for Excel for Windows, Social Survey Research Information Co.). All tests were 2-tailed and $P<0.05$ was considered significant. Continuous variables are expressed as mean ± SD or median and interquartile range (IQR), where indicated. A Steel-Dwass test was used for continuous variables. The ICC was used to assess the intra-rater reproducibility of the PEM of NP in SWE. ICC values were defined as indicating slight (ρ<0.2), fair (ρ=0.2-0.4), moderate (ρ=0.4-0.6), substantial (ρ=0.6-0.8), and almost perfect (ρ=0.8-1.0) reproducibility (Landis et al.1977).

Results

Pancreatic elasticity modulus and measurement success rate for NP using SWE

SWE with propagation display method was performed 5 times for 109 NP cases. Seventeen cases were excluded as unmeasurable due to a deep location of the pancreas (n=4), failed breathholding (n=4), and difficulty with pancreatic visualization due to intestinal gas (n=9) (Fig. 2). In SWE using propagation display method in the 92 measurable cases, the measurement success rate was 93.9±11.0% and the median PEM (IQR) was 14.6 (12.3-17.3) kPa (Fig. 3).

Appropriate number of SWE measurements

The ICC (1, 1) for SWE performed for NP was 0.7629 and the appropriate number of measurements obtained from this value was 2.7970. This indicates that an appropriate value can be obtained from three or more measurements, which is fewer than the 5 measurements required using the conventional method.

Comparison between NP and other pancreatic diseases

The median (IQR) PEMs for SWE performed three times for CP (n=10), IPMN (n=31) , and AIP (n=5) cases were 19.6 (15.6-22.4), 18.1 (13.3-20.9), 17.2 (15.6-40.4), respectively. PEMs for CP and IPMN were significantly higher than PEM for NP (P=0.0133, P=0.0436). There was no significant difference between PEMs for NP and AIP (P=0.1809) (Fig. 4).

Discussion

In the current study, we examined improvement of SWE reproducibility using the propagation display method, and further examined PEM for several pancreatic disorders. When SWE was measured, good reproducibility is required to get the reliable data on the elasticity of a target tissue. Therefore, we examined whether reproducibility is improved using the propagation display method in SWE. The propagation display method can display and visualize the propagation of the shear wave in the target tissue. Measurements using this method indicated that reliable data can be obtained by measuring only three times, which is less than the number of measurements required for reproducibility of SWE using the conventional method (Kuwahara et al. 2016).

Comparison of PEM values between NP and pancreatic diseases (CP, IPMN, AIP) showed that CP and IPMN had significantly higher elasticity than NP. CP has a high elastic modulus due to chronic inflammation and accompanying fibrosis. A relationship between fibrosis and elastography has been reported in liver diseases (Castera 2008; Friedrich 2009; Cassinotto

2013; Ogawa 2016; Sande 2017; Ferraioli 2012). Ferraioli et al. described the relationship between liver fibrosis and SWE measurements (Ferraioli et al. 2012), and this relationship was confirmed between SWE and fibrosis in pancreatic parenchyma by Kuwahara et al. (2016) and Harada et al. (2014). Using acoustic radiation force impulse (ARFI) elastography, Yashima et al. found that the shear wave velocity in CP was higher in the pancreatic head, body, and tail, compared with NP (Yashima et al. 2012). The shear wave velocity in the pancreatic body in Yashima et al. was 2.09±1.03 m/s, which is similar to the value in the present study (19.6 (15.6-22.4）kPa, which converts to 2.54 (2.28-2.73）m/s). In IPMN, the higher PEM compared to NP is due to mucus produced by IPMN, which exerts pressure on the pancreatic duct. This leads to the pathology of chronic obstructive pancreatitis in the pancreatic parenchyma, and resulting chronic inflammation causes a high PEM (Rickaert 1991; Zapiach 2004; Venkatesh 2011; Pelletier 2010).

