Nonoperative Measurement of Pancreatic and Common Bile Duct Pressures with a Microtransducer Catheter and Effects of Duodenoscopic Sphincterotomy

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Duodenoscopic manometry of the pancreatic duct (PD) and common bile duct (CBD) using a microtransducer catheter has distinct advantages over infusion manometry, giving absolute values of in situ *intraluminal pressure. Microtransducer manometry was performed without medication in 49 patients with gallbladder stones (10), common bile duct stones (24), hepatic duct stones (6) and common bile duct dilatation (9), and was successful in 42 (86%) for PD and 36 (73%) for CBD. Ductal pressures showed respiration-synchronized biphasic variations superimposed by the arterial pulsation effect. Considerable postural change of the pressure values suggested that the recording posture should be predetermined. The PD-to-duodenum pressure gradient was higher than the CBD-to-duodenum gradient in most cases. Both were lower than those obtained previously by infusion methods. No significant differences were found in pressure profiles of the four disease groups. Endoscopic sphincterotomy significantly reduced not only CBD pressure but also PD pressure.*

The recent advent of duodenofiberscopy, cannulation, and simultaneous manometry allowed nonoperative measurement of pressures in the pancreatic and common bile ducts. In most previous studies, a fluid-filled or slow infusion catheter coupled with an external pressure transducer has been employed (1–10). However, since the pressure values obtained by infusion catheter manometry depend on the catheter size and compliance, and more decisively on the infusion rate (1), these variable factors do not permit precise interstudy comparison. On the other hand, microtransducer manometry has distinct advantages over infusion catheter manometry, giving absolute values of *in situ* intraluminal pressure. Von Vondrasek et al were the first to describe the use of a microtransducer catheter in duodenoscopic manometry. They introduced the catheter tip 5–7 mm into the papilla and recorded pressures in three patients, but they could not determine whether the common bile duct or the pancreatic duct was entered (11). Mitani et al, using their self-made microtransducer, measured pressures in the pancreatic and common bile ducts. The majority of their patients, however, had undergone transduodenal sphincteroplasty previously (12). In the present communication, a study was undertaken to measure common bile duct and pancreatic duct pressures in 40 patients with cholelithiasis and 9 with common bile duct dilatation, using a thinner microtransducer catheter than that employed before to facilitate

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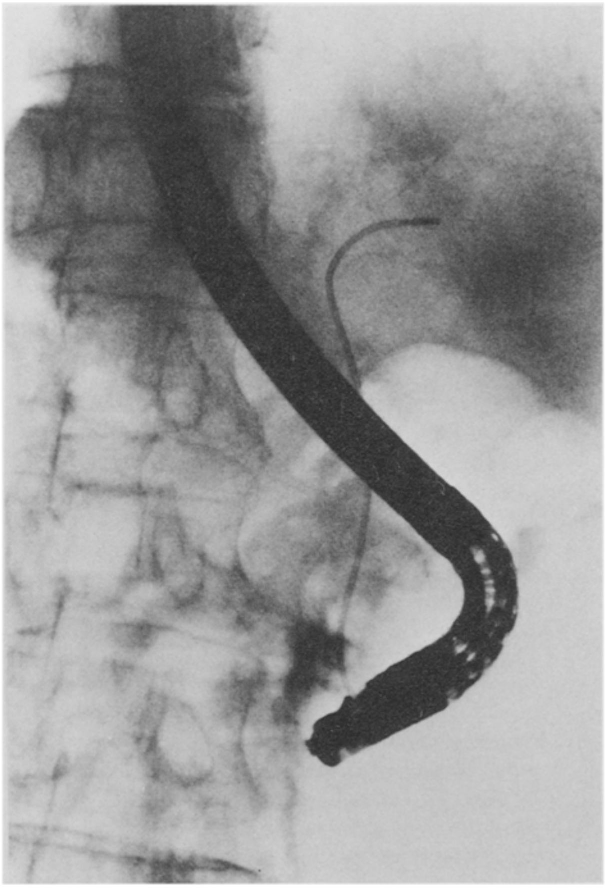

Fig 1. Roentgenogram from the prone position showing the microtransducer catheter advanced up to the liver hilum to confirm the position of the catheter in the common bile duct.

cannulation and minimize the possible effect of introduction of the catheter on the ductal pressure; also the effects of endoscopic sphincterotomy on the ductal pressures were evaluated in 19 patients.

