# Hemodynamics of the Interposition Mesocaval Shunt

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**Eighty interposition mesocaval shunts, using a knitted Dacron large diameter prosthesis, have been performed during the past five and one-half years. Patients were evaluated from the standpoint of protection from recurrent esophageal hemorrhage, shunt patency, encephalopathy and cumulative survival analysis. In a selected group of patients, hemodynamic measurements were also obtained in the pre, intra, and postoperative periods. These included measurements of wedged hepatic vein pressure, superior mesenteric venous blood flow, and residual superior mesenteric, hepatic sinusoidal and inferior vena cava pressures following the shunt procedure. Additionally, direct shunt flow measurements utilizing a square wave of electromagnetic flowmeter were also performed. Results indicate that the shunt patency is 95%; adequate decompression of the portal system was accomplished; recurrent variceal hemorrhage did not occur if the shunt remained patent; the incidence of encephalopathy was low (11%); and the operative mortality for the entire series was 9%. Continued perfusion of the liver was documented in 44% of patients and appears to be a function of the residual total portal resistance largely controlled by inferior vena caval pressure at the level of graft placement. Life survival analysis indicated that 72% of the patients were surviving at 5 years. It is concluded that the interposition mesocaval shunt appears to be an effective technique for the control of variceal hemorrhage, has important hemodynamic advantages and can be applied to most patients for the control of variceal hemorrhage due to portal hypertension.**

IN 1968, distressed with the numerous problems related to the use of portacaval or other shunts for the relief of hemorrhage from esophageal varices due to portal hypertension, we began a prospective evaluation of the interposition mesocaval shunt which consisted of a large diameter Dacron graft interposed between the superior mesenteric vein and the vena cava. Our initial results with this form of shunt in 25 patients were reported in early 1972[3] and we concluded that synthetic grafts, when placed between the superior mesenteric vein and the vena cava for the relief of portal hypertension, were extremely effective in protecting against recurrent hemorrhage, were easily performed, had a low operative mortality, remained patent and were accompanied with an extremely low incidence of hepatic encephalopathy. It was further suggested that a portion of portal flow to the liver could be maintained by this technique, in contrast to the total diversion of flow noted in the standard portacaval shunts.

Since our initial report, 55 additional patients have been offered this procedure. The present report constitutes our total experience to date with 80 such patients with particular emphasis on flow hemodynamics and cumulative life survival analysis.

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## Patient Selection

In Figure 1 is shown the classification of these 80 patients according to the criteria of Child, grouping the patients into Group A (excellent risk), Group B (moderate risk) and Group C (poor risk). The majority of patients (91%) were in the moderate and poor risk category and only 8% of the patients were excellent risks.

There were 52 men and 28 women with a median age of 46 years. The youngest patient was 21 years of age and the oldest was 69 years of age. All patients were admitted to the hospital because of the presence or history of acute variceal hemorrhage. No prophylactic shunts were performed in any patient who had never bled, despite the presence of varices.

Our initial management continues to be that of control of acute hemorrhage by Blakemore-Sengstaaken tube, restoration of blood volume, correction of metabolic al-

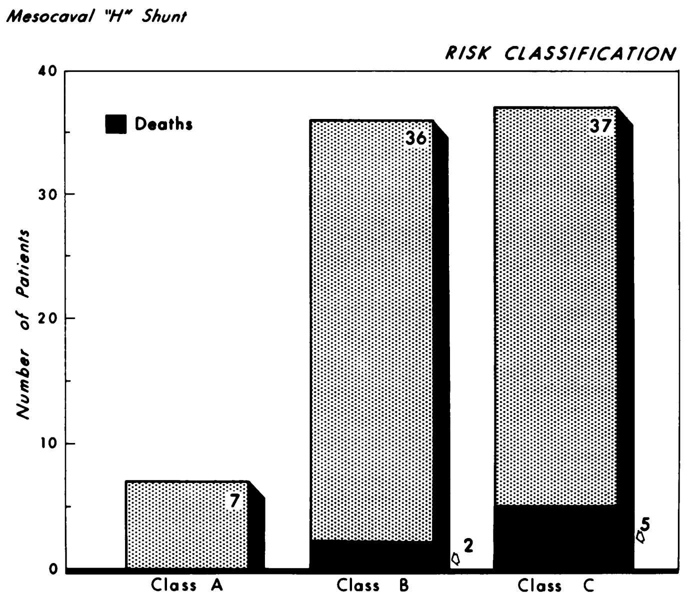



FIG. 1. Total patients in present series. Classification according to the criteria of Child.

terations, control of ascites and maximum improvement of hepatic function and nutrition. Such an elective preoperative course and evaluation was possible in 66 patients, however, in 14 patients the shunt was performed as an emergency or semi-emergency procedure early in the patient's hospital course because of continuing or recurrent hemorrhage despite the use of esophageal balloon tamponade. Thus, in 82% of the patients, the shunt was performed as an elective procedure, a factor which we believe most important in our low operative mortality and satisfactory results.