This study has several limitations. First, because the number of cases with a diseased pancreas was small, we could not conclude the comparison of PEM among pancreatic diseases in this study. Second, histopathological evidence was not obtained for the elasticity modulus. Third, the results were taken from examples that were valid in the propagation display method, and invalid or unmeasurable cases could not be evaluated. Fourth, in SWE for the pancreas, there is a difference in the distance from the body surface to the pancreas in each individual, and this may alter the elastic modulus (Wang et al. 2014). Fifth, the viscosity of the target tissue is not considered in this study. Given these limitations, the results of the study are not conclusive and further data are required from more disease cases. However, we showed that PEM measurements in SWE using propagation display method are reproducible from as few as three measurements, and this suggests that this method may be viable for clinical application in pancreatic disease.

Conclusion

Shear wave elastography using propagation display method improves the reproducibility of measurement of PEM.

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Conflict of Interest

Hashizume K declares no conflict of interest.

Table list

Table 1. Patient characteristics

Characteristic

Pancreatic diagnosis	Number of cases	Age(years)	Sex(Male/Female)
NP	109	62.6±13.8	46/63
CP	10	53.7±18.2	6/4
IPMN	31	67.6±7.4	11/20
AIP	5	71.8±8.3	4/1

NP nomal pancreas
CP chronic pancreatitis
IPMN intraductal papillary mucinous neoplasms
AIP autoimmune pancreatitis

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References list

Arena U, Vizzutti F, Corti G, Ambu S, Stasi C, Bresci S, Moscarella S, Boddi V, Petrarca A, Laffi G, Marra F, Pinzani M. Acute viral hepatitis increases liver stiffness values measured by transient elastography. Hepatology. 47 (2008) 380-384.

Cassinotto C, Lapuyade B, Aït-Ali A, Vergniol J, Gaye D, Foucher J, Bailacq-Auder C, Chermak F, Le Bail B, de Lédinghen V. Liver fibrosis: noninvasive assessment with acoustic radiation force impulse elastography--comparison with FibroScan M and XL probes and FibroTest in patients with chronic liver disease. Radiology. 269 (2013) 283-92.

Castera L, Forns X, Alberti A. Non-invasive evaluation of liver fibrosis using transient elastography. J Hepatol 48 (2008) 835-847.

Castera L, Forns X, Alberti A. Non-invasive evaluation of portal hypertension using transient elastography. J Hepatol 56 (2012) 696-703.

Colli A, Pozzoni P, Berzuini A, Gerosa A, Canovi C, Molteni EE, Barbarini M, Bonino F, Prati D. Decompensated chronic heart failure: increased liver stiffness measured by means of transient elastography. Radiology. 257 (2010) 872-878.

Ferraioli G, Tinelli C, Dal Bello B, Zicchetti M, Filice G, Filice C. Accuracy of real-time shear wave elastography for assessing liver fibrosis in chronic hepatitis C: a pilot study. Hepatology. 56 (2012) 2125-2133.

Friedrich-Rust M, Wunder K, Kriener S, Sotoudeh F, Richter S, Bojunga J, Herrmann E, Poynard T, Dietrich CF, Vermehren J, Zeuzem S, Sarrazin C. Liver fibrosis in viral hepatitis:

