
Acoustic Radiation Force Impulse Imaging of the Pancreas for Estimation of Pathologic Fibrosis and Risk of Postoperative Pancreatic Fistula



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- BACKGROUND:** We sought to evaluate whether pancreatic elasticity, measured using acoustic radiation force impulse (ARFI) imaging, can determine the degree of pancreatic fibrosis and risk of pancreatic fistula (PF) in patients undergoing pancreatic resection. Although soft pancreatic texture is a reliable predictor of postoperative PF, noninvasive, quantitative methods of assessing pancreatic hardness have not been established.
- STUDY DESIGN:** Shear wave velocity (SWV) of the pancreas was preoperatively measured by ARFI imaging in 62 patients undergoing pancreatic resection. Correlations of SWV with pathologic degree of fibrosis in the resected pancreas, exocrine function of the remnant pancreas, and the incidence of postoperative PF were determined.
- RESULTS:** The SWV was positively correlated with the degree of pancreatic fibrosis (Spearman's rank correlation coefficient [ρ] = 0.660, $p < 0.001$) and inversely correlated with postoperative amylase concentrations and daily output of pancreatic juice. The incidence of postoperative PF was significantly higher in the 32 patients with soft (SWV < 1.54 m/s) than in the 30 with hard (SWV \geq 1.54 m/s) pancreata (63% vs 17%, $p < 0.001$). Multivariate analysis showed that a soft pancreas (SWV < 1.54 m/s) was an independent predictor of postoperative PF (odds ratio 38.3; 95% CI 5.82 to 445; $p = 0.001$).
- CONCLUSIONS:** Pancreatic elasticity on preoperative ARFI imaging accurately reflected the pathologic degree of fibrosis and exocrine function of the pancreas, enabling surgeons to adopt appropriate surgical procedures according to the risk of postoperative PF in each patient undergoing pancreatic resection. (J Am Coll Surg 2014;219:887–894. © 2014 by the American College of Surgeons)
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Despite recent advances in surgical techniques and perioperative management of pancreatic resection, postoperative pancreatic fistula (PF) remains a major postoperative concern, with an incidence of 10% to 50%.¹⁻⁵ Because postoperative PF can lead to life-threatening events such

as severe infections and massive hemorrhage, it is important to accurately estimate the risk of PF in individual patients undergoing pancreatic resection. Several clinical factors were found to be significant predictors of postoperative PF, including soft pancreatic texture,^{2,6-11} small main pancreatic duct,¹¹⁻¹⁵ tumor pathology other than adenocarcinoma,^{15,16} and larger amounts of intraoperative blood loss.^{6,15,17} Despite its subjectivity, hardness of the pancreas by palpation during surgery is regarded as a simple and reliable indicator for the development of postoperative PF. Quantitative methods are needed to assess the hardness of pancreatic tissue and to determine whether hardness correlates with the degree of pathologic fibrosis.

Several ultrasound elastographic techniques were recently developed for noninvasive evaluation of tissue elasticity.^{18,19} One method, acoustic radiation force impulse (ARFI) imaging, measures the velocity of shear waves generated by tissue after irradiation with

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Abbreviations and Acronyms

ARFI	= acoustic radiation force impulse
DP	= distal pancreatectomy
MPD	= main pancreatic duct
OR	= odds ratio
PD	= pancreatoduodenectomy
PF	= pancreatic fistula
POD	= postoperative day
ROC	= receiver operating characteristic
ROI	= region of interest
SWV	= shear wave velocity

short-duration acoustic pulses and enables evaluation of tissue elasticity in a small (<1.0 cm) region of interest (ROI) on conventional B-mode ultrasonographic images.^{20,21} Using this technique, shear wave velocity (SWV) correlates with tissue hardness. In clinical settings, ARFI imaging has been used mainly to estimate the degree of hepatic fibrosis without biopsy in patients with chronic liver disease,^{19,22-24} and has been used for the differential diagnosis of nodular lesions in the liver,²⁵ breast,²⁶ thyroid,²⁷ and pancreas.²⁸ To our knowledge, however, ARFI imaging has not been used to estimate pancreatic hardness or whether the latter predicts a risk of PF after pancreatic surgery, except in the recent preliminary study by Lee and colleagues.²⁹ The aim of this study was to evaluate whether the SWV of the pancreas, as measured by preoperative ARFI imaging, correlates with the pathologic degree of pancreatic fibrosis and pancreatic exocrine function in patients undergoing pancreatic resection. The ability of “soft” vs “hard” pancreata, based on preoperative SWV, to predict postoperative PF was also assessed.