We continue to believe that the acutely bleeding cirrhotic patient with massive ascites, hypoalbuminemia, poor nutrition, and marked derangement of liver function with hepatic coma is not a candidate for emergency portacaval shunt and we do not perform a shunt under any circumstances in the latter type of patient. This approach is generally accepted by most authors in this field with the exception of Orloff and his associates[13] who continue to routinely use emergency portacaval shunts in all patients, albeit with a very high operative mortality in the poor risk group.

We have emphasized the correction of metabolic and biochemical abnormalities including hypokalemic alkalosis and secondary hyperaldosteronism which we have encountered in over two-thirds of our patients. With potassium ion replacement and the use of spironolactone to control hypokalemia and metabolic alkalosis, along with massive infusions of salt-poor albumin to restore oncotic pressure and to aid in the control of ascites, we have been able to markedly improve the condition of such patients, including the control of encephalopathy when present preoperatively.

Figure 1 also shows the operative mortality in this group of patients. It is predictably higher in the poor risk patient. We have had no deaths in the class A, good risk patient group to date. The overall operative mortality in the entire series was 7 patients (9%) and this has remained essentially unchanged since our initial report.

## Method

Our operative technique has been previously described[3,4] but important additional details gleaned from our larger experience are herewith presented. Most important of these relates to the *diameter* of the graft. In both experimental and clinical studies it has been definitely shown that synthetic grafts of small diameter will uniformly occlude in the immediate postoperative period. This is undoubtedly related to turbulence which, when combined with lower flows and pressures in the venous system along with the development of a thick neo-intima, will result in too small a channel in the graft to maintain flow. It has been brought to our attention that a number of surgeons during the past few years have interposed a small diameter graft (8-10mm in size) based on the erroneous concept that this will diminish shunt flow significantly in order to maintain portal perfusion and decrease the incidence of encephalopathy. In our experience such grafts are doomed to failure and we caution against their use. Furthermore, as will be subsequently detailed in our hemodynamic measurements, flow through a large diameter (18-20 mm) graft is dependent on a variety of more important factors.

Extreme care must be taken in the approach to and the dissection of the superior mesenteric vein, lest injury to the main vessel or one of its branches occur, resulting in massive hemorrhage from this high pressure system. Our approach to the superior mesenteric vein is initially directed at the root of the transverse mesocolon where the main trunk of the superior mesenteric vein crosses the fourth portion of the duodenum, just distal to the middle colic branch take-off. An important landmark here is the third position of the duodenum as it crosses beneath the superior mesenteric vein and we have found that by initially mobilizing this portion of the duodenum, the vein can be approached laterally and if necessary adequate control of bleeding can be obtained by compression of the mesenteric vein between the index finger and thumb.

We occasionally find during the dissection of the anterior surface of the retroperitoneal vena cava that it is covered by a thick, edematous layer of fibro-areolar tissue containing numerous venous collaterals. We do not hesitate to use the electrocautery freely in coagulating even the tiniest of venous collaterals and lymphatic channels in

TABLE 1. *Hemodynamic Studies in Patients undergoing interposition mesocaval shunt obtained intra-operatively.**

| | Pre-shunt | Post-shunt | % Change |
|---|---|---|---|
| Superior mesenteric vein pressure (mm $H_2O$) | 342 ± 56 | 168 ± 22 | ↓ 51% P <0.001 |
| Inferior vena cava pressure (mm $H_2O$) | 127 ± 46 | 165 ± 22 | ↑ 30% P <0.01 |
| Superior mesenteric vein flow (ml/min) | 258 ± 42 | 293** ± 159 | ↑ 14% P >0.05 |

*Post-shunt flow obtained directly on graft. Pressure change in the inferior vena cava and the superior mesenteric vein were significant by Student's test. Shunt flow was not significantly different from flow in the superior mesenteric vein prior to shunt.
**Shunt Flow Measured in 4 Patients

this area for we have found that this markedly reduces operative blood loss and postoperative ascites.

We continue to prefer the large diameter (18 mm) knitted Dacron graft but have recently changed to the Weaveknit® type prosthesis which is softer and easier to suture in place. The operative time for the procedure averages 2 hours or less and rarely is more than 1 unit of blood needed for the entire procedure.

