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Changes in portal vein hemodynamics after hepatic portoenterostomy in biliary atresia

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Abstract. Portal vein (PV) shrinkage sometimes eliminates the possibility of liver transplantation in biliary atresia patients after hepatic portoenterostomy. To determine the factors leading to PV shrinkage, we performed a serial sonographic study of the portal venous system in 21 children. Cross-sectional PV area and mean portal venous velocity (PVV) were reduced in patients with refractory cholangitis and those with gastroesophageal varices and cholangitis. Although the reduction in cross-sectional PV area was greater in patients with four-time laparotomy than single laparotomy, the mean PVV was not reduced by repeated laparotomy. Patients with varices were lower in age, weight, mean PVV, cross-sectional PV area for age, and had higher serum total bilirubin levels. In conclusion, refractory cholangitis is a significant factor in shrinking the PV. With active bile drainage, varices spontaneously regress, the PV increases in both caliber and total length per unit hepatic volume, and PVV normalizes. It is suggested that pulsed Doppler PV sonography can help to determine the optimal time for liver transplantation referral in biliary atresia patients with progressive cirrhosis.

Key words: Biliary atresia – Portal vein hemodynamics – Pulsed Doppler sonography

Introduction

The patency of the recipient's portal vein (PV) is an important prerequisite for successful liver transplantation (LT) [3, 4]. Biliary atresia (BA) is the disease condition leading to LT in 50% to 75% of pediatric recipients [5, 15]; PV shrinkage, however, sometimes eliminates the possibility of performing LT in BA patients. It is hypothesized that in BA patients with worsening liver function, the PV shrinks due to decreased hepatopetal flow [3]. To determine the factors that may contribute to shrinkage of the cross-sectional PV area, we performed a serial sonographic study of the portal venous system with reference to clinical review in 21 children with BA after hepatic portoenterostomy (HPE).

Materials and methods

The present study involved 21 of 46 patients with BA who underwent HPE at the Second Department of Surgery, Kyoto University Hospital, from June 1978 to September 1988. They consisted of 9 females and 12 males with an age range from 24 to 147 months (mean 71.7 ± 37.6). After HPE was performed by techniques previously described [14], the patients were evaluated by pulsed Doppler sonography as part of the routine follow-up care from May 1988 to September 1990. Informed consent was obtained from each patient, if possible, and/or the parents.

Pulsed Doppler sonography was performed 23 times in the 21 patients. (Two patients had repeated studies between 8 and 24 months apart and 19 had a single study). The device used was an ultrasonic duplex system composed of a real-time electronic linear-type B-mode scanner and a pulsed Doppler flowmeter using Fast Fourier Transform (Toshiba Sonolayer α SSA-270A, Toshiba Corp., Japan). The specifications of the system and the principle of measurement have been described in previous reports [9, 10]. Measurement was carried out with fasted subjects resting in a 30° head-up position without anesthesia to avoid interference with the ultrasound beam by bowel gas. The PV was displayed first along the longitudinal axis by the B-mode scanner and the site for volume sampling was set at the porta hepatis.

The cross-sectional area (A) of the PV was calculated using the following equation from the minor and major axes (X and Y): $A = XY\ \pi/4$. Mean portal venours velocity (PVV) was calculated by the following equation, employing values for the maximum velocity (V_{max}) at the central axis obtained from the Doppler spectrum and the angle (θ) between the ultrasonic beam for Doppler mode and $PV:V = 0.57\ V_{max}/\cos\theta$ (cm/s) [9]. In practice, the mean PVV was computer-derived from the spectral waveform (Fig. 1).

Six splanchnic angiographies were performed in 5 patients with abnormal PVV (below 7 cm/s) [16]. Histopathologic examination of the PV was performed in 1 patient who underwent orthotopic LT using the left lobe from a living related donor.

