Cirrhosis with Ascites: *
Hemodynamic Observations

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Introduction

THERE IS considerable experimental data and pathologic evidence supporting the concept of hepatic outflow obstruction in the pathogenesis of ascites in cirrhosis. Recently the use of portacaval anastomosis has been used in the treatment for the medically-intractable ascitic patient, with good success. Hemodynamic data on these patients, however, has been fragmentary. We have studied five patients before and after portacaval surgery; this report attempts to integrate some of the hemodynamic data we have obtained with other published information on the pathogenesis and treatment of ascites in cirrhosis.

Methods and Materials

The indication for portacaval anastomosis in these patients was medically-intractable ascites, although patient D. S. had one episode of gastro-intestinal bleeding. In all of these patients cirrhosis developed on an alcoholic nutritional basis, and all had prolonged periods of medical therapy with diuretics and numerous paracenteses. The patients M. D. and D. S. were presented, in part, in a previous report.[6]

Prior to operation all patients were studied by hepatic vein catheterization by a method previously described.[9] A cardiac catheter was wedged into a small hepatic venule on deep inspiration, impacting the catheter and thus permitting the measurement of the hepatic sinusoidal pressure. This sinusoidal pressure represents a combined effect of portal vein and hepatic artery pressures preoperatively but has been shown in most instances to be equivalent to the portal vein pressure. A correction was made for the intra-abdominal pressure caused by the fluid; the gradient in pressure from the abdominal inferior vena cava to the thoracic vena cava was subtracted from the hepatic wedge pressure. In our experience, the removal of ascitic fluid generally reduced the wedged pressure to the extent of this abdominal vena cava-thoracic vena cava gradient. A free hepatic vein pressure was also obtained. Following complete diversion of the portal blood flow by end-to-side portacaval anastomosis, the studies were repeated. The wedged hepatic vein pressure obtained at the postoperative catheterization represents the intrasinusoidal pressure developed by the remaining perfusion source, the hepatic artery. Measurements were recorded with a Sanborn electromanometer and direct writing oscillograph, the external estimation of the right atrium serving as the zero level. Simultaneous blood samples were drawn from the hepatic vein and the brachial artery for oxygen content.

Hepatic blood flows were determined by a colloidal gold extraction technic previously described.[3] The blood volumes

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were determined using radioactive iodinated human serum albumin.

The hepatic vascular resistance, (the ratio of wedged hepatic vein pressure in mm. of Hg to the hepatic blood flow in ml. per min. times 100), was calculated. A process such as cirrhosis which reduces blood flow and increases intrasinusoidal pressure causes an increase in this ratio. At laparotomy the portal vein pressure was measured with a saline manometer before and after effecting the shunt. During convalescence hepatic vein catheterization and the estimation of hepatic blood flow were repeated.

Results

Preoperative Studies. The intrasinusoidal pressures and the "free" hepatic vein pressures obtained preoperatively were abnormally elevated in all patients, the wedged pressures ranging from 20 to 50 mm. Hg with a mean of 30.7 mm. Hg. After correcting for the ascitic fluid the wedge pressures ranged from 15.0 to 35.0 mm. Hg with a mean of 24.5 mm. Hg. These are considerably above our *normal* values of 9.0 to 11.0 mm. Hg. The free hepatic vein pressures ranged from 8.0 to 27.0 mm. of Hg with a mean of 14.2 mm. Hg; our *normal* values are 2.0 to 5.0 mm. Hg.

The hepatic blood flows were reduced in all patients. The mean effective hepatic blood flow was 379 cc. compared to a mean hepatic blood flow of 392 ml. for cirrhotics and a mean of 1,100 ml. for *normals* in our clinic.

The hepatic vascular resistance was elevated, ranging from 3.2 to 11.6. A *normal* subject with a wedged pressure of 10.5 ml. of Hg and a flow of 1,100 ml. per minute has a resistance of 0.95.

The hepatic vein-brachial artery oxygen difference varied considerably, but ranged from 3.0 to 6.3 volumes per cent. In our laboratory the difference is usually about 4.0 volumes per cent.

Operative Studies. The corrected wedged pressures obtained at catheterization correlated well with the portal pressures obtained at laparotomy. The mean difference was 3.5 mm. Hg (4.7 cm. H_2O) with a range from 1.1 to 7.1 mm. Hg. The uncorrected pressures ranged from 0.3 to 17.0 mm. Hg difference with a mean difference of 4.7 mm. Hg (6.4 cm. H_2O). The corrected indirect measurements were lower than the pressures taken at laparotomy in four of the five patients.