### Intra-operative Hemodynamics

Intra-operative portal pressure measurements were obtained in every patient in this series before and after the mesocaval shunt (Table 1). A satisfactory reduction of portal pressure as measured through the superior mesenteric vein was noted in every patient, with a mean reduction of 51 percent. As previously pointed out, the reduction in portal pressure obtained by this technique was not as dramatic as that previously noted by ourselves and by others following a standard end-to-side portacaval shunt. The mean post-shunt portal pressure in this series was 168 mm of water and this initially caused concern. However, simultaneous measurements of inferior vena cava pressure after the completion of the shunt revealed a 30% rise to a mean of 165 mm $H_2O$. This caval pressure was practically identical to the mean residual portal pressure after the shunt and confirmed our thesis that the resulting caval pressure (out-flow pressure) was the controlling factor responsible for the residual pressure in the portal system. It is further evident from these pressure measurements that there was very low resistance across the shunt or a mean shunt pressure gradient from the superior mesenteric vein to the inferior vena cava of only 3 mm of water. We believe that it is this low resistance across the shunt which may also be responsible for the high rate of shunt patency encountered in this series. These residual portal vein pressures are in the same order of magnitude as those obtained by Linton and his associates following a standard splenorenal shunt[8] and by Bismuth and his associates after splenorenal anastomosis or after a partial direct portosystemic shunt by "small stoma" side-to-side portacaval anastomosis.[2]

Of further interest in these measurements is the value of flow through the anastomosis obtained by a noncannulating square wave electromagnetic flowmeter with a probe placed directly on the shunt. In these patients a mean shunt flow of 293 ml/min was encountered with a range of 134 ml/min to 452 ml/min. When compared to superior mesenteric vein flow obtained prior to the shunt by the flowmeter in these same patients it is noted that there was only a minimal rise in flow through the graft from 258 ml/min to 293 ml/min (Table 1). This 14% increase in flow was not significant and indicates that almost all of shunt flow was derived from the superior mesenteric vein. Based on portal flow measurements previously reported by us,[17] McDermott,[10] Warren[23] and Moreno and their associates[11,12] we conclude that this shunt flow represented at best no more than 50% of total portal blood flow. It can be further concluded that the shunt was obviously draining most, if not all, of the superior mesenteric vein flow and that no significant reversal of portal flow was occurring through the shunt inasmuch as direct measurement of shunt flow revealed it to be almost identical to superior mesenteric venous flow.

These hemodynamic studies confirm our earlier conclusion which was derived from angiographic studies, that the interposition mesocaval shunt was not necessarily a totally diverting shunt and that perfusion of the liver through the main portal vein was probably occurring in a significant proportion of patients, particularly in those in whom hepatic sinusoidal resistance was sufficiently low to permit this.

In Figure 2 is the pressure tracing obtained in one of our patients at the inferior vena cava before and after the shunt. The clear and distinct rise in caval pressure is noted as is the suggested pulsatile nature of the pressure in the inferior vena cava after the shunt. The latter observation appears to confirm the observation by others, that

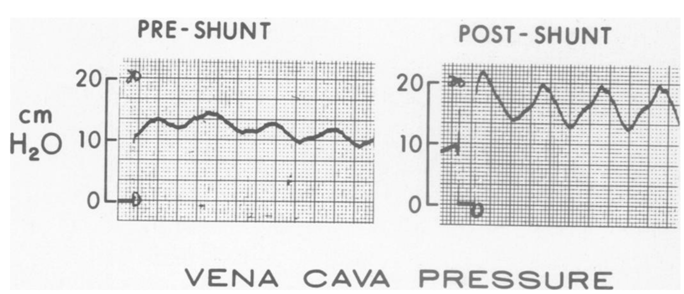
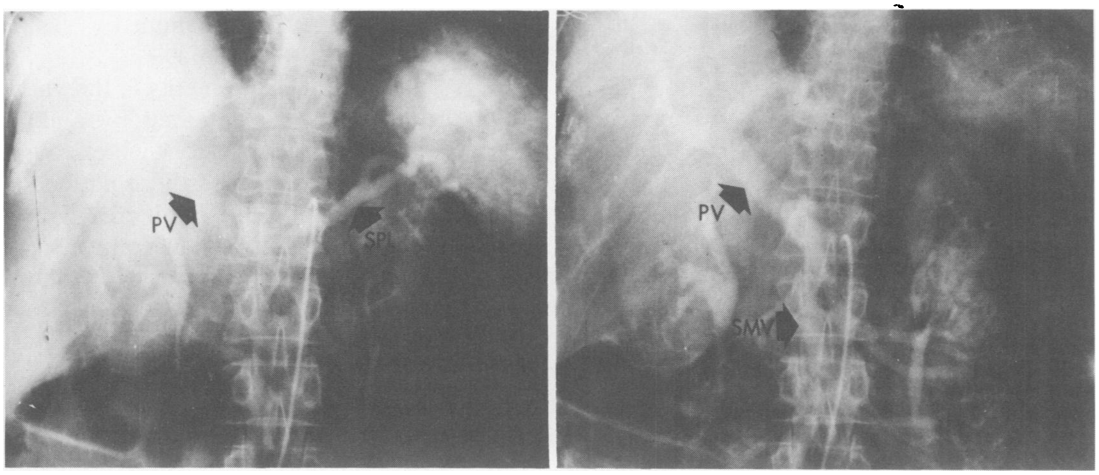