The patients were divided into clinical groups according to clinical status: degree of postoperative cholangitis; time of laparotomy; and

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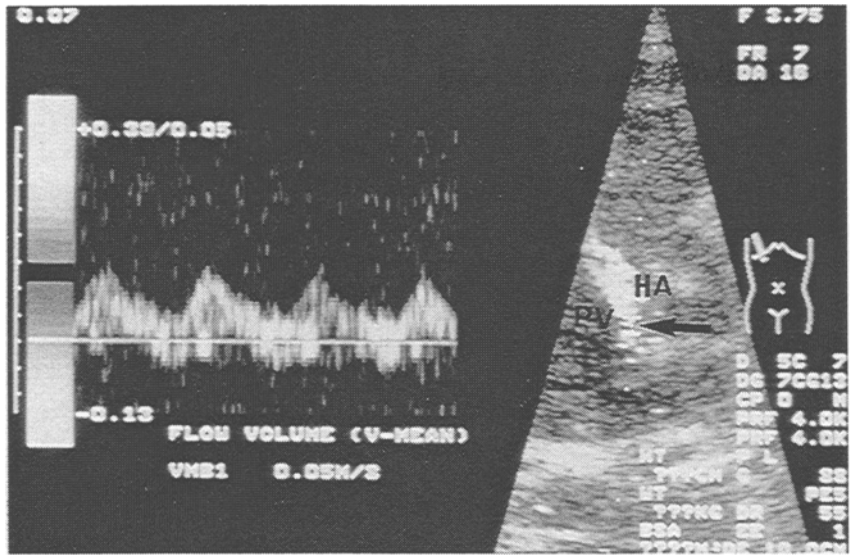

Fig. 1. B-mode scan of the portal vein (right). The site for volume sampling is set at the porta hepatis (*arrow*). The mean portal venous velocity is computer-derived from the spectral waveform (left). *PV*, Portal vein; *HA*, Hepatic artery

presence of absence of gastroesophageal varices. The diagnosis of post-operative cholangitis was made from the tetrad of unexplained fever (>38°C), elevated serum bilirubin level, acholic stool, and leukocytosis. Cholangitis was graded according to the severity of inflammation: (+) = tractable cholangitis controlled by antibiotic therapy in an ambulatory setting; (++) = refractory cholangitis treated with hospitalization. Gastroesophageal varices were diagnosed by endoscopy and sonography. Statistical analysis was carried out using the Student's *t*-test and the Wilcoxon rank-sum test.

Results

Hemodynamic changes and cholangitis

The mean cross-sectional PV area was 38.2±21.8 mm² in 16 patients without cholangitis, 46.3±21.0 mm² in 4 patients with tractable cholangitis, and 2.40±4.16 mm² in 3 patients with refractory cholangitis (Table 1). The difference between cholangitis(–) and cholangitis(++) was statistically significant at levels below 0.05, as was the difference between cholangitis(+) and cholangitis(++).

The mean PVV was 13.5±4.63 cm/s in 16 patients without cholangitis, 14.0±6.16 cm/s in 4 patients with tractable cholangitis, and 1.70±2.94 cm/s in 3 patients with refractory cholangitis. The difference between cholangitis(–) and cholangitis(++) was statistically significant at levels below 0.01, that between cholangitis(+) and cholangitis(++) at levels below 0.05.

Among these three groups, there were no significant differences regarding age, weight, and serum total bilirubin levels (T-Bil).

Hemodynamic changes and re-laparotomy

The mean cross-sectional PV area was 45.9±25.0 mm² in 9 patients with one-time laparotomy, 34.2±23.2 mm² in 7 patients with two-time laparotomy, 34.5±17.1 mm² in 3 patients with three-time laparotomy, and 15.7±7.80 mm² in 3 patients with four-time laparotomy (Table 2). The difference between the one-time laparotomy group and the four-time group was statistically significant at the level of 0.05. Among those two groups, there were no significant differences in age, weight, and T-Bil. The other matching between groups was not significant.