MATERIALS AND METHODS

Patient Population. Forty-nine patients subjected to endoscopic retrograde cholangiopancreatography (ERCP) form the basis of the present study. Ten patients with a mean age of 63 years (range, 44–77) had stones only in the gallbladder, and 24, with a mean age of 58 years (range, 35–79), had stones in the common bile duct with (6) or without (18) gallbladder stones. Twelve patients with common bile duct stones had cholecystectomy previously. Six patients with a mean age of 45 years (range, 29–74) had stones in the hepatic ducts with (4) or without (2) common bile duct stones. Three had undergone cholecystectomy previously. In the remaining 9 cases with a mean age of 61 years (range, 36–80), no stone but merely dilatation of the common bile duct was observed. The mean diameter of the common bile duct, corrected by magnification factor using the width of the endoscope used as a reference, was 17.5 mm (range, 12.2–21.2). All patients gave verbal permission for the studies.

Manometric Method. No sedative or anticholinergic agents were used to avoid their possible effects on the pressure values. After pharyngeal anesthesia with lidocaine spray, the papilla was identified in the standard manner using the Olympus JF-B_3 or JF-1T duodenoscope with the patient in the left lateral position. A 2-m-long microtip catheter transducer (model PC-340, Miller Instruments, Inc., Texas) connected to a control unit (model TCB-100, Miller) and a pen recorder (model VP-6621 A, National Electric Co., Tokyo, Japan) was introduced into the duodenum through the catheter channel of the scope. The catheter size was 4 French and was flexible to facilitate insertion into the papilla. Just before introduction, the microtransducer was calibrated at 38° C with atmospheric pressure as zero reference.

After the pressure in the duodenal lumen was recorded, the catheter was introduced into the papilla as gently as possible and ductal pressure was measured. Stable pressure tracings could be recorded at any point within 5 cm of the papilla. To ascertain that the sensor portion was not in the "common channel" but in the ductal lumen and to avoid possible influences by twisting or bending the tip in the duct, the pressures were measured with the catheter advanced 3 cm from the papilla. The position of the catheter was confirmed by advancing it deep into the duct and changing the posture of the patient to the prone position. Since the catheter was radiopaque, whether it went up toward the liver hilum in the common bile duct (Figure 1) or whether it ran leftwards in the pancreatic duct (Figure 2) could be determined under image intensification. The posture was then changed to the left lateral position again. The catheter was withdrawn and the sensor portion was placed about 3 cm from the papilla during the pressure recording. After the ductal pressure was measured, the catheter was slowly withdrawn to the duodenum, and the pressure in the duodenal lumen was recorded again. Following the pressure measurement of one duct, the same procedure was repeated on the other duct. Air insufflation was kept at a minimum during the whole procedure. Manometry could usually be accomplished within 15 min and was followed by other procedures such as cholangiopancreatography or sphincterotomy. An inherent "drift" curve of the microtransducer employed, determined at 38° C and at atmospheric pressure, showed that the calibrated baseline shifted by 1.5 mm Hg in 10 min and 2.0 mm Hg in 20 min, reaching the maximum of 2.5 mm Hg in 40 min. Absolute values of ductal and duodenal pressures were determined by subtracting the time-corresponding baseline pressure from the midrespiratory values of each tracing obtained. Strict consideration of the baseline drift, however, was not necessary when a pressure gradient between the duct and duodenum was measured, because it was read from tracings recorded just before and after a withdrawal of the catheter from the duct to duodenum, and the drift during such short time interval was negligible.