FIG. 2. Measurement of inferior vena caval pressure at level of interposition shunt, immediately prior to and after formation of the shunt. Mean caval pressure rises from 12 cm of water to 16 cm of water in this patient. The almost pulsatile nature of the caval pressure is also demonstrated.




FIGS. 3A and B. Visualization of portal venous system in patients with portal hypertension by selective celiac (A, left) and superior mesenteric (B, right) angiography. The venous phase of the contrast medium filling the splenic and portal veins is shown in A. The superior mesenteric vein and its branches are shown in B.

arteriovenous shunts may exist in the submucosa of the intestine in patients with portal hypertension and that these may play a role in the hyperdynamic cardiovascular status often encountered.

## Angiographic Studies

Preoperative angiographic evaluation of the portal system by selective visceral arteriography was performed in most patients when their general condition permitted this. This information was deemed important not only to delineate the patency of the portal venous system and its major branches but also to determine indirectly the status of portal perfusion of the liver. An example of the type of information which can be obtained in the average patient is shown in Figs. 3A and B.

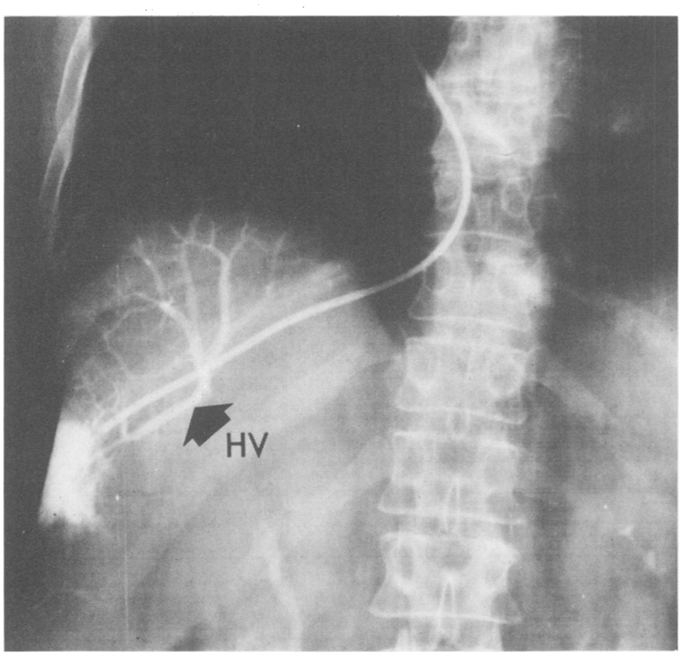
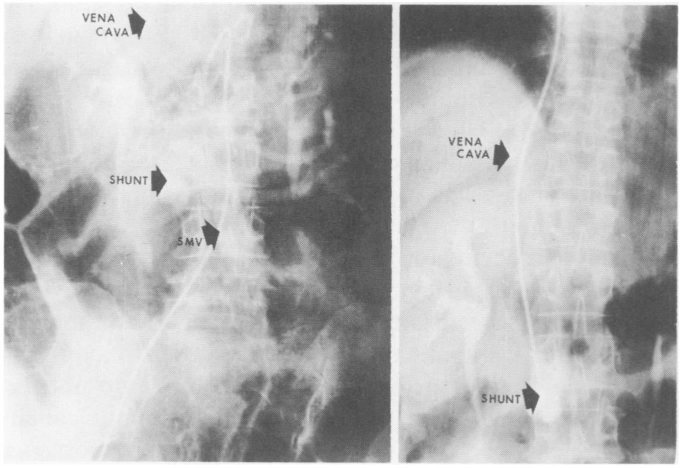



FIG. 4. Technique of hepatic vein wedge pressure measurements and injection of contrast medium to determine magnitude and direction of hepatic venous flow in same patient.