303 noninvasive assessment with acoustic radiation force impulse imaging versus transient
304 elastography.Radiology.252(2009)595-604.
305
306 Harada N, Ishizawa T, Inoue Y, Aoki T, Sakamoto Y, Hasegawa K, Sugawara Y, Tanaka M,
307 Fukayama M, Kokudo N. Acoustic radiation force impulse imaging of the pancreas for
308 estimation of pathologic fibrosis and risk of postoperative pancreatic fistula. J Am Coll Surg.
309 219 (2014) 887-894.
310
311 Hirooka Y, Kuwahara T, Irisawa A, Itokawa F, Uchida H, Sasahira N, Kawada N, Itoh Y,
312 Shiina T. JSUM ultrasound elastography practice guidelines: pancreas. J Med Ultrasonics. 42
313 (2015) 151-174.
314
315 Ichikawa S, Motosugi U, Ichikawa T, Sano K, Morisaka H, Enomoto N, Matsuda M, Fujii H,
316 Araki T. Magnetic Resonance Elastography for Staging Liver Fibrosis in Chronic Hepatitis
317 C.Magn Reson Med Sci. 11 (2012) 291-297.
318
319 Iijima H. Approaches to the Diagnosis of Liver Fibrosis. Medical review Japan, 2014.
320
321 Kuwahara T, Hirooka Y, Kawashima H, Ohno E, Sugimoto H, Hayashi D, Morishima T,
322 Kawai M, Suhara H, Takeyama T, Yamamura T, Funasaka K, Nakamura M, Miyahara R,
323 Watanabe O, Ishigami M, Shimoyama Y, Nakamura S, Hashimoto S, Goto H. Quantitative
324 evaluation of pancreatic tumor fibrosis using shear wave elastography. Pancreatology. 16
325 (2016) 1063-1068.
326
327 Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data.
328 Biometrics. 33(1977) 159-174.

Millonig G, Reimann FM, Friedrich S, Fonouni H, Mehrabi A, Büchler MW, Seitz HK, Mueller S. Extrahepatic cholestasis increases liver stiffness (FibroScan) irrespective of fibrosis. Hepatology. 48 (2008) 1718-1723.

Ogawa S, Moriyasu F, Yoshida K, Oshiro H, Kojima M, Sano T, Furuichi Y, Kobayashi Y, Nakamura I, Sugimoto K. Relationship between liver tissue stiffness and histopathological findings analyzed by shear wave elastography and compression testing in rats with non-alcoholic steatohepatitis. J Med Ultrasonics. 43 (2016) 355-360.

Pelletier AL, Hammel P, Rebours V, Couvelard A, Vullierme MP, Maire F, Hentic O, Aubert A, Sauvanet A, Lévy P, Ruszniewski P. Acute pancreatitis in patients operated on for intraductal papillary mucinous neoplasms of the pancreas. frequency, severity, and clinicopathologic correlations. Pancreas. 39 (2010) 658-661.

Rickaert F, Cremer M, Devière J, Tavares L, Lambilliotte JP, Schröder S, Wurbs D, Klöppel G. Intraductal mucin-hypersecreting neoplasms of the pancreas. A clinicopathologic study of eight patients. Gastroenterology. 101 (1991) 512-519.

Sande JA, Verjee S, Vinayak S, Amersi F, Ghesani M. Ultrasound shear wave elastography and liver fibrosis: A Prospective Multicenter Study. World J Hepatol. 9 (2017) 38-47.

Shiina T. JSUM ultrasound elastography practice guidelines: basics and terminology. J Med Ultrasonics.40 (2013) 309-323.

Shimosegawa T, Kataoka K, Kamisawa T, Miyakawa H, Ohara H, Ito T, Naruse S, Sata N,

355 Suda K, Hirota M, Takeyama Y, Shiratori K, Hatori T, Otsuki M, Atomi Y, Sugano K, Tanaka
356 M. The revised Japanese clinical diagnostic criteria for chronic pancreatitis. J Gastroenterol.
357 45 (2010) 584-91.
358
359 Tanaka M, Fernández-del Castillo C, Adsay V, Chari S, Falconi M, Jang JY, Kimura W, Levy
360 P, Pitman MB, Schmidt CM, Shimizu M, Wolfgang CL, Yamaguchi K, Yamao K.
361 International consensus guidelines 2012 for the management of IPMN and MCN of the
362 pancreas. Pancreatology. 12 (2012) 183-197.
363
364 The Japan Pancreas Society, the Ministry of Health and Welfare Investigation Research Team
365 for Intractable Pancreatic Disease. Clinical Diagnostic Criteria for Autoimmune Pancreatitis
366 2011. J Jpn Pancreas(Suizo). 27 (2012) 17-25.
367
368 Venkatesh PG, Navaneethan U, Vege SS. Intraductal papillary mucinous neoplasm and acute
369 pancreatitis. J Clin Gastroenterol. 45 (2011) 755-758.
370
371 Wang CZ, Zheng J, Huang ZP , Xiao Y, Song D, Zeng J, Zheng HR, Zheng RQ. Influence of
372 measurement depth on the stiffness assessment of healthy liver with real-time shear wave
373 elastography. Ultrasound Med Biol. 40(2014) 461–469
374
375 Yashima Y, Sasahira N, Isayama H, Kogure H, Ikeda H, Hirano K, Mizuno S, Yagioka H,
376 Kawakubo K, Sasaki T, Nakai Y, Tada M, Yoshida H, Omata M, Koike K. Acoustic radiation
377 force impulse elastography for noninvasive assessment of chronic pancreatitis. J
378 Gastroenterol. 47 (2012) 427-432.
379
380 Youk JH, Son EJ, Gweon HM, Han KH, Kim JA. Quantitative Lesion-to-Fat Elasticity Ratio