Endoscopic Sphincterotomy. Endoscopic sphincterotomy was performed on 19 patients in this series, 8 males

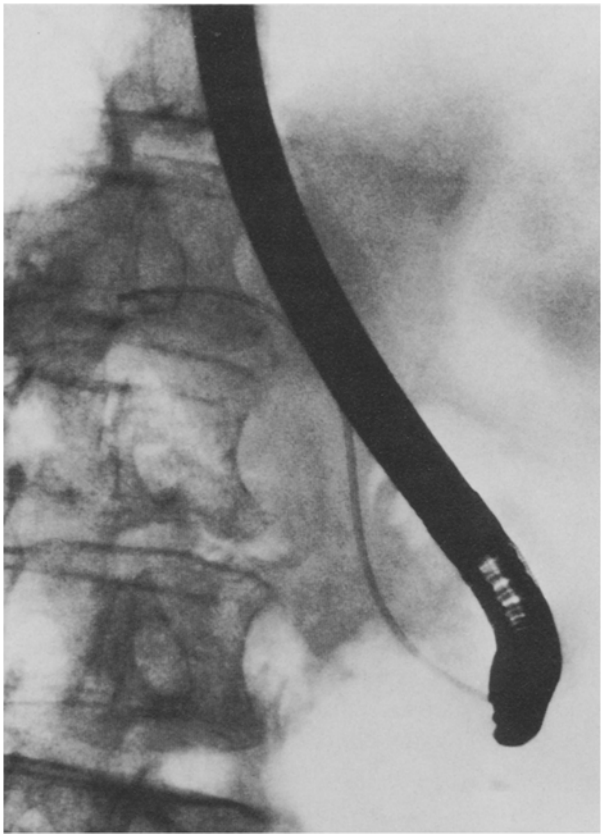

Fig 2. Roentgenogram from the prone position demonstrating the microtransducer catheter advanced leftwards in the pancreatic duct.

and 11 females. Twelve patients with a mean age of 61 years (range, 48–74) had common bile duct stones retained after previous biliary operation. One of them also had stones in the hepatic ducts. Five patients with a mean age of 67 years (range, 56–79) had common bile duct stones with acalculous gallbladder in place. One had undergone common duct exploration before. The remaining two cases, 70- and 36-year-old females, had sphincterotomy performed to relieve stenosis of the sphincter of Oddi causing jaundice or relapsing pancreatitis. The technique used was similar to that described by others (13–15) except that we employed a long-tip sphincterotome (16, 17). Manometry was carried out just before and 2–4 weeks after the procedure with the exception of two cases, in which the second manometry was done after 2 months.

Statistical Analysis. The values are given as mean ± standard error of the mean (SEM). Student's t test for paired or unpaired data was used for statistical evaluation. Differences with P values of less than 0.05 were considered significant.

RESULTS

Success Rates of Manometry. In 49 cases attempted, pressure measurement was successful in both ducts in 29 cases (59%), and in either duct in all. Pancreatic duct pressure was recorded in 42 cases (86%), and common bile duct pressure in 36 (73%). Insertion into the common bile duct seemed to be slightly more difficult.

Characteristics of Pressure Tracings. Actual pressure tracings of the pancreatic and common bile ducts are shown in Figure 3 along with a pneumogram and a pulse record obtained simultaneously. The ductal pressures showed fundamentally biphasic variations, rising on inspiration and falling on expiration. The direct influence of respiration on the pressures is well documented by the tracings during deep respiration and breath-holding. During apnea, the only change noticed on the tracings is the effect of arterial pulsation, which is normally submerged in the respiratory variations. No peristaltic activity could be demonstrated in either duct. Duodenal pressure was delineated as irregular waves partly synchronized to respiration but complicated by the peristaltic movement. As the catheter was advanced deep into the pancreatic duct, the pressure became unstable and slightly elevated. This was probably due to a twisting or bending of the sensor portion within the small and tortuous duct. Deep advancement of the catheter into the bile duct produced a very slight decrease of the pressure in most cases, which might probably be attributable to some anatomical factor. These changes were not observed within 5 cm from the papilla and, therefore, ductal pressure was recorded with the sensor tip introduced only 3 cm into the duct. Stable pressure tracings could be obtained as long as the sensor tip was placed in this position. Placement of the catheter in the pancreatic or common bile duct for a longer period was attempted in five cases to observe the possible effect of obstruction of the papilla by the catheter. However, practically no or negligible increase of pressure during the continued measurement was observed for at least 10 min. The pressure measurement of either duct was usually accomplished within 1–2 min.