Table 1. Mean and SD values of data according to cholangitis

	Cholangitis		
	(–)	(+)	(++)
No. of patients	16	4	3
Age (months)	67.6±35.7	97.8 ±49.4	51.0 ±19.7
Weight (kg)	20.4 ± 7.57	25.8 ±11.8	14.0 ± 5.22
T-Bil (mg/dl)	3.11± 4.95	1.10± 0.632	9.77± 7.48
A (mm²)	38.2 ±21.8	46.3 ±21.0	2.40± 4.16[a]
V (cm/s)	13.5 ± 4.63	14.0 ± 6.16	1.70± 2.94[b]

T-Bil: total bilirubin
A: cross-sectional portal vein area
V: mean portal venous velocity
[a] Significant difference from cholangitis (–) and cholangitis (+) groups; $P < 0.05$
[b] Significant difference from cholangitis (–) ($P < 0.01$) and cholangitis (+) groups ($P < 0.05$)

The mean PVV was 13.5±6.43 cm/s in 9 patients with one-time laparotomy, 13.4±5.87 cm/s in 7 patients with two-time laparotomy, 10.0±3.61 cm/s in 3 patients with three-time laparotomy, and 10.4±5.46 cm/s in 3 patients with four-time laparotomy. The difference was not significant among these four groups.

In a 33-month-old female who had five laparotomies consisting of HPE and revisions of the hilar anastomosis due to refractory cholangitis, PV occlusion was demonstrated by sonography and splanchnic angiography.

Hemodynamic changes and gastroesophageal varices

The mean cross-sectional PV area was 52.3±13.7 mm² in 10 patients without gastroesophageal varices and 21.6±21.1 mm² in 13 with varices (Table 3). The difference was significant at levels below 0.01. The mean PVV

Table 2. Mean and SD of data according to time of laparotomy

	Time of laparotomy				
	1	2	3	4	5
No. of patients	9	7	3	3	1[b]
Age (months)	89.0 ±29.4	68.6 ±46.0	32.3 ± 7.51	71.3 ±37.8	33.0
Weight (kg)	24.4 ± 7.86	19.9 ± 8.84	11.8 ± 1.76	23.0 ± 5.50	8.00
T-Bil (mg/dl)	2.36± 4.94	3.66± 4.38	6.63± 9.42	1.27± 0.551	12.5
A (mm^2)	45.9 ±25.0	34.2 ±23.2	34.5 ±17.1	15.7 ± 7.80[a]	0
V (cm/s)	13.5 ± 6.43	13.4 ± 5.87	10.0 ± 3.61	10.4 ± 5.46	0

T-Bil: total bilirubin

[a] Significant difference from time of operation 1 group; $P = 0.05$

[b] A 33-month-old female with refractory cholangitis, varices, and 5-time laparotomy developed PV occlusion

Table 3. Mean and SD of data according to gastroesophageal varices

	Varices	
	(–)	(+)
No. of patients	10	13
Age (months)	96.4 ±34.9	50.8 ±27.0[a]
Weight (kg)	26.5 ± 7.05	15.9 ± 6.39[a]
T-Bil (mg/dl)	0.660± 0.35	5.92± 6.23[a]
A (mm^2)	52.3 ±13.7	21.6 ±21.1[a]
V (cm/s)	15.9 ± 3.69	9.02± 5.99[a]

T-Bil: total bilirubin

[a] Significant difference from varices (–) group; $P < 0.01$

Table 4. Mean and SD of data in patients without gastroesophageal varices according to cholangitis

	Cholangitis	
	(–)	(+)
No. of patients	7	3
Age (months)	86.4 ±34.4	120 ±28.0
Weight (kg)	24.5 ± 6.74	31.0 ± 6.56
T-Bil (mg/dl)	0.56± 0.14	0.90± 0.60
A (mm^2)	50.4 ±16.0	56.5 ± 5.77
V (cm/s)	15.6 ± 3.90	16.7 ± 3.79

T-Bil: total bilirubin

was 15.9±3.69 cm/s in 10 patients without varices and 9.02±5.99 cm/s in 13 with varices. The difference was statistically significant at levels below 0.01; there were also significant differences in age, weight, and T-Bil.

Hemodynamic changes and cholangitis with varices

The mean cross-sectional PV area was 50.4±16.0 mm^2 in 7 patients who had neither varices nor cholangitis and 56.5±5.77 mm^2 in 3 patients who had tractable cholangitis without varices (Table 4). The mean PVV was 15.6±3.90 cm/s in 7 patients who had neither varices nor cholangitis and 16.7±3.79 cm/s in 3 who had tractable cholangitis without varices. The differences were not significant. There were also no significant differences in age, weight, and T-Bil.

