

Impairment of Changes in the Diameter of the Pancreatic Portion of the Superior Mesenteric Vein

An Ultrasonographic Sign of Chronic Pancreatitis or Fibrosis

Hiroshi Kitamura, MD, Kazuhiko Nomura, MD, Masayuki Arai, MD, Masakazu Kobayashi, MD, Hideharu Miyabayashi, MD, Kiyoshi Furuta, MD, Shoichiro Koike, MD, Kan Nakagawa, MD

Objective. A new ultrasonographic technique for detecting parenchymal stiffness of the pancreas is proposed. This technique measures changes in the diameter of the origin of the superior mesenteric vein (SMV) induced by deep inspiration. The origin of the SMV has extensive attachments to the pancreatic parenchyma; therefore, both physiologic enlargement and shrinkage of the venous lumen cannot occur without changes in the shape of the surrounding parenchyma. Therefore, increased parenchymal stiffness due to chronic pancreatitis (CP) may result in impaired changes in the venous diameter. To confirm this hypothesis, patients with CP and those with a normal pancreas were examined in this study. **Methods.** Twelve patients in each group were examined. Images of the origin of the SMV were obtained with a commercial ultrasound system. The smallest diameter of the SMV was measured during normal breathing. The patients were then asked to take a deep breath to increase the portal blood pressure followed immediately by the same measurements as performed during normal breathing, and the ratio of the change was calculated. **Results.** In the normal group, the diameter of the SMV changed by $79.5\% \pm 43.8\%$ (mean \pm SD), whereas a change of $1.4\% \pm 7.3\%$ was observed in the CP group. The difference between the two groups was statistically significant ($P < .0001$). **Conclusions.** The physiologic change in the diameter of the origin of the SMV enhanced by deep inspiration may reflect the stiffness of the pancreatic parenchyma. Therefore, detection of an impaired diameter change may be useful for screening of CP. **Key words:** chronic pancreatitis; pancreas stiffness; superior mesenteric vein.

Abbreviations

CP, chronic pancreatitis; CT, computed tomography; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasonography; SMV, superior mesenteric vein

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Address correspondence to Hiroshi Kitamura, MD, Department of Surgery, National Hospital Organization, Matsumoto Medical Center, Matsumoto Hospital, 1209 Yoshikawamura, Matsumoto, Nagano 390-0021, Japan.

E-mail: kitamurh@cmatumoto.hosp.go.jp

Chronic pancreatitis (CP) is an inflammatory disease characterized by replacement of the glandular elements of the pancreas with fibrous tissue, resulting in increased parenchymal stiffness. Common etiologies of CP are excessive alcohol use, hyperlipidemia, hyperthyroidism, cystic fibrosis, and hereditary and idiopathic causes. Autoimmune CP is a particular type of CP with a very recent pathologic definition caused by an autoimmune mechanism and related diseases, such as primary sclerosing cholangitis and ulcerative colitis. The diagnosis and staging of CP, however, are still challenging. Advances have been made in the standard modalities for imaging the pancreas, such as endoscopic ultrasonography (EUS), multidetector com-

puted tomography (CT), and secretin-stimulated magnetic resonance cholangiopancreatography. Other novel methods of pancreatic imaging have recently been described, including EUS elastography, optical coherence tomography, and diffusion-weighted magnetic resonance imaging.¹⁻³ Although these efforts were dedicated to early diagnosis of CP, their limitations include the lack of establishment of reliable criteria.

In this article, we propose a new ultrasonographic technique for simple detection of pancreatic parenchymal stiffness involving measurement of changes in the diameter of the origin of the superior mesenteric vein (SMV) induced by changes in the portal blood pressure. The portal blood pressure was presumably affected by intra-abdominal and intra-thoracic pressure. It is assumed that, in normal respiration or expiration, the portal blood pressure counts are low. However, the pressure would rise substantially in deep inspiration or the Valsalva maneuver. Because of the nature of the extendable venous vessel wall, the portal vein would change its diameter with the blood pressure.⁴⁻⁶