Posture Changes and Pressure Values. The posture of the patient had to be changed from the left lateral to prone position in the present procedure in order to identify the position of the catheter introduced deep into the duct under image intensification. Therefore, we could note the postural changes of ductal and duodenal pressures in the early phase of our study. To evaluate the effect of the posture on pressure values, manometry was carried out in both positions in 12 patients, in which pressures

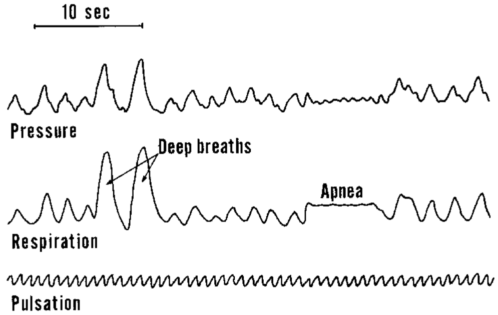

Fig 3. A representative tracing of common bile duct pressure at the paper speed of 20 cm/min. The respiration curve simultaneouly recorded with a balloon attached to the patient's chest shows deep breathing and breath-holding (apnea) interposed among normal respiration. Pulsation was also simultaneously recorded with the microtransducer catheter placed on the radial artery at the wrist. The pressure tracing demonstrates two types of ductal pressure change. One is large biphasic variations synchronized to and directly influenced by respiration, and another is small waves transmitted from arterial pulsation, which are usually submerged in the large variations but become obvious during apnea.

were successfully measured in both ducts. A change of the posture from the left lateral to prone position produced increases of pressure values in all but one patient for the pancreatic duct and one for the common bile duct. These changes were statistically significant (Figure 4). As demonstrated by continuous monitoring with the catheter in place during the repeated posture changes, the postural change in ductal pressure was highly reproducible

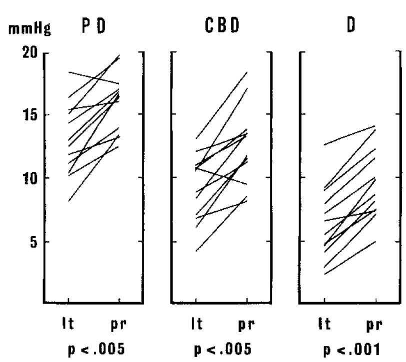

Fig 4. Postural change of pressures in the pancreatic duct (PD), common bile duct (CBD), and duodenum (D) determined in 12 patients. All but one PD or CBD pressures and all D pressures are higher in the prone position (pr) than in the left lateral position (lt). The changes are statistically significant ($P < 0.005$).

(Figure 5). The possible stimulation of the sphincter by the catheter had virtually no noticeable effect on pressure values.

Pressure Values. Duct-to-duodenum pressure gradients are shown in Figure 6. All are the values measured on the left lateral position. No statistically significant differences were observed between groups with gallbladder stones, common bile duct stones, hepatic duct stones, and common bile duct dilatation. Pressures in both ducts were measured in the same patient in 29 cases. The pressure gradient between the pancreatic duct and duodenum was higher than that between the common bile duct and duodenum in 25 cases, and the reverse was true in only 4 cases, 2 of which had common bile duct stones and the others had common bile duct dilatation.