Table 5. Mean and SD of data in patients with gastroesophageal varices according to cholangitis

	Cholangitis	
	(–)	(+) or (++)
No. of patients	9	4
Age (months)	52.9 ±30.8	46.3 ±18.7
Weight (kg)	17.2 ± 6.85	13.0 ± 4.71
T-Bil (mg/dl)	5.04± 6.02	7.75± 7.32
A (mm^2)	28.6 ±21.6	5.70± 7.42[a]
V (cm/s)	11.8 ± 4.67	2.78± 3.23[a]

T-Bil: total bilirubin

[a] Significant difference from cholangitis (–) group; $P < 0.05$

The mean cross-sectional PV area was 28.6±21.6 mm^2 in 9 patients who had varices without cholangitis and 5.70±7.42 mm^2 in 4 who had both varices and cholangitis (1 tractable, 3 refractory) (Table 5). The mean PVV was 11.8±4.67 cm/s in 9 patients who had varices without cholangitis and 2.78±3.23 cm/s in 4 who had both varices and cholangitis. The differences were statistically significant at levels below 0.05. There were no significant differences in age, weight, and T-Bil.

Hemodynamic assessment with splanchnic angiography

Six splanchnic angiographies were performed in 5 patients with abnormal PVV (below 7 cm/s). PV occlusion was observed in 2 patients who had both refractory cholangitis and varices: a 33-month-old female who had five laparotomies and PV occlusion extending to the superior mesenteric and splenic veins and a 72-month-old female who had a one-time laparotomy and occlusion of the entire PV. PV stenosis was observed in another 2 patients, both of whom had varices. One was a 32-month-old male who had poor bile drainage after HPE due to biliary obstruction without cholangitis and had not established active bile drainage after reoperation. His cross-sectional PV area and mean PVV were 6.9 mm^2 and 5.0 cm/s, respectively; the other was a 48-month-old male who had four laparotomies due to refractory cholangitis, whose cross-sectional PV area and mean PVV were 7.2 mm^2 and 5.1 cm/s. Our 5th and final patient, a 32-month-old female, had good bile drainage in spite of tractable cholangitis, three-time la-

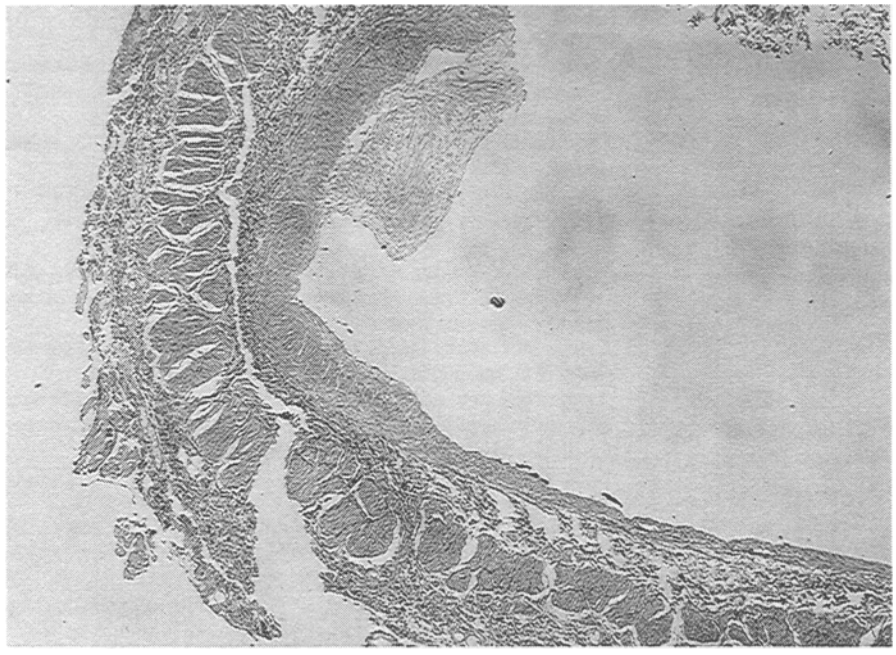

Fig. 2. Section from portal vein (PV) in patient who had been observed for PV stenosis for over 8 months. Thickening and focal protuberance of the intima are observed (H&E, ×40)

parotomies, and varices. She did not develop PV shrinkage, and her cross-sectional PV area and mean PVV were 15.6 mm^2 and 6.0 cm/s.