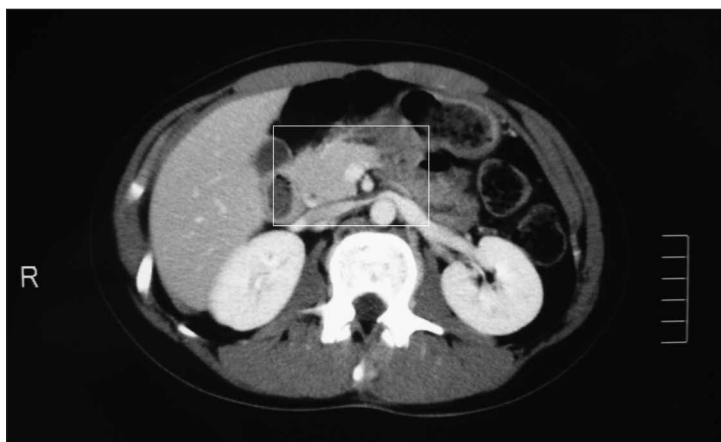
The gross anatomic structure of the pancreas consists of a long, thin body and tail, a thick head, and the characteristic uncinate process, which originates from the pancreatic head and lies posterior to the SMV. The SMV runs anteriorly to the uncinate process and posteriorly to the transitional parenchyma of the pancreatic head and body. Therefore, the complex of the head, body, and uncinate process surrounds the

SMV at a level just distal to the confluence of the splenic vein (pancreatic portion of the SMV). This is remarkably evident in horizontal and sagittal sections on ultrasonography and CT (Figure 1). One hundred CT examinations conducted in our institution have revealed that pancreatic parenchyma encircled 90° to 180° of the circumference of the pancreatic portion of the SMV in 5 cases, 181° to 270° in 45, and 271° to 360° in 55. These patients were randomly selected from all who came to our hospital. In addition, several small drainage veins from the pancreas connect the parenchyma to the SMV so that neither physiologic enlargement nor shrinkage of the venous lumen can occur without a change in the shape of the surrounding pancreatic parenchyma. Therefore, increased parenchymal stiffness due to CP or fibrosis may result in impairment of such changes in the venous diameter. To confirm this hypothesis, we examined patients with CP and control patients with a normal pancreas.

Materials and Methods

A commercial ultrasound system (LOGIQ P5; GE Healthcare, Milwaukee, WI) was used in conjunction with a convex probe at a center frequency of 4.0 MHz. With the patient in a supine position, either cross-sectional or longitudinal images of the pancreatic portion of the SMV, in which the extent of attachment of pancreatic parenchyma to the SMV was maximal, were obtained through the window in the epigastrium. This level was usually just before the confluence of the vessels into the portal vein. The minimal diameter of the anteroposterior axis of the SMV was measured during normal breathing. The patients were then asked to take a deep breath to produce changes in either the intra-thoracic or intra-abdominal pressure to increase the portal blood pressure. In addition, the maximal diameter of the same portion as during normal breathing was measured immediately. The means of the data from the cross-sectional and longitudinal images were considered corresponding data of the samples. The data were expressed as a percent ratio of 2 respiratory phases (diameter in deep inspiration/minimal diameter in normal breathing × 100 - 100).

Figure 1. Pancreatic portion of the SMV showing extensive attachment to the pancreatic parenchyma.



Ultrasonographic examinations were performed as routine checkups for CP and as abdominal examinations for various reasons in patients without aforementioned symptoms and findings suggestive of CP with written informed consent. The approval of the local Institutional Review Board was obtained.

Twelve patients with clinically and radiographically diagnosed CP and the same number of patients with a normal pancreas were matched for age and sex. The mean age \pm SD and male to female sex ratio were 56 ± 8 years (range, 47–77 years) and 8:4, respectively. The etiology of CP was alcoholic in 10 cases and idiopathic in 2. Patients with liver cirrhosis were excluded because existing portal hypertension may have affected the results.^{5,7}

The clinical stage of CP was determined according to diagnostic criteria of the Japan Pancreas Society (Table 1).⁸ In the pancreatitis group, 10 of 12 patients were classified as having probable CP, whereas the remaining 2 were classified as having definite CP. The examiner (H.K.) was blinded to the details of the patients' diseases except for the ultrasonographic findings.

All results are expressed as mean \pm SD. Statistical analysis of the change in diameter was performed by an unpaired *t* test. In addition, an *F* test was used to compare variance. Differences at $P < .05$ were considered statistically significant.