Similarly, hepatic vein wedged pressures were obtained by retrograde inferior vena cava and hepatic vein cannulation in the majority of patients in an attempt to correlate preoperative wedged hepatic vein pressure to the direct intraoperative measurement of portal vein pressure. In 35 patients the preoperative hepatic vein wedged pressure of 329 mm of water compared most favorably to a mean intraoperative portal pressure of 342 mm/$H_2O$ through the superior mesenteric vein. The difference between these measurements of 13 mm/$H_2O$ was not statistically significant and we therefore can infer from these studies that measurement of hepatic vein wedged pressure gives an accurate assessment of mean portal pressure.

Figure 4 depicts a retrograde hepatic vein wedge injection of contrast medium and filling of hepatic vein radicals. There was rapid clearing of the contrast material indicating good portal flow through the liver in this same patient preoperatively.

Angiographic demonstration of shunt hemodynamics was also obtained in 45 patients at varying intervals following the shunt, up to 5 years postoperatively. The simplest technique to determine graft patency involves retrograde catheterization of the shunt *via* the femoral vein and the vena cava (Fig. 5B). However, we continue to prefer selective celiac and superior mesenteric arterial angiography which also permits an accurate assessment of the arterial and venous flow dynamics in such patients. This is depicted in Fig. 5A and visualization of the shunt with rapid emptying into the inferior vena cava can be readily appreciated following injection of a 50 cc bolus of contrast medium into the superior mesenteric artery and following the egress of the dye with multiple films obtained with a rapid change cassette over a 15-20 second period.




FIGS. 5A and B. Patency of the interposition graft by selective superior mesenteric injection (venous phase) is shown (A) (left). Rapid egress of contrast medium into the vena cava occurs and within two seconds all dye has left the shunt. (B right) The shunt is also visualized by retrograde cannulation *via* the inferior vena cava.

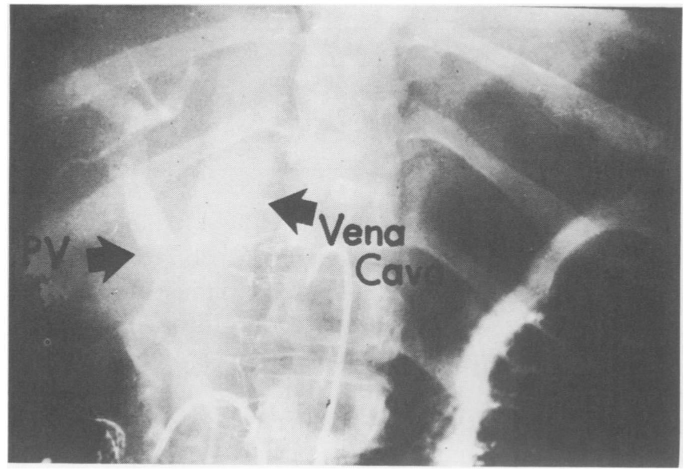



FIG. 7. Simultaneous demonstration of shunt patency with egress of dye in inferior vena cava and portal perfusion *via* the portal vein is shown from another patient. Two injection catheters were used in this patient and a bolus of contrast medium was injected simultaneously into the celiac axis and the superior mesenteric artery.

In Fig. 6 is shown, in the same patient as Figs. 5A and B, filling of the portal vein obtained by injection of contrast medium *via* the celiac axis. This flow does not appear to be static in the portal vein for the "blush" of the contrast material can be seen in the hepatic parenchyma and there is rapid emptying of this contrast material without further visualization of the shunt. In this particular patient it can therefore be assumed that the bulk of shunt flow was from the superior mesenteric vein while the bulk of splenic and portal flow was continuing to perfuse the liver.