METHODS

This study was conducted with the approval of the Institutional Ethics Review Board of our institution. All patients provided written informed consent.

Patients

The study cohort consisted of 68 patients who underwent pancreatic resection at the University of Tokyo Hospital between February 2012 and February 2013. Preoperative ARFI imaging could not be performed in 6 of these patients because of difficulties obtaining clear and static images of the pancreatic parenchyma. In the remaining 62 patients, the SWV of the pancreas was measured by ARFI imaging before pancreatoduodenectomy (PD, $n = 35$) or distal pancreatectomy (DP, $n = 27$), with these SWVs compared with postoperative pancreatic exocrine function and the incidence of PF.

Pancreatoduodenectomy was performed as previously described.^{30,31} Briefly, the pancreatic parenchyma was divided using the clamp crushing method, with meticulous ligation of small vessels. Two Roux limbs were created and used for digestive reconstruction: one for biliary and pancreatic anastomoses, and the other for gastrojejunostomy. Patients with a narrow main pancreatic duct (MPD) and/or a soft pancreatic texture, as assessed by manual palpation, underwent PD without pancreatojejunostomy, ie, totally external tube pancreatostomy, followed 3 months later by 2-stage pancreatojejunostomy.³⁰ Other patients underwent pancreatojejunostomy with duct-to-mucosa anastomosis and external tube pancreatostomy during PD. Distal pancreatectomy was also performed by dividing the pancreatic parenchyma using the clamp crushing

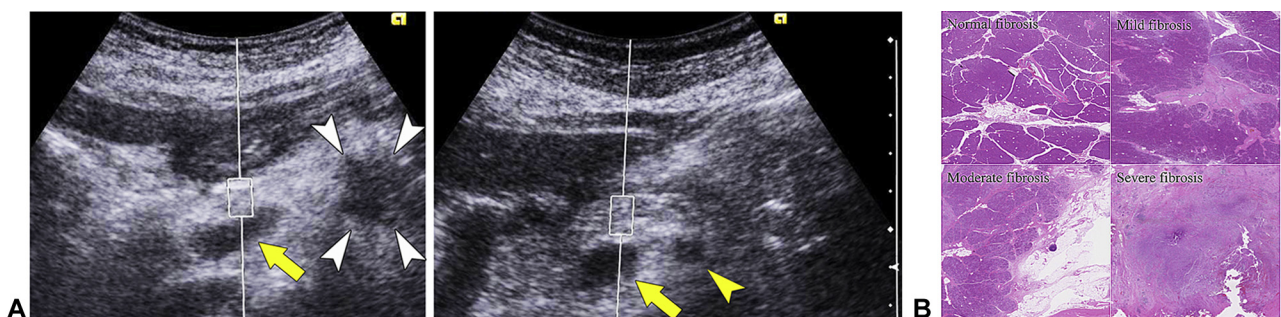


Figure 1. Preoperative acoustic radiation force impulse imaging of the pancreas and pathologic images of the resected specimen. (A) The shear wave velocity (SWV) of the pancreas was measured by setting a region of interest (ROI) in the pancreatic body above the confluence of the splenic and superior mesenteric veins (yellow arrows), away from the pancreatic tumor (arrowheads in left) and the superior mesenteric artery (yellow arrowhead in right). (B) Pathologic pancreatic fibrosis grading according to Klöppel's criteria. The SWVs were 1.01 m/s for normal fibrosis, 1.35 m/s for mild fibrosis, 1.70 m/s for moderate fibrosis, and 1.81 m/s for severe fibrosis.

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