Measured by Shear-Wave Elastography for Breast Mass: Which Area Should Be Selected as the Fat Reference? PLoS One. 10 (2015) 1-11.

Zapiach M, Yadav D, Smyrk TC, Fletcher JG, Pearson RK, Clain JE, Farnell MB, Chari ST. Calcifying obstructive pancreatitis:A study of intraductal papillary mucinous neoplasm associated with pancreatic calcification. Clin Gastroenterol Hepatol. 2 (2004) 57-63.

Figure Captions list

Fig. 1. Shear wave elastography using the propagation display method in the pancreas.
(a) Images showing measurement success have equal width balance. (b) Images showing measurement failure have heterogeneous widths.

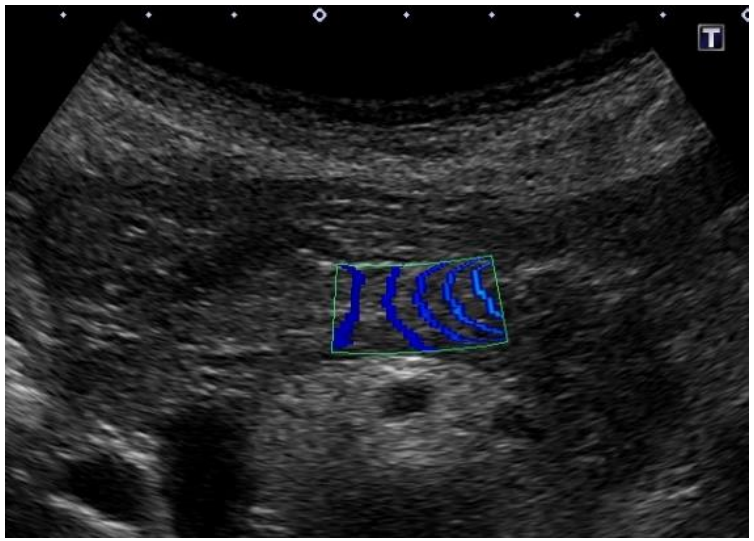
Fig. 2. Flowchart of subjects.
A total of 109 cases with normal pancreas (NP) were enrolled in the study. Seventeen cases with failed measurements in shear wave elastography were excluded, leaving 92 cases for analysis.

Fig. 3. Median of the pancreatic elastic modulus (PEM) of the normal pancreas (NP).
The median measured in each case five times was taken as the PEM of each case. The median (IQR) of the PEM of 92 normal pancreas cases was 14.6(5.0) kPa.

Fig. 4. Comparison of PEM values for normal pancreas (NP) and cases of chronic pancreatitis (CP), intraductal papillary mucinous neoplasm (IPMN), and autoimmune pancreatitis (AIP), PEMs for CP and IPMN were significantly higher than that for NP ($P = 0.0133$, $P = 0.0436$).