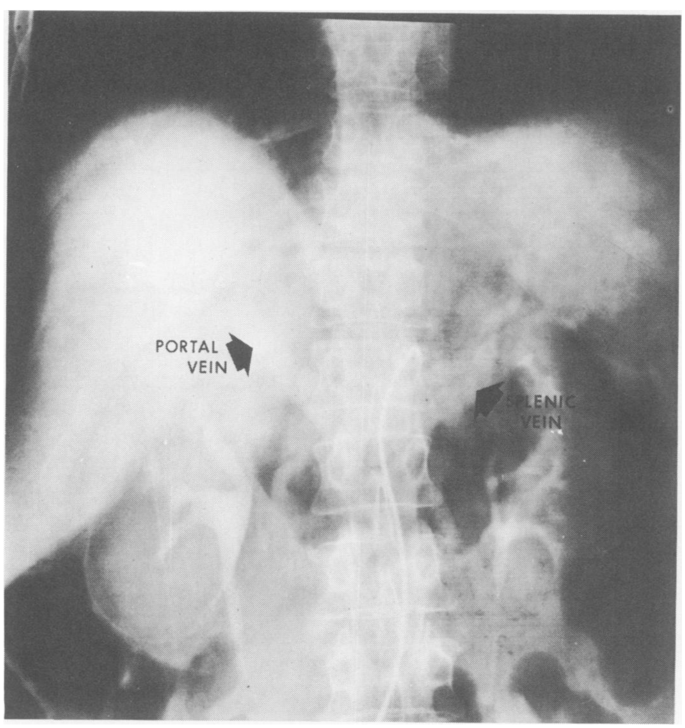



FIG. 6. Demonstration of continued hepatic perfusion *via* portal vein in the same patient obtained by selective celiac injection (venous phase). Rapid egress of contrast medium into the portal vein and liver is shown and the "blush" of contrast medium within the liver confirms hepatic portal perfusion.

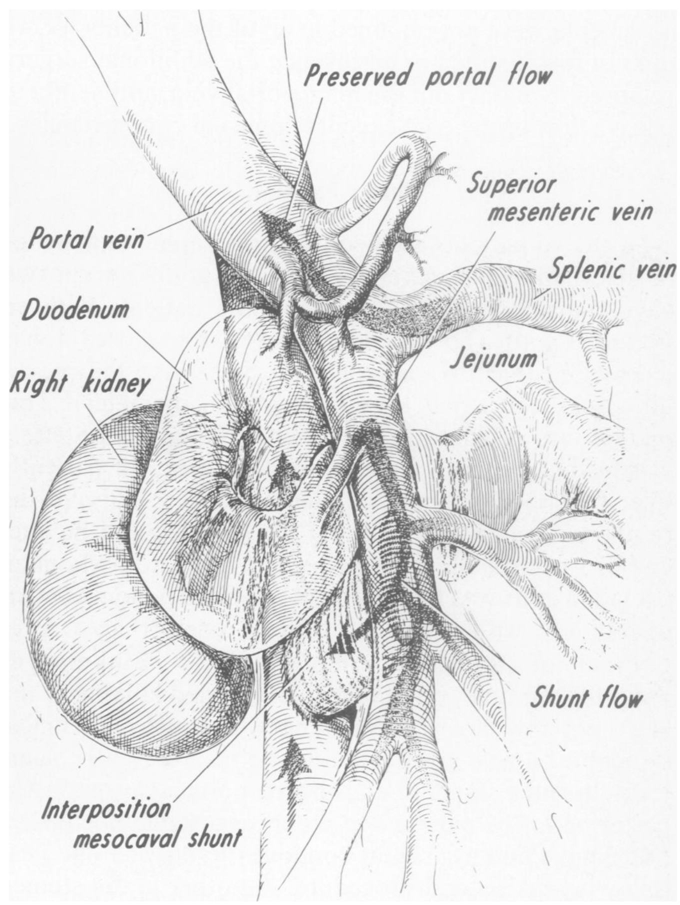



FIG. 8. Concept of partition of flow of the portal system following interposition mesocaval shunt.

TABLE 2. *Incidence of Encephalopathy.*

| | Total Survivors | Encephalopathy | | |
|---|---|---|---|---|
| | | Mild | Moderate | Severe |
| Class A | 7 | 0 | 0 | 0 |
| Class B | 34 | 2 | 0 | 0 |
| Class C | 32 | 4 | 2 | 1 |

Another example of continued perfusion of the liver is shown from another patient (Fig. 7). In this patient simultaneous injection of contrast medium through the celiac axis and the superior mesenteric artery reveals rapid filling of the cava *via* the shunt and also rapid filling of the portal vein and the intra-hepatic portal radicals, again indicating continued perfusion of the liver. We have been able to demonstrate hepatic portal perfusion in 20 of the 45 patients (44%) studied by this technique.

Figure 8 depicts our concept of portal flow redistribution in these patients following a successful interposition mesocaval shunt based on angiographic and flow studies. Hepatic perfusion from the portal vein is maintained from the spleen and pancreas while the superior mesenteric venous flow is diverted through the shunt. Nevertheless, what proportion of total preshunt flow this represents cannot be accurately stated for direct portal flow measurements were not obtained in all of the patients for we did not feel justified in performing the additional surgery required to dissect out the main portal vein sufficiently to place a flow probe on it except in unusual circumstances.