Effects of Endoscopic Sphincterotomy. Common bile duct pressure was evaluated both before and after endoscopic sphincterotomy in 14 patients, and pancreatic duct pressure in 16. Individual values of the duct-to-duodenum pressure gradient before and after the procedure are shown in Figure 7. The mean common bile duct-to-duodenum pressure gradient before sphincterotomy was 5.8 ± 1.1 (SEM) mm Hg. After the procedure, it was reduced to 1.5 ± 0.3 mm Hg. The difference was statistically significant ($P < 0.001$). The majority of the post-sphincterotomy patients had a common bile duct pressure gradient of less than 3 mm Hg. The mean pancreatic duct-to-duodenum pressure gradient before the procedure was 8.6 ± 0.9 mm Hg. A significant decrease of the pressure to 5.3 ± 0.7 mm Hg was also found after sphincterotomy ($P < 0.001$). The degree of the pressure reduction was variable from person to person.

DISCUSSION

The present work showed that a #4 French microtransducer catheter, 1.33 mm in outside diameter, could safely be introduced into the pancreatic and common bile ducts, and stable pressure tracings could be obtained. In six previous cases we used an ordinary side-view duodenoscope (JF-B3), with which cannulation of the catheter was feasible but somewhat difficult. Later, a new model of duodenoscope equipped with a large catheter channel and a backward-tilted objective lens (JF-1T) was utilized. Manipulation of the catheter and its insertion into the papilla were much easier with this instrument. Thus fragility of the sensor tip, former-

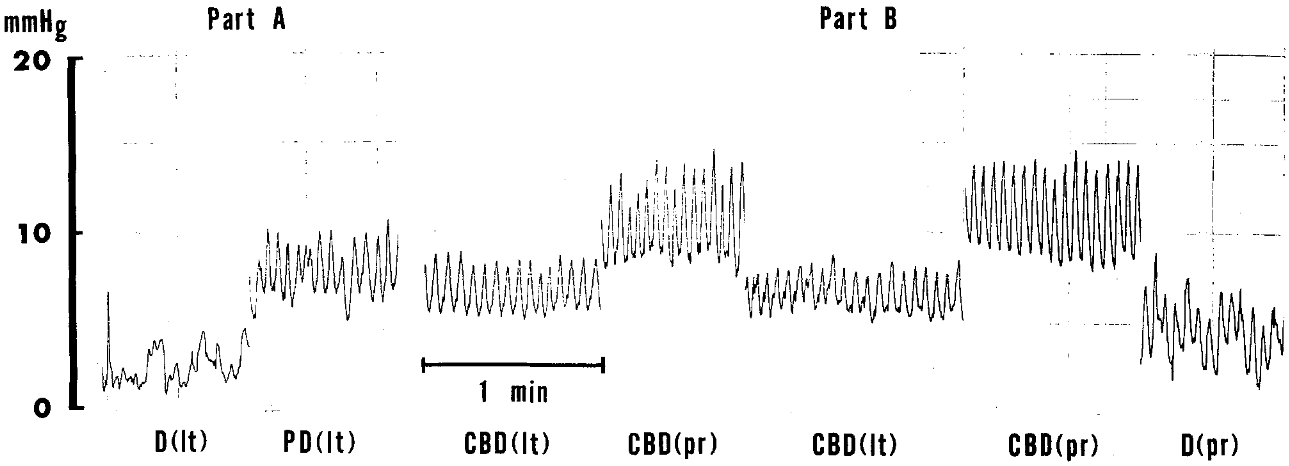

Fig 5. Actual pressure tracings in a patient with common bile duct stones retained after cholecystectomy and common bile duct exploration. Pressures in the pancreatic duct (PD), part A, common bile duct (CBD), part B, and duodenum (D) are demonstrated. Both ductal and duodenal pressures are higher in the prone position (pr) than in the left lateral position (lt). The postural change of the pressure is highly reproducible during repeated posture changes with the microtransducer catheter in place (part B).

ly a major drawback of microtransducer manometry (2) is no longer a serious problem. In this manometric system, the position of the catheter could be confirmed under image intensification by advancing it deep into the duct. This process itself did not affect the pressure values. Since the microtransducer used is commercially available, the manometric study can be performed in a uniform manner using standard equipment, making interstudy comparison more reliable.