Pathology of PV shrinkage

Pathologic examination of the PV was performed in 1 of the patients who had been observed for PV stenosis for more than 8 months and underwent orthotopic LT using the left lobe of a living related donor (Fig. 2). Diffuse thickening and focal protuberance of the intima were observed, but there was no evidence of a thrombus. Thickening in the media and adventitia of the PV was not pronounced.

Discussion

Portal venous flow is an important hemodynamic parameter in the preoperative evaluation of patients requiring LT. Reduction of PV blood flow in adult patients with liver cirrhosis, associated with a nearly constant plateau of portal pressure, was initially reported by Ferguson [2] and Moreno et al. [8]. The direct analysis technique involves the use of an electromagnetic flowmeter requiring anesthesia and laparotomy, and hence is too invasive and complex for routine use [13]. However, PV blood flow can also be calculated from PVV and cross-sectional PV area as measured by pulsed Doppler sonography [11, 13, 17]. The pulsed Doppler method gives accurate values of PVV, but there are some inherent errors in flow estimation when the venous blood vessel is somewhat compressed by adjacent structures and when the diameter of the vessel is small [11, 13, 16, 17]. Therefore, we adopted the mean PVV and cross-sectional PV area as hemodynamic parameters. A skilled examiner was asked to perform these measurements.

HPE for BA permits bile drainage, and immediate postoperative bile drainage is achieved in more than 80% of cases [14]. After bile drainage is obtained, the most serious complication is ascending cholangitis, which can lead to biliary reobstruction and/or progressive liver fibrosis. On the other hand, re-laparotomy, including revision of the hilar anastomosis, lysis of adhesions, and surgery for peritonitis, is required in a number of cases [1]. Both the surgery and the general anesthesia required for re-laparotomy induce retention and regurgitation of intestinal contents, which interferes with the outflow of bile excreted from the fine bile ducts, leading to ascending cholangitis and biliary reobstruction [1]. In our study, cross-sectional PV area and mean PVV were significantly reduced in patients with refractory cholangitis, but were not reduced in patients with tractable cholangitis (Table 1). Although the cross-sectional PV area was reduced in the patients with four-time laparotomies compared to those with a single laparotomy, mean PVV was not reduced by repeated laparotomy (Table 2). It is suggested that refractory cholangitis, which may shrink the PV and occasionally eliminate the possibility of performing LT in BA patients, is a more serious factor than repeated laparotomies. Knowledge of deterioration of PVV and cross-sectional area would allow early transplant referral in those patients who have progressive cirrhosis. In patients who require repeated laparotomies, the cross-sectional PV area may be reduced, and hence close observation with pulsed Doppler sonography and splanchnic angiography is recommended.

Portal hypertension is a major late complication even in children who are jaundice-free following successful surgery for BA [12]. High portal pressure also has been shown to exist in the majority of patients during corrective surgery [6]. However, when there is active bile drainage and postoperative cholangitis is not a problem, PV pressure

decreases and the portal veins increase in total length per unit hepatic volume as the child grows [6].

In our study, patients with varices were significantly lower in age, weight, mean PVV, and cross-sectional PV area and higher in T-Bil for their ages (Table 3). Since the development of natural portosystemic shunts is apt to occur in growing children [6, 7], both cross-sectional PV area and mean PVV can be reduced in spite of the presence of portal hypertension, whereas portal venous caliber tends to enlarge in adult cirrhotics [17]. In our patient who received two examinations over a 24-month period because he had active bile drainage without cholangitis, the varices spontaneously regressed. The PV increased in cross-sectional area as he grew and normal PVV was established. Therefore, when active bile drainage is present, varices can spontaneously regress. The PV increases not only in total length per unit hepatic volume, but also in caliber at the porta hepatis, and PVV normalizes.