The conventional ultrasonographic criteria for CP, such as microcalcifications, an irregular contour, and main duct dilatation, were also recorded.

Table 1. Diagnostic Criteria for the CP Group According to the Japan Pancreas Society

Criterion	Patients (n)
Definite CP on ultrasonography ^a	2
Probable CP	
CT ^b	2
ERCP ^c	8

^aPancreatic stones evidenced by intrapancreatic hyper-reflective echoes with acoustic shadows behind.

^bPancreatic deformity with an irregular contour.

^cIrregular dilatation of the main pancreatic duct alone and intraductal filling defects suggestive of noncalcified pancreatic stones or protein plugs.

Results

There were no technical difficulties in visualizing the region of interest in any of these cases (Table 2). The patients classified as having probable CP showed no intrapancreatic coarse hyper-reflectivity, irregular dilatation of the pancreatic duct, or pancreatic deformity with an irregular contour. In contrast, images showing microcalcifications and an irregular contour were obtained in both cases classified as definite CP. However, the main pancreatic duct was not irregularly dilated, and no pseudocysts were detected in either of these cases.

In the normal group, the minimal diameter of the anteroposterior axis of the pancreatic portion of the SMV was 6.4 ± 1.9 mm, and this was changed by $79.5\% \pm 43.8\%$ during deep inspiration (Figure 2). In the CP group, the minimal diameter was 8.0 ± 2.0 mm, and this was changed by $1.4\% \pm 7.3\%$ during deep inspiration (Figure 3). The difference between the two groups was statistically significant ($P < .0001$).

Discussion

The overall sensitivity of ultrasonography in diagnosis of CP is variable, with an average range in most series of 60% to 70%. Alterations in the size, shape, and surface irregularities of the pancreas may be seen in less than half of all patients affected by CP.^{9–11} This percentage drops markedly in the early stages of the disease. The echogenicity of the pancreas is usually increased in CP because of adipose infiltration and fibrosis.^{12–15} Hyperechogenicity is not a specific finding, however, because it is also seen in elderly and obese patients. Alteration of the parenchymal echo structure, on the other hand, is a more specific sign of CP. The pancreatic echo texture is inhomogeneous and coarse because of the coex-

Table 2. Changes in the Diameter of the Pancreatic Portion of the SMV in the Normal and CP Groups

Group	Minimal Diameter, mm	Maximal Diameter, mm	Caliber Change, %
Normal (n = 12)	6.4 ± 1.9	11.1 ± 2.7	79.5 ± 43.8
CP (n = 12)	8.0 ± 2.0	8.1 ± 2.0	1.4 ± 7.3

Values are mean \pm SD.