In two patients a pressure was obtained in the proximal occluded portal vein (mesenteric side), prior to the vascular anastomosis. In patient M. D., the occlusive portal pressure rose from 350 to 530 mm. H_2O and fell to 170 mm. H_2O when the end-to-side portacaval anastomosis was opened. In patient D. S. the occlusive portal pressure rose from 480 to 540 mm. H_2O, and fell to 220 mm. H_2O when the shunt was opened.

Postoperative Studies. The corrected wedged hepatic vein pressure fell from a mean of 24.5 mm. to 15.4 mm. Hg; a mean decline of 37 per cent (the decrease in uncorrected wedged pressure ranged from 6.5 to 58%). The free hepatic vein pressures also fell, declining an average of 8.0 mm. of Hg (56.5%). The range of the decline of the free hepatic vein pressure was from 25 to 85 per cent.

The mean postoperative estimated hepatic blood flow was essentially unchanged from the preoperative level. The range of change in flow, however, was from an increase of 34 per cent to a decline of 53 per cent.

The hepatic vein–arterial oxygen difference postoperatively was essentially unchanged in three patients (D. S., M. B., and R. W.), in one patient (J. D.) there was a moderate decline, and in the final patient there was a moderate increase. Patient D. S., catheterized seven months post-shunt, had a mild increase in the A-V difference from the postoperative catheterization. Pa-

TABLE 1. *Summary of Hemodynamic Data on Five Ascitic Patients Subjected to End-to-Side Portacaval Anastomosis*

Patient	Preoperative					Laparotomy		Postoperative					Remarks
	Wedged Hepatic Vein Pressure mm. Hg	Hepatic Vein Pressure mm. Hg	Hepatic Blood Flow, ml./min.	Hepatic Resistance	Arterial Hepatic Vein O_2 Diff., vol. %	Port Vein Press., mm. saline (mm. Hg.) Pre-Shunt	Port Vein Press., mm. saline (mm. Hg.) Post-Shunt	Wedged Hepatic Vein Pressure mm. Hg	Hepatic Vein Pressure mm. Hg	Hepatic Blood Flow, ml./min.	Hepatic Resistance	Arterial Hepatic Vein O_2 Diff., vol. %	
D.S.	34.8	16.1	273	11.3	4.7	480 (35.3)	220 (16.2)	17.0	8.0	245	6.9	4.6	
	30.9*							16.0	2.7	207	7.7	3.8	6 months post-shunt
								16.0	5.0	215	7.4		1 year post-shunt
M.B.	28.9	9.0	487	4.9	3.0	350 (25.7)	170 (12.5)	10.0	5.0	231	4.3	2.9	
	23.8*							10.0	5.5	233	4.2	6.2	16 months post-shunt
S.W.	20.0	8.0	494	3.2	3.9	310 (22.1)	300 (22.0)	14.0	6.0	664	4.7	5.7	
	15.0*												
J.D.	50.0	27.0	300	11.6	4.8	460 (33.0)	390 (28.6)	10.0	4.0	188	10.6	3.5	
	35.0*												
R.N.	20.0	11.0	342	4.1	6.3	260 (19.1)	250 (18.3)	16.0	8.0	210	7.6	6.2	
	18.0*												
Mean	30.7	14.2	379	7.02	4.54	372 (27.0)	266 (19.5)	14.88	5.52	274.1	6.68	4.7	
	24.5*												

* Wedged hepatic vein pressure "corrected" for hydrostatic pressure caused by ascites.

tient M. D., catheterized 16 months post-shunt, showed a marked increase in the A-V difference.

Patient D. S., operated upon two and one-half years ago, was catheterized six months and 12 months postoperatively. Her wedge pressure remained unchanged. The free hepatic vein pressures fell to 2.7 mm. Hg six months after surgery and was 5.0 mm. Hg one year after surgery. The hepatic blood flow remained essentially unchanged.

Patient M. D., operated upon three years ago, was recatheterized 16 months after operation. Her wedged pressure, free hepatic vein pressure, and hepatic blood flow were all unchanged from the first postoperative determinations. (The data is summarized in Table 1.)

Clinical Results. All the patients became free of ascites and the four survivors have remained so for one and a half to three years after operation. Patient J. D. had several episodes of ammonia intoxication requiring re-hospitalization after operation and died in hepatic failure three months after the operation. While his bilirubin rose to 50 and his thymol turbidity rose to 12, he died without clinical ascites, and none was found at autopsy; his portacaval shunt was patent at autopsy. Patient D. S. has had recurrent difficulty with peripheral edema but is responsive to mercurial diuretics which were ineffective preoperatively.