## Shunt Patency

Of the 45 patients studied by angiographic techniques to determine shunt patency, all of the grafts except two have remained patent. In one of the patients with an occluded graft who was subsequently re-explored it was discovered that the surgeon who performed the procedure used too small a graft (8 mm in diameter). This patient was re-admitted with hemorrhage and an effort was made to insert a larger graft. However, the patient's liver function was not sufficiently good to survive the re-operation and the repeated hemorrhage and he succumbed to liver failure. The second patient in whom an occluded graft was found was re-admitted 6 months postoperatively with recurrent variceal hemorrhage. After control of the hemorrhage with a Blakemore-Sengstaaken tube, re-exploration revealed kinking of the graft, possibly due to excess length. Because of technical difficulties a new graft could not be inserted in the same location and a standard end-to-side portacaval shunt was performed. The patient had an unremarkable postoperative course and at present continues to do well one year following his second procedure. All other grafts studied to date have remained patent and our longest followup is 67 months.

Additionally, we have been able to evaluate shunt patency in 11 patients who have succumbed to their liver disease during the followup period. In 10 of the latter grafts there was complete patency with a smooth, glistening, pseudo-intima on the inner surface of the graft. One of these deaths, which occurred 3 weeks after the operative procedure, was a patient in whom a febrile course was encountered. At autopsy the graft was found to be infected and occluded. This patient, encountered early in our series, also had a gastrotomy and transgastric ligation of the varices performed at the initial operation and we suspect that contamination of the peritoneal cavity and the graft was responsible for the sepsis. We do not feel that it is necessary to ligate varices if a shunt can be accomplished and now prefer to control hemorrhage even in the acute bleeder by the continued use of the Blakemore-Sengstaaken tube if necessary throughout the operative procedure.

Our total experience with those patients studied either angiographically or at autopsy indicates that 3 out of 56 grafts thus studied have occluded, for a patency rate of 95% for the entire group. We are now in the process of evaluating the remaining patients but graft patency may be inferred for there have been no further episodes of hemorrhage in these patients in long-term followup.

## Encephalopathy

The incidence of encephalopathy encountered in our series of 80 patients is depicted in Table 2. Encephalopathy of some degree was encountered in nine

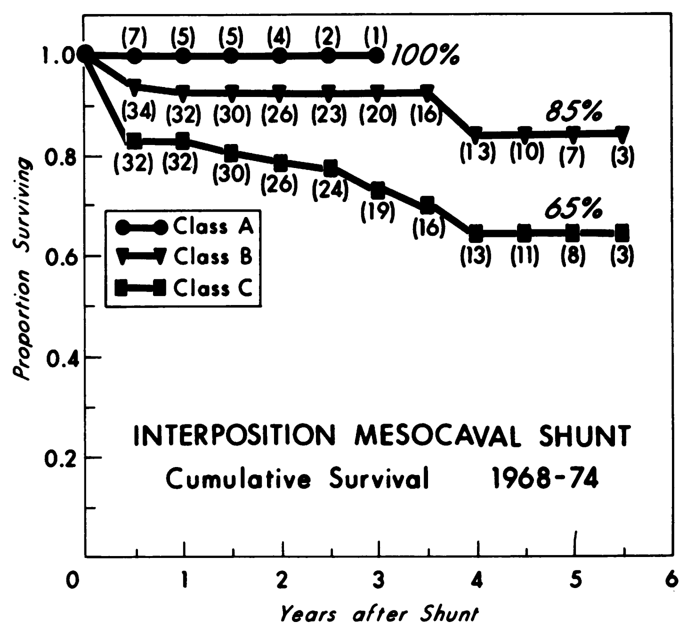



FIG. 9. Cumulative life survival table—80 patients with interposition mesocaval shunt, according to preoperative risk classification.

patients or a rate of 11 per cent. It should be noted however that many of these patients had encephalopathy preoperatively and it is difficult, if not impossible to determine what role the interposition mesocaval shunt played in producing encephalopathy in this small group of patients. This incidence of encephalopathy compared favorably to that obtained following splenorenal shunt by Grace, *et al.*,[6] Barnes, *et al.*,[1] Bismuth, *et al.*,[2] Linton,[8] and McDermott.[10]

### Cumulative Survival

Our earlier impressions that these patients were doing very well in the followup period are confirmed by the long-term followup in the group of 80 patients. Figure 9 depicts the cumulative 5-year survival curve, calculated by the actuarial method of analysis. A separate curve is shown for the A, B and C risk groups. Of interest is the fact that there has been no operative mortality or followup mortality in the 7 patients in the good risk group. Nor have we encountered any encephalopathy in this group. All patients have returned to work and appear to be leading a normal life. However, the followup in this group of patients is not as long as in the intermediate or poor risk groups for we began applying the interposition mesocaval shunt to the A-risk patients only recently after we had become convinced of the efficacy of this procedure in the poorer risk patient. In the 5 year followup to date there is an 85% cumulative survival in the 36 patients who were in the intermediate risk (class B) category and 65% in the 37 patients in the poor risk (class C) category. The cumulative survival derived for the entire group is depicted in Fig. 10 as an overall 72% cumulative 5-year survival.