Pressure tracings obtained from the common bile duct and pancreatic duct showed rhythmic changes synchronized to respiration and superimposed by arterial pulsation. Mitani et al, who studied one case with gastritis, one with ampullary carcinoma, and seven after transduodenal sphincteroplasty with their self-made microtransducer, also found rhythmic variations in the common bile duct pressure but not in the pancreatic duct pressure (12). Their failure to prove the changes in the pancreatic duct may be ascribed to the difference in sensitivity of the microtransducer employed. Although Hauge and Mark, using a triple-lumen catheter inserted through the cystic duct, demonstrated small phasic changes unrelated to respiration in the fasting pressure of the canine common bile duct which, they believed, were transmitted from the sphincteric zone (18), no peristaltic or phasic activity but only the effect of arterial pulsation was shown in both ducts in the present study. Since they did not investigate the possible association between the phasic changes and pulsation, the discordance of the findings cannot be explained well. While cannulating or withdrawing the catheter through the papilla, a sharp spike was often recorded. However, we could not obtain reproducible results on the pressure within the sphincter, which has been demonstrated by others using a slow-infusion catheter (1, 4, 6–10).

The existence of a pressure gradient between the pancreatic or common bile duct and duodenum was demonstrated by the microtransducer method. This finding is consistent with the previous studies using a slow-infusion catheter and an external pressure transducer (1–10). Csendes et al stated that the mean pancreatic duct pressure was two to three times higher than the mean common bile duct pressure (9). Both pressure gradients were determined in the same individual in 29 patients in the present study, thus making the comparison between common bile duct and pancreatic duct pressures more reliable using duodenal pressure as a basis of comparison. The pressure gradient between the pancreatic duct and duodenum was higher than that between the common bile duct and duodenum in the majority of cases, but some cases did exist in which the reverse was true.

For purposes of comparison, the methods and results of the prior and present manometric studies are listed in Table 1. Pressure values of 2.2–10.3 mm Hg, described in the first microtransducer study by von Vondrasek et al, may likely be ductal

TABLE 1. COMPARISON OF METHODS AND RESULTS OF DUODENOSCOPIC MANOMETRY*

Authors	Methods	Recording posture	Premedication	Patients	Mean values of pressure gradient† PD/D	CBD/D
Rösch et al (2)	Infusion, open-tip, 0.5 ml/min	ND	Used but not defined	Controls	10.9(15)‡	8.8(21)
				Common duct stones		10.0(40)
				Stenosis of papilla		17.8(12)
Weiss et al (3)	Fluid-filled, open-tip	Left lateral	Atropine, triflupromazin, meperidine	Miscellaneous including 42 with normal ERCP	12.5(50)	4.9(20)
Geenen et al (5)	Infusion, side-hole, 0.25 ml/min	ND	Diazepam	Controls		9.3(7)
				Subjects for EST		16.8(5)
Hogan et al (6)	Infusion, side-hole, 0.25 ml/min	ND	ND	Patients with normal ERCP		12.5(12)
Bar-Meir et al (7)	Infusion, side-hole, 0.25 ml/min	ND	ND	Controls	15(12)	12(10)
				Stenosis of papilla		19(13)
				Recurrent pancreatitis	12(13)	
Funch-Jensen et al (8)	Infusion, side-hole, 1 ml/min	ND	Atropine, pethidine, diazepam	Subjects for EST		10.4(15)
Csendes et al (9)	Infusion, side-hole, 1 ml/min	ND	Atropine, pethidine, diazepam, glucagon	Controls	32.5(5)	11.4(8)
				Common duct stones		
				Gallbladder stones, postcholecystectomy		
				Hepatic duct cancer	25.3(5)	8.9(17)
				Three patients (not defined	28.4(9)	12.8(17)
					35.5(3)	11.7(3)
von Vondrasek et al (11)	#5 French microtransducer§	ND	Atropine, triflupromazin, meperidine		Pressures of 2.2–10.3 were recorded without duct differentiation	
Mitani et al (12)	Self-made micromanometer	ND	ND	Gastritis		6.6(1)
				Cancer of papilla		14.0(1)
				Postsphincteroplasty	5.9(1)	5.0(7)
Present studies	#4 French microtransducer***	Left lateral	Not used	Gallbladder stones	7.9(8)	3.6(6)
				Common duct stones		
				Hepatic duct stones		
				Common duct dilatation	8.3(22)	4.6(18)
					9.9(4)	2.8(4)
					6.8(8)	4.5(8)