Discussion

While this series of patients is too small to allow definite conclusions certain factors appear worthy of emphasis. All five patients presented with medically-intractable ascites. They all had elevated hepatic vein and sinusoidal pressures. All had abnormally low 24-hour urinary sodium excretions, and all were cleared of their ascites following and end-to-side portacaval shunt. Following the portacaval shunt the wedged hepatic vein pressure and free hepatic vein

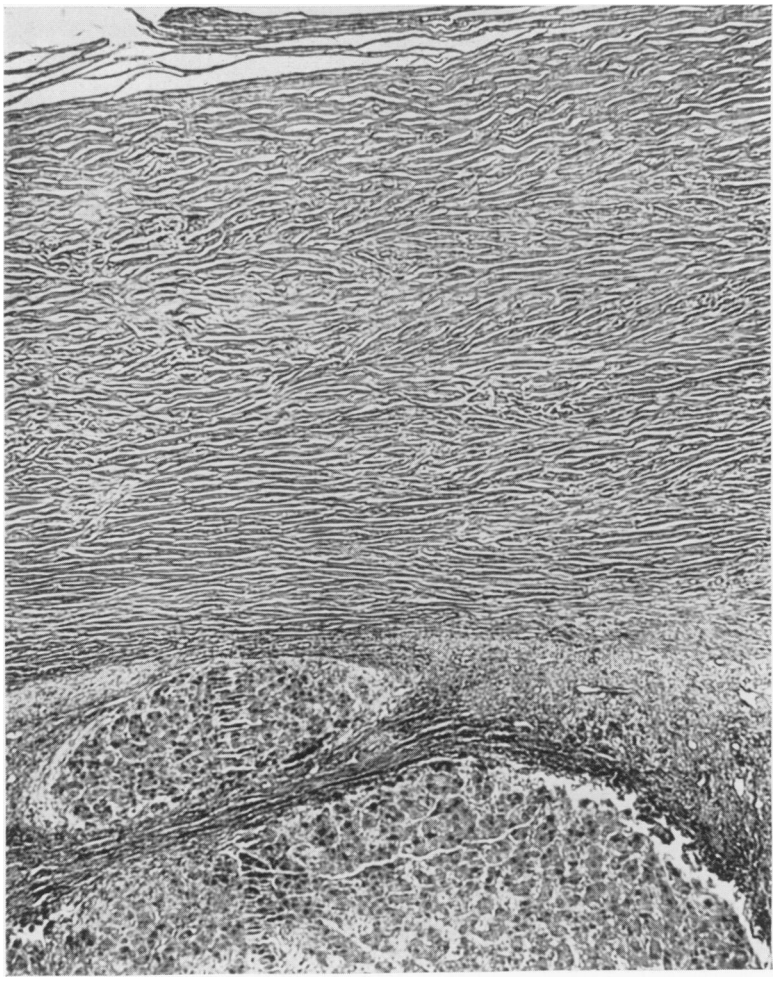

FIG. 1. Photomicrograph of the liver biopsy of patient S. W. (from × 44). The fibrous capsule appeared to enclose completely the cirrhotic liver.

pressure decreased in all. The hepatic blood flow and hepatic resistance, however, varied in both directions following operation-rising in some and falling in others. The urinary salt excretion rose to normal in all cases after operation.

How can the hemodynamic data obtained in these patients be related to a concept of the pathogenesis of ascites? The anatomical studies of Madden[10] have suggested that outflow obstruction which causes a disproportion between the inflow to the liver and the outflow to the vena cava is the primary problem. Kelty[7] and Roth[13] have shown hepatic vein distortion due to the regenerating hepatic nodule, and presumably the resultant hepatic vein distortion decreases hepatic outflow. Krook[8] showed this to be a hemodynamic entity; he found a significant elevation in the wedged hepatic vein pressure in ascitic cirrhotics as opposed to cirrhotics without ascites. Similarly, he found a significantly elevated free hepatic venous pressure in ascitic cirrhotics over nonascitic cirrhotics. Our studies also show higher wedge pressures and free hepatic vein pressures in cirrhotics with ascites than in non-ascitic cirrhotics. In all likelihood the back pressure put upon the sinusoidal bed by the outflow obstruction leads to increased filtration through the sinusoidal wall and an