Postoperative cholangitis aggravates portal hypertension and fibrosis of the liver [6]. In our study, when cholangitis was tractable in the patients without varices neither cross-sectional PV area nor mean PVV was reduced (Table 4). However, when cholangitis was present in patients with varices, both cross-sectional PV area and mean PVV were reduced (Table 5). It is suggested that cholangitis has serious effects, especially on smaller children with portal hypertension.

Pathologic examination of the PV showed that diffuse thickening of the intima is not only indicative of portal hypertension, but may also be a sign of periportal fibrosis as diagnosed by sonography in most patients with decreasing PV size (Fig. 2).

In conclusion, refractory cholangitis reduced both cross-sectional PV area and mean PVV in BA patients. It is possible that postoperative cholangitis aggravates liver function, liver fibrosis, portal hypertension, and PV shrinkage. PV sonography by the pulsed Doppler method may be helpful in determining the optimal time for LT referral in BA patients with progressive cirrhosis.

References

1. Chiba T (1988) Problems involved in re-laparotomy for congenital biliary atresia: with special reference to postoperative ascending cholangitis. Z Kinderchir 43: 95–98
2. Ferguson DJ (1963) Hemodynamics in surgery for portal hypertension. Ann Surg 158: 383–386
3. Hernandez-Cano AM Jr, Geis JR, Rumack CH, Stellin GP, Lilly JR (1987) Portal vein dynamics in biliary atresia. J Pediatr Surg 22: 519–521
4. Jocyline LM, Rodrigo D, A'Delbert B, Lionel WY, Klaus MB (1985) Pediatric liver transplantation. Part 1. Standardization of preoperative diagnostic imaging. Radiology 157: 335–338
5. Kalayoglu M, Stratta RJ, Sollinger HW et al. (1989) Liver transplantation in infants and children. J Pediatr Surg 24: 70–76
6. Kasai M, Okamoto A, Ohi R, Yabe K, Matsumura Y (1981) Changes of portal vein pressure and intrahepatic blood vessels after surgery for biliary atresia. J Pediatr Surg 16: 152–159
7. Lilly JR, Karrer FM, Hall RJ et al. (1989) The surgery of biliary atresia. Ann Surg 210: 289–296
8. Moreno AH, Burchell AR, Rousselot LM, Panke WF, Slafsky SF, Burke JH (1967) Portal blood flow in cirrhosis of the liver. J Clin Invest 46: 436–445
9. Moriyasu F, Ban N, Nishida O et al. (1986) Clinical application of an ultrasonic duplex system in the quantitative measurement of portal blood flow. J Clin Ultrasound 14: 579–588
10. Moriyasu F, Ban N, Nishida O et al. (1984) Quantitative measurement of portal blood flow in patients with chronic liver disease using an ultrasonic duplex system consisting of a pulsed Doppler flowmeter and B-mode electroscanner. Gastroenterol Jpn 19: 529–536
11. Nelson RC, Lovett KE, Chezmar JL et al. (1987) Comparison of pulsed Doppler sonography and angiography in patients with portal hypertension. Am J Radiol 149: 77–81
12. Ohi R, Mochizuki I, Komatsu K, Kasai M (1986) Portal hypertension after successful hepatic portoenterostomy in biliary atresia. J Pediatr Surg 21: 271–274
13. Ohnishi K, Saito M, Koen H, Nakayama T, Nomura F, Okuda K (1985) Pulsed Doppler flow as a criterion of portal venous velocity: comparison with cineangiographic measurements. Radiology 154: 495–498
14. Tanaka K, Shirahase I, Utsunomiya H et al. (1991) A valved hepatic portoduodenal intestinal conduit for biliary atresia. Ann Surg 213: 42–47
15. Vacanti JP, Shamberger RC, Eraklis A, Lillehei CW (1990) The therapy of biliary atresia combining the Kasai portoenterostomy with liver transplantation: a single center experience. J Pediatr Surg 25: 149–152
16. Wanek EA, Horgan JG, Karrer FM et al. (1990) Portal venous velocity in biliary atresia. J Pediatr Surg 25: 146–148
17. Zoli M, Marchesini G, Cordiani MR et al. (1986) Echo-Doppler measurement of splanchnic blood flow in control and cirrhotic subjects. J Clin Ultrasound 14: 429–435