*PD/D = pressure gradient between the pancreatic duct and duodenum. CBD/D = pressure gradient between the common bile duct and duodenum. ND = not described in the article. EST = endoscopic sphincterotomy. ERCP = endoscopic retrograde cholangiopancreatogram.
†All values expressed as mm Hg.
‡Numbers in parentheses represent number of patients studied.
§Manufactured by Miller Instruments, Inc., Texas, U.S.A.

pressures but not sphincter pressures, although they could not determine which duct was entered (11). Common bile duct-to-duodenum pressure gradient was measured in eight previous studies and pancreatic duct-to-duodenum pressure gradient in five. Although the values could not be compared directly because of the differences in the manometric methods employed and in the disease groups studied, the values obtained by microtransducer manometry are generally lower than those measured by infusion methods. While the pressure values by infusion manometry are the composite of many variables, including the rate of infusion, length and diameter of the catheter, and viscosity of the infusion fluid as well as intraductal pressures, microtransducer manometry can record absolute *in*

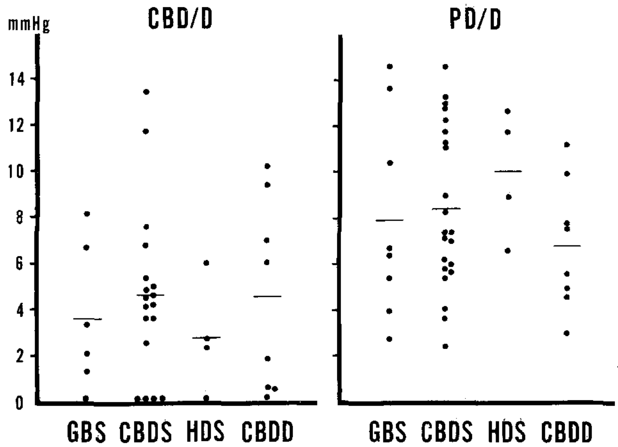

Fig 6. Individual values of pressure gradients between the common bile duct and duodenum (CBD/D), and between the pancreatic duct and duodenum (PD/D) in patients with gallbladder stones (GBS), common bile duct stones (CBDS), hepatic duct stones (HDS), and common bile duct dilatation (CBDD). Horizontal bars represent mean values. No significant differences are found among the mean values of the four disease groups.

situ intraductal pressures (19). Moreover, all medications that might affect pressure values were avoided in this study. We believe, therefore, the pressure data presented in the present communication seem to be more representative of actual biliary and pancreatic dynamics.

An attempt to divide the patients into four groups such as gallbladder stones, common bile duct stones, hepatic duct stones, and common bile duct dilatation failed to show any significant differences in the pressure profile. Csendes et al also found no significant differences between pancreatic duct and common bile duct pressures in controls and in patients with gallbladder stones, common bile duct stones, previous cholecystectomy, hepatic duct cancer, and chronic pancreatitis (9). Even the common bile duct dilatation group we studied did not have a significantly higher common bile duct pressure. This finding suggests that common bile duct dilatation does not always indicate the presence of stenosis of the sphincter. In patients with hepatic duct stones, endoscopists often notice that the sphincter is loose at cannulation. Common bile duct pressure in these patients hitherto uninvestigated was evaluated in the present work for the first time. It seemed to be lower than that in other groups, but the difference was not significant.