increase in the lymphatic flow from the liver. Baggenstoss [1] has demonstrated increased hilar lymphatics in the ascitic, suggesting a lymphatic proliferation to carry the excess fluid from the liver. If hepatic lymph production exceeds what can be removed via the hepatic lymphatics, fluid may "sweat" from the surface of the liver into the peritoneal cavity. The high protein content of hepatic lymph obligates fluid to maintain osmotic equilibrium in the peritoneal fluid. If absorption from the peritoneal cavity is slower than the hepatic supply ascites will result. The data of these five patients would support this concept. Prior to surgery they had marked elevations in their sinusoidal pressure and marked elevations in their hepatic venous pressure evidencing outflow obstruction. All had increased hilar lymphatics noted at surgery. Following surgery there was a fall in both hepatic pressures and the loss of ascites.

While there is much in favor of this concept, this small group of patients provides some disquieting information. Patient S. W. was found at laparotomy to have a liver entirely encased in firm fibrous tissue. No hepatic parenchyma could be seen at any hepatic surface. Whether the lymph passed through this "capsule" or was produced elsewhere is unknown but grossly and microscopically the capsule appeared to be a formidable barrier to the passage of fluid (Fig. 1). If one assumes that the end-to-side portacaval anastomosis had an effect on the ascites production, one must assume that the mode of action was the diversion of the portal blood flow. This would—using the outflow block concept of ascites production—decrease hepatic inflow to a level where the limited hepatic outflow becomes adequate. The hepatic blood flow measurements, however, show a significant fall in only three of the patients studied. In addition, we have operated upon two other patients who were nonascitic before surgery. Following shunting both had marked ascites, requiring reinfusion of up to eight liters of ascitic fluid by vein per day in one and up to 800 cc. of salt poor albumin per day in the other in order to prevent hypovolemia from the extreme fluid and protein loss. Both died due to inability to control the ascites production. One of these patients had a preoperative wedged hepatic vein pressure of 17 and a free hepatic vein pressure of five with an estimated blood flow of 476 cc. per minute. The second patient had a wedged pressure of 27 and a free hepatic vein pressure of seven. The hemodynamic situation after surgery was not determined. Why these two patients were not protected from ascites production by the shunt is not apparent. Perhaps the portal vein was being used as an outflow vent prior to surgery and division of the portal vein overloaded the outflow, and resulted in sudden, severe hepatic congestion.

The fall in free hepatic vein pressure and/or the wedged hepatic vein pressure seen in our patients with the loss of ascites was also noted in two patients with end-to-side portocaval anastomosis reported by Ekman [5] and in one patient reported by Redeker.[11] Krook showed a similar fall in wedged and free hepatic vein pressure in two ascitic patients treated medically, and who were studied ten and 18 months later when they were free of ascites. Another patient studied while ascites-free was studied again when ascitic and found to have an increased wedged hepatic vein pressure. However, Reynolds [12] has recently reported two groups of patients and showed loss of ascites coincident with a rise in hepatic vascular pressures in one group and a loss of ascites and a lowering of the hepatic vascular pressures in the other group. Therefore, a loss of ascites in a cirrhotic can be accomplished in some patients without a coincident decrease in outflow or in sinusoidal pressure.

There does not appear to be any doubt that ascites can be relieved following portacaval anastomosis. Some believe a side-

to-side portal vein to inferior vena cava anastomosis is physiologically sounder in the treatment of ascites because the liver can decompress into the vena cava via the portal vein. However, considerable success has attended the use of the end-to-side shunt in the treatment of ascites. Ekman [5] reports 11 patients free of ascites one to six years after surgery, using end-to-side portacaval anastomosis or splenorenal anastomosis. Eisenmenger and Nickel [4] and Blakemore,[2] as well, have had success with this type of anastomosis. Because of the relative ease of the end-to-side operation, and our satisfactory results in these five patients, we presently favor this procedure and will use it until further information is available.

Summary

1. Hemodynamic data on five patients operated upon for medically-intractable ascites are presented.

a. All patients had elevated wedged hepatic vein pressures, elevated free hepatic vein pressures, and decreased hepatic blood flows before surgery.

b. The hepatic pressures fell following end-to-side portacaval anastomosis.

c. Hepatic blood flows showed changes with operation, ranging from an increase of 34 per cent to a decrease of 53 per cent.

2. All patients lost their ascites following the shunt procedure.

3. The relation of these pressures to the pathogenesis of ascites and the relation of the changes in pressures to the relief of ascites by shunting procedures is discussed.

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