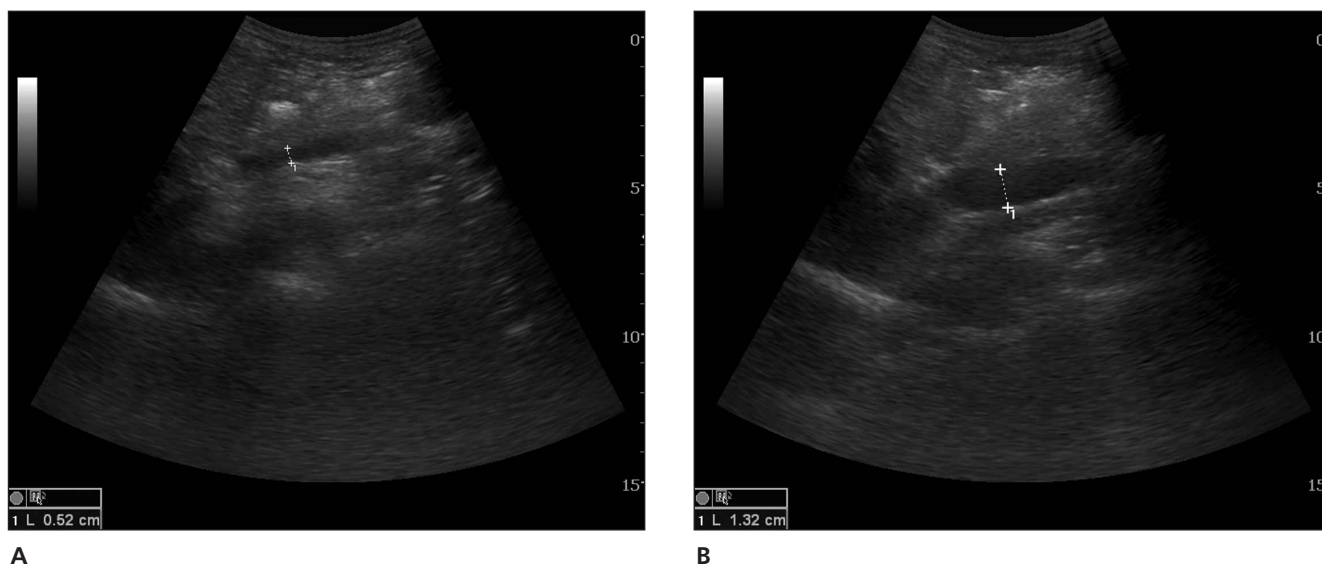
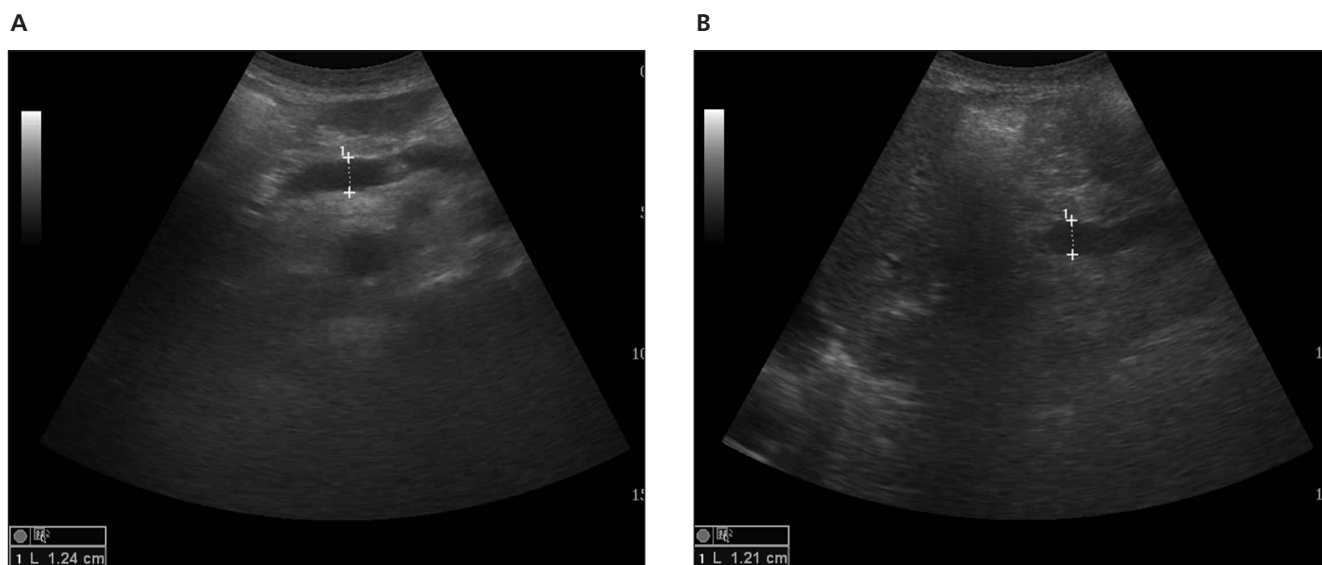


Figure 2. Images from a patient with a normal pancreas. A longitudinal image of the pancreatic portion of the SMV in the expiration phase during normal breathing (A) shows its minimal diameter. The diameter of the SMV lumen is markedly enlarged on deep inspiration (B). The number 1 that labels the cursor is automatically numbered for numeric order of measurements by a preinstalled application.

istence of hyperechoic and hypoechoic foci and foci of fibrosis and inflammation, respectively.^{12,15} These findings have been described in 50% to 70% of cases.^{10,11} Apparent normality of the glandular echo structure in CP has been reported in up to 40% of cases, and this is expected, especially in the early stages of the disease.^{10,16–18} According to the Japan Pancreas Society,⁸ the

most important diagnostic criterion for CP is the presence of pancreatic calcifications, the identification of which is pathognomonic. Pancreatic calcifications are calcium carbonate deposits, usually on a protein matrix or in areas of interstitial necrosis. On ultrasonography, these appear as hyperechoic foci with posterior shading; however, they may be hardly detectable if the calcifi-

Figure 3. Images from a patient with CP. There is no change in the diameter of the SMV lumen between the expiratory (A) and deep inspiratory (B) phases. The number 1 that labels the cursor is automatically numbered for numeric order of measurements by a preinstalled application.