Fig.1

a)



b)

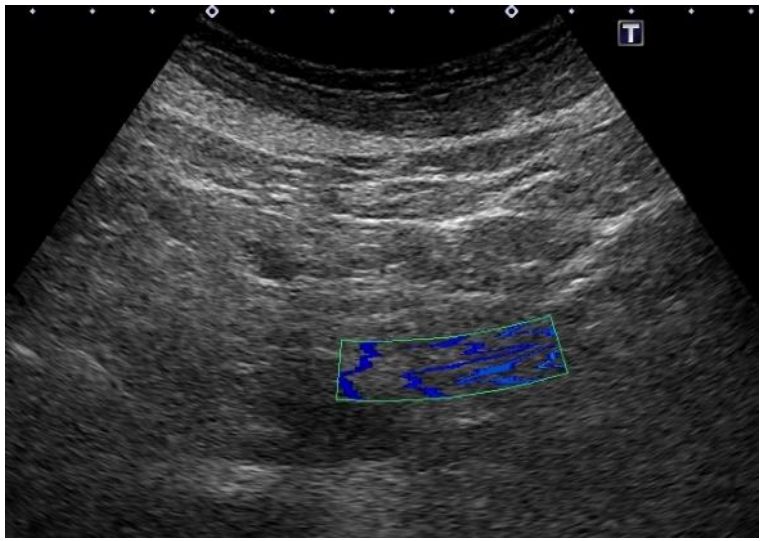


Fig.2

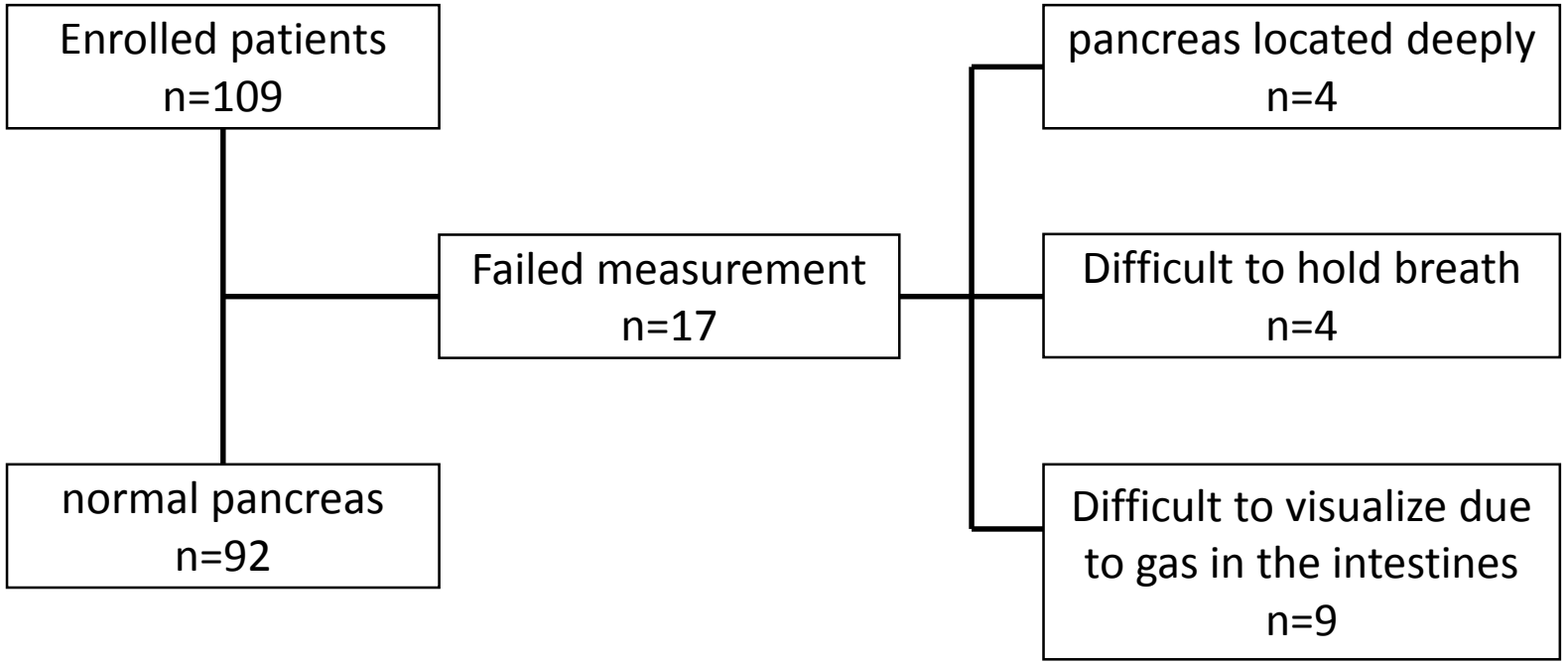

Enrolled patients
n=109
Failed measurement
n=17
normal pancreas
n=92
pancreas located deeply
n=4
Difficult to hold breath
n=4
Difficult to visualize due to gas in the intestines
n=9