A postural change of intraductal pressures is an important yet uninvestigated aspect of endoscopic measurement of pancreatic or common bile duct pressure. The presence of the postural change was not mentioned by other investigators (Table 1). In the present study, pressures in both ducts and the duodenum were found to be significantly higher in the prone position than in the left lateral position. Since the posture change did not affect ductal and duodenal pressures equally, pressure gradients between the duct and duodenum were variable. The posture at recording should therefore be predetermined, even when only pressure gradient, not absolute pressure, is to be obtained. We prefer the left lateral position for two reasons. First, recording in the prone position would be subject to individual differences to a greater extent than in the left lateral position, because the higher pressure values in the prone position seem to be largely attributable to the increased abdominal pressure, which may vary from person to person, probably depending on the thickness of the abdominal wall. Second, the patient's discomfort during the procedure is less and calmer respiration can be attained in the left lateral position.

Endoscopic sphincterotomy significantly reduced common bile duct-to-duodenum pressure gradient. This is in accord with the findings reported by others previously (2, 5, 8). The gradient after the procedure measured by microtransducer manometry was less than 3 mm Hg in most cases. There have been few reports describing the effect of endoscopic sphincterotomy on pancreatic duct

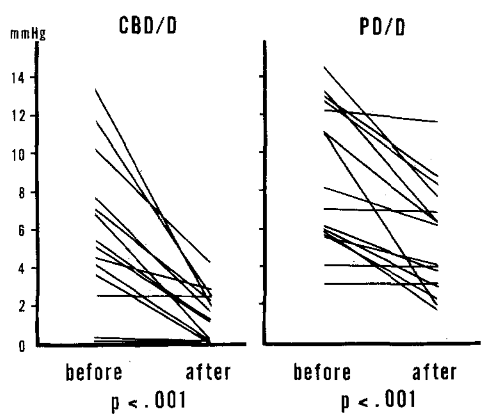

Fig 7. Individual changes in pressure gradients between the common bile duct and duodenum (CBD/D), and between the pancreatic duct and duodenum (PD/D) in 19 patients before and after endoscopic sphincterotomy. Both pressure gradients are significantly reduced after the procedure ($P < 0.001$).

pressure. A significant decrease of pancreatic duct-to-duodenum pressure gradient after sphincterotomy shown in this study may justify a treatment of recurrent pancreatitis due to obstruction at the distal pancreatic duct by the endoscopic procedure. However, we have to be well aware of the historical background of the evolution of transduodenal sphincteroplasty instead of sphincterotomy (20). Sphincteroplasty is a logical approach as a long-term biliary drainage procedure and was originated to abolish the sphincter mechanism more completely and to improve the effect of sphincterotomy for relieving recurrent pancreatitis (21). Since the endoscopic incision cannot be extended to the point where the whole sphincter mechanism is cut because of a risk of duodenal perforation, endoscopic sphincterotomy for treatment of recurrent pancreatitis should preferably be carried out under ductal pressure monitoring. If sufficient decompression is not obtained, an incision should be made on the pancreatic ductal orifice, or surgical sphincteroplasty be considered.

No complications were encountered in either the previous studies using an infusion catheter or in the present work. Manometry seems to be no more hazardous than diagnostic ERCP. Further, the microtransducer method is preferable, especially in the measurement of pancreatic duct pressure, because no infusion of the fluid into the duct is required, thus minimizing the possible adverse effect by the increased, although transient, intraductal pressure, and it permits prolonged monitoring of the ductal pressure, which is valuable in physiological and pharmacological research. The advent of the microtransducer approach could help with new physiological and clinical investigations of the biliary and pancreatic duct systems.

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