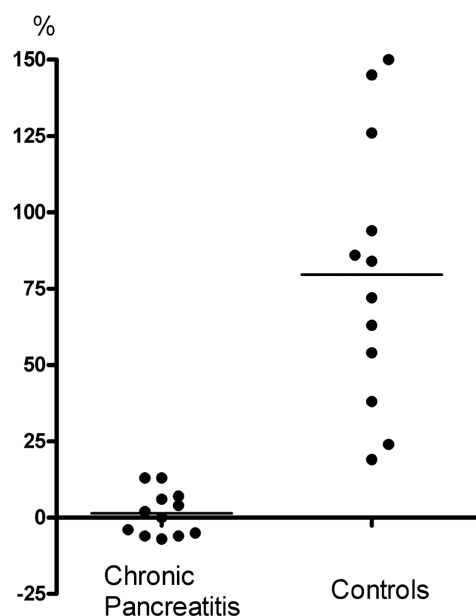


Figure 4. Caliber variation in the pancreatic portion of the SMV measured as percent change from the expiratory phase during normal breathing to deep inspiration.

cations are small because of the presence of artifacts from ultrasound beam refraction. Color Doppler ultrasonography can facilitate the identification of small pancreatic calcifications, which are barely visible on conventional gray scale imaging because of the presence of twinkling artifacts. Color Doppler ultrasonography also allows the detection of vascular complications of pancreatitis. In particular, pseudoaneurysms can be identified. These lesions may be misinterpreted as pseudocysts on gray scale ultrasonography.¹⁹ Caliber abnormalities in CP are essentially represented by main pancreatic duct dilatation. Endoscopic ultrasonography has a strong correlation with moderate to severe pancreatitis on endoscopic retrograde cholangiopancreatography (ERCP). However, there is a poor correlation between ERCP and EUS in mild disease. This is a group of patients suspected of having CP with minimal features of CP on EUS and normal ERCP findings. These patients are presumed to have early CP, leading to the hypothesis that EUS is more sensitive than ERCP for diagnosis of CP. Endoscopic ultrasonographic changes in early CP may be seen in up to 58% of asymptomatic alcoholic patients with no history of pancreatic disease.²⁰ Endoscopic ultra-

sonographic elastography may be well suited for diagnosis of early CP by assessing the amount of fibrous tissue present, although further work in this area is needed to establish reliable criteria.^{2,21} In this study, 10 of 12 patients with CP were classified as having a normal pancreas by conventional ultrasonographic criteria alone. Therefore, detection of an impaired change in the diameter of the pancreatic portion of the SMV may be useful for diagnosis of the early stage of CP.

In previous prospective ultrasonographic studies, various factors that may influence the portal vasculature were evaluated in unaffected patients; the correlations of the portal diameter with physical factors such as age, sex, and body texture were poor, whereas the caliber variation was significantly related to respiration, posture, and meals.^{22–24} Those physiologic changes in the SMV were hampered by portal hypertension, and that has therefore been used as a diagnostic tool for this disease.^{25,26}

Signs in the pancreatic portion of the SMV are quite simple to determine, making this approach feasible as a means of first-line diagnosis. In this preliminary study, however, we noted several limitations. Although with the sample size and a cutoff increment value set between 14% and 18%, the sensitivity and specificity were both 100% (Figure 4), these values have yet to be elucidated in a large series of patients with early CP. Future studies should also include comparisons of data obtained by the present technique with the actual physical stiffness of the pancreas and other standard modalities, as well as a discussion of false-positive and -negative results.

In conclusion, the physiologic changes in the diameter of the pancreatic portion of the SMV enhanced by deep inspiration may reflect stiffness of the pancreatic parenchyma. In addition, detection of an impaired change in the diameter may be especially useful for screening of the early stage of CP.

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