

The portal pressure-blood volume relationship in cirrhosis¹

DAVID S. ZIMMON AND RICHARD E. KESSLER

From the Medical and Surgical Services, Veterans Administration Hospital, and New York University School of Medicine, New York, New York

SUMMARY Portal pressure-blood volume curves were derived in 13 cirrhotic patients with portal hypertension and oesophageal or gastric varices by measuring portal pressure at two levels of blood volume. Portal pressure varied directly with blood volume. In seven patients where portal pressure was measured at three levels of blood volume separated by 500 ml or more the portal pressure-blood volume relationship was found to be approximately linear.

Life-threatening haemorrhage from oesophageal or gastric varices occurs in patients with cirrhosis and portal hypertension. The frequency of this feared complication increases with increasing portal pressure (Rousselot, Moreno, and Panke, 1959; Jackson, Perrin, Felix, and Smith, 1971). Expansion of the blood volume raises portal pressure (Losowsky, Jones, Lieber, and Davidson, 1963). To quantitate the relationship between portal pressure and blood volume in cirrhosis we have studied the response of portal pressure to rapid augmentation or diminution of the intravascular volume.

Methods

All patients had oesophageal varices demonstrated by oesophagoscopy and were being evaluated for portal-systemic shunt surgery after suspected or documented variceal haemorrhage. The presence of cirrhosis with postsinusoidal portal hypertension was ultimately confirmed in every patient by liver biopsy, wedged hepatic venous pressure measurement, or necropsy.

Immediately before study ¹³¹I albumin was injected intravenously. Peripheral venous blood samples at 10 and 12 minutes measured plasma volume. Whole blood volume was calculated from the peripheral venous haematocrit performed in triplicate and corrected for trapped plasma, and the

difference between peripheral and whole body haematocrit (Nadler, Hidalgo, and Bloch, 1962; Lieberman and Reynolds, 1967). Portal pressure was measured by umbilical venous or wedged hepatic venous catheterization. Central venous pressure was monitored through an additional central venous catheter. Pressures were recorded through Statham P-37 perfused strain gauges with zero pressure level taken as 12 cm above the couch. When the umbilical vein was catheterized, it was used for phlebotomy or infusion. Otherwise the central venous catheter was used for infusion and the femoral vein catheterized for phlebotomy. Whole blood was withdrawn into acid-citrate-dextrose solution and reinfused. To increase vascular volume whole blood, packed cells, or 6% Dextran were infused. Since large-bore catheters and large vessels were used it was possible to infuse or withdraw 500 ml in less than five minutes. These rapid changes in vascular volume minimized compensatory shifts of fluid into or out of the vascular space. Thus, change in vascular volume was calculated from the initial isotopic measurement and the volume of fluid withdrawn or infused during the brief period of study.

Results

Within the range (8.6-3.6 litres) of whole blood volume studied portal pressure varied directly with blood volume. In seven patients portal pressure-blood volume curves were constructed by measuring portal pressure at three different quantities of blood volume separated by 500 ml or more. The portal pressure-blood volume relationship was approxi-

¹Supported by research funds from the Veterans Administration.

Please address correspondence to: David S. Zimmon, M.D. Veterans Administration Hospital, 408 First Avenue, New York, New York 10010

Received for publication 28 November 1973.

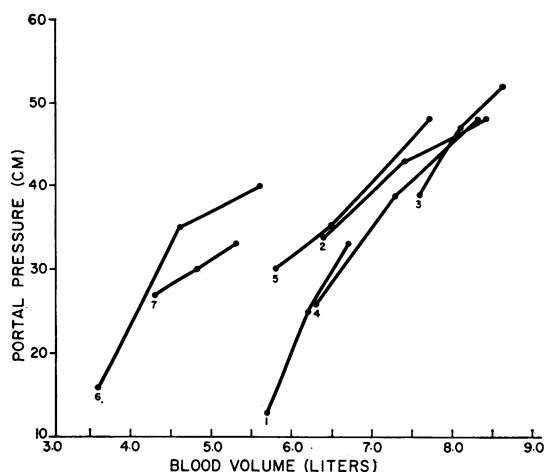


Fig. 1 Portal pressure-blood volume curves from seven cirrhotic patients with portal hypertension derived from three measurements of portal pressure at blood volumes differing by more than 500 ml.

mately linear (fig 1). In six additional patients curves were constructed from two portal pressure measurements at blood volumes differing by at least 500 ml. The range of pressure-volume slopes in 13 patients was 0.6 to 2.8 cm change in portal pressure per 100 ml change in blood volume. The mean change in portal pressure was 1.4 ± 0.7 (mean \pm SD) cm per 100 ml change in blood volume. Although central venous pressure increased or decreased in response to volume loading or withdrawal in individual patients, it remained within the normal range (4-14 cm).

Discussion

The inadequacy of central venous pressure measurement in reflecting changes in vascular volume has been well documented (Prout, 1968; Irvin, Hayter, Modgill, and Goligher, 1972). Thus, it is not surprising that central venous pressure failed to indicate the induced changes in blood volume or portal pressure.