Fig.3

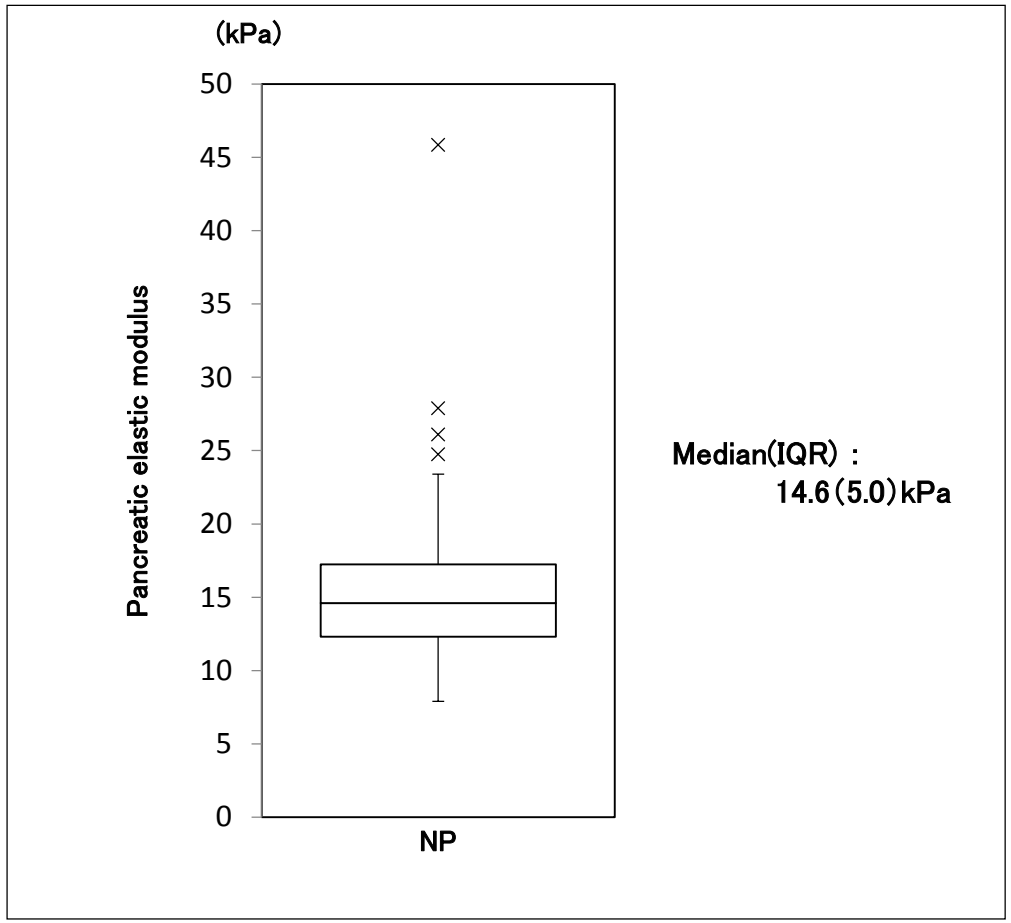
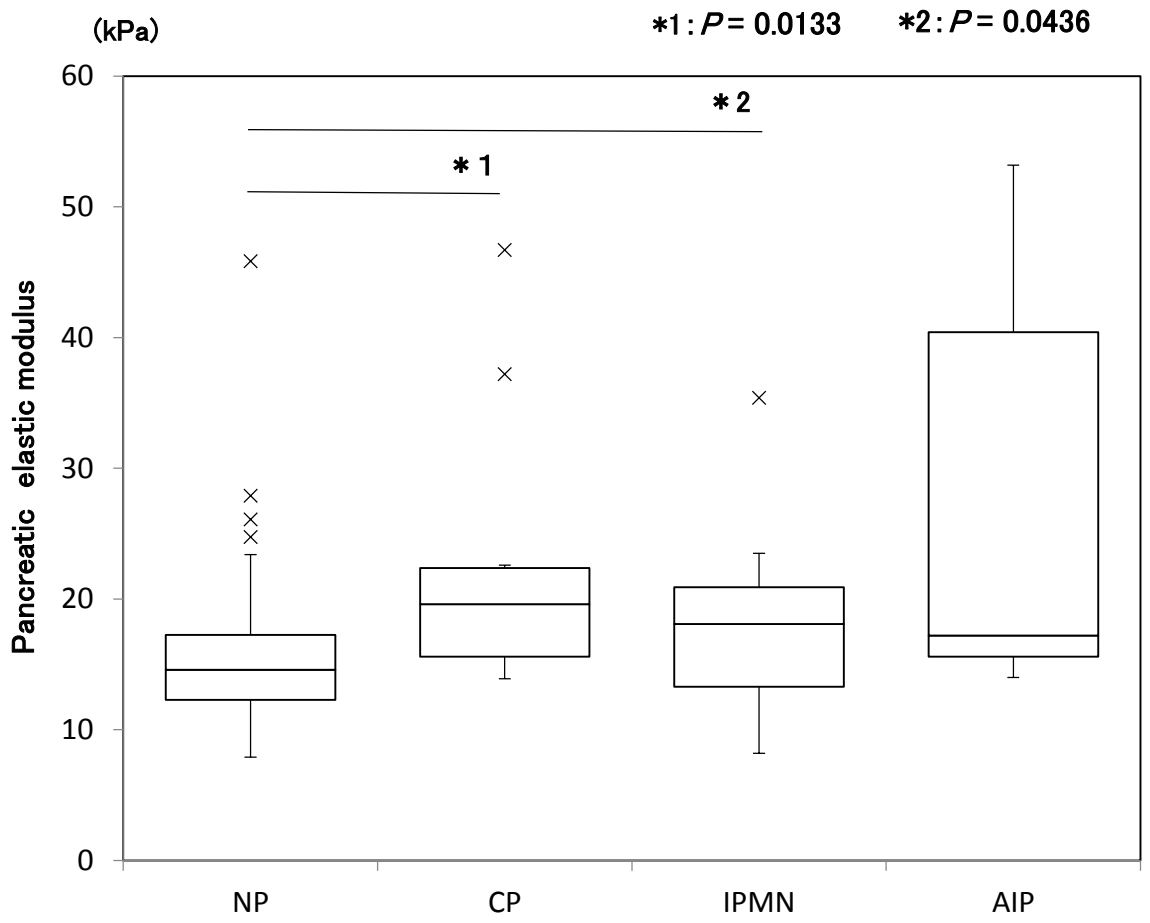

(kPa)
50
45
40
35
30
25
20
15
10
5
0
Pancreatic elastic modulus
NP
Median(IQR) :
14.6 (5.0) kPa

Fig.4


(kPa)
*1 : P = 0.0133
*2 : P = 0.0436
Pancreatic elastic modulus
60
50
40
30
20
10
0
* 2
* 1
NP
CP
IPMN
AIP