It appears clear from these survival curves that our survival experience is better than that reported by many investigators following standard, elective portosystemic shunts,[1,6,7,10,15] except possibly for the recent reports by Lord,[9] Bismuth[2] and that of Stipa and associates[20,21] who had survival rates almost identical to ours. However, it must also be noted that 60% of the shunts performed by Bismuth, *et al.* were standard splenorenal shunts and that all of the 53 patients operated upon by Stipa and his associates had an interposition mesocaval shunt.

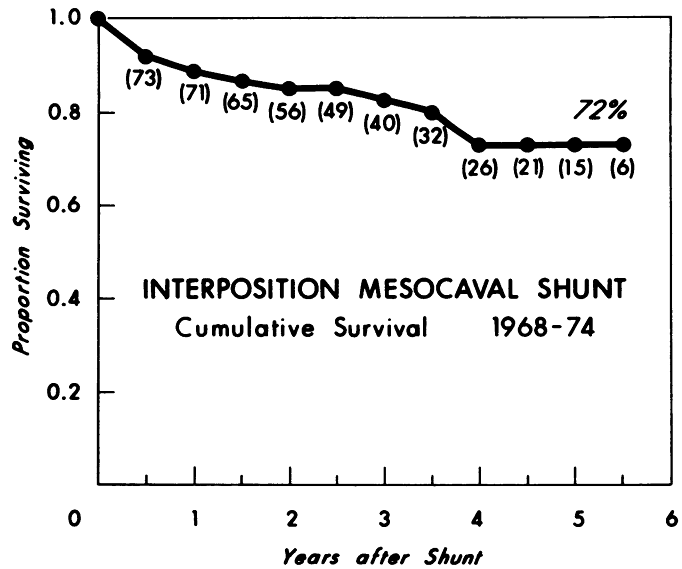


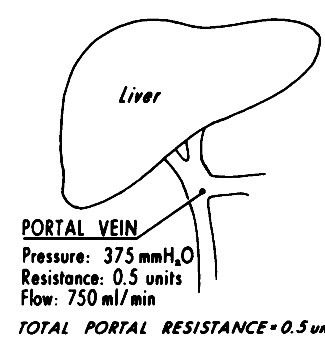

FIG. 10. Cumulative life survival analysis of entire group of patients.

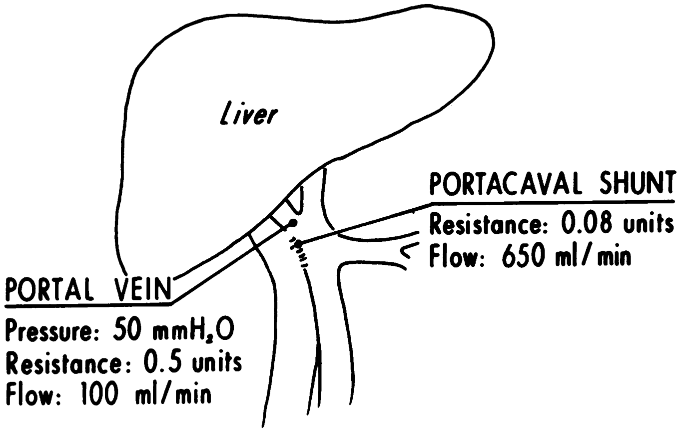
### Discussion

Based on the observed hemodynamic changes we have derived an electrical analogue which fits well with the intraoperative studies obtained in our patients. In Fig. 11A are shown pressure and flow measurements obtained from a patient before the performance of a side-to-side portacaval shunt. By direct measurement of portal vein flow, hepatic arterial flow and wedged sinusoidal pressure, total intrahepatic sinusoidal resistance can be calculated as shown. As expected, following side-to-side portacaval shunt, a marked drop in portal pressure to 50 mm of water resulted in almost complete diversion of portal flow (Fig. 11B). Because sinusoidal resistance remains fixed due to the pathological changes within the liver, it is not surprising that in many of these patients a side-to-side portacaval shunt results in total or near total deprivation of portal flow as suggested by Warren and his associates.[16,23,24] On the other hand, following interposition mesocaval shunt (Fig. 11C), it can be seen that a higher residual pressure in the portal system remains following the shunt and that in this patient only 50% of total portal flow was diverted from the liver. Salam and his associates[16] have also noted the same phenomenon after a splenorenal shunt and attributed