The prime factor responsible for portal hypertension in cirrhosis is increased hepatic outflow resistance. Plasma volume expansion by salt and water loading (Losowsky *et al*, 1963), infusion of albumin (Losowsky and Atkinson, 1961) or dextran (Boyer, Chatterjee, and Iber, 1966) aggravates portal hypertension. Boyer *et al* (1966) emphasized the prolonged elevation in portal pressure that may follow dextran infusion in cirrhotic patients unable to excrete a volume load. Conversely, blood volume

depletion through haemorrhage, phlebotomy, or fluid removal reduces pressure (Kessler, Santoni, Tice, and Zimmon, 1969).

Cirrhotic patients have an increased plasma volume and proportionately increased whole blood volume (Lieberman and Reynolds, 1967). The quantity of plasma volume that does not serve essential functions in cirrhotic patients and contributes to increasing portal pressure with the attendant risk of variceal haemorrhage ought to be considered excess volume. Particularly during episodes of fluid retention or inadequately monitored blood or fluid replacement, intravascular excess volume produces elevations in portal pressure that are avoidable and could precipitate variceal haemorrhage (Taylor, 1954).

Normal subjects tolerate acute reduction in whole blood volume approaching 1 litre without significant change in cardiac dynamics or hepatic venous pressure (Price, Deutsch, Marshall, Stephen, Behar, and Neufeld, 1966). Repeated episodic depletion of plasma volume and presumably reduction of portal pressure occurs covertly during diuretic therapy of cirrhotic patients with ascites (Shear, Ching, and Gabuzda, 1970). As evidenced by the favourable clinical response to diuretic therapy, the majority of cirrhotic patients with fluid retention may achieve a reduction in portal pressure without reducing plasma volume to the point where cerebral, renal, or hepatic perfusion is impaired.

We have observed individual patients with severe portal hypertension, probably due to markedly increased hepatic outflow resistance, who are not amenable to these manoeuvres. Depletion of plasma volume to a level where urine output ceases and shock supervenes leaves portal pressure markedly elevated (Kessler *et al*, 1969). On the other hand, patients presenting with oedema and ascites frequently have a significant amount of excess plasma volume that increases portal pressure and can be removed with immunity.

By emphasizing the portal pressure-blood volume relationship we wish to achieve precision in the management of patients with portal hypertension at risk from variceal haemorrhage. One hopes to tread the narrow path between the hazards of plasma volume depletion leading to hepatic and renal malfunction and plasma volume excess leading to increased portal pressure and its complications.

References

- Boyer, J. L., Chatterjee, C., Iber, F. L., and Basu, A. K. (1966). Effect of plasma-volume expansion on portal hypertension. *New Engl. J. Med.*, 275, 750-755.
- Irvin, T. T., Hayter, C. J., Modgill, V. K., and Goligher, J. C. (1972). Clinical assessment of post-operative blood volume. *Lancet*, 2, 446-449.

- Jackson, F. C., Perrin: E. B., Felix, W. R., and Smith, A. G. (1971). A clinical investigation of the portacaval shunt: V. Survival analysis of the therapeutic operation. *Ann. Surg.*, **174**, 672-701.
- Kessler, R. E., Santoni, E., Tice, D. A., and Zimmon, D. S. (1969). The effect of lymph drainage on portal pressure and bleeding esophageal varices. *Gastroenterology*, **56**, 538-547.
- Lieberman, F. L., and Reynolds, T. B. (1967). Plasma volume in cirrhosis of the liver: its relation to portal hypertension, ascites and renal failure. *J. clin. Invest.*, **46**, 1297-1308.
- Losowsky, M. S., and Atkinson, M. (1961). Intravenous albumin in the treatment of diuretic-resistant ascites in portal cirrhosis. *Lancet*, **1**, 386-389.
- Losowsky, M. S., Jones, D. P., Lieber, C. S., and Davidson, C. S. (1963). Local factors in ascites formation during sodium retention in cirrhosis. *New Engl. J. Med.*, **268**, 651-653.
- Nadler, S. B., Hidaigo, J. U., and Bloch, T. (1962). Prediction of blood volume in normal human adults. *Surgery*, **51**, 224-232.
- Price, H. L., Deutsch, S., Marshall, B. E., Stephen, G. W., Behar, M. G., and Neufeld, G. R. (1966). Hemodynamic and metabolic effects of hemorrhage in man, with particular reference to the splanchnic circulation. *Circulat. Res.*, **18**, 469-474.
- Prout, W. G. (1968). Relative value of central-venous pressure monitoring and blood-volume measurement in the management of shock. *Lancet*, **1**, 1108-1112.
- Rousselot, L. M., Moreno, A. H., and Panke, W. F. (1959). Studies on portal hypertension. IV. The clinical and physiopathologic significance of self-established (nonsurgical) portal systemic venous shunts. *Ann. Surg.*, **150**, 384-412.
- Shear, L., Ching, S., and Gabuzda, G. J. (1970). Compartmentalization of ascites and edema in patients with hepatic cirrhosis. *New Engl. J. Med.* **282**, 1391-1396.
- Taylor, F. W. (1954). Portal tension and its dependence on external pressure. *Ann. Surg.*, **140**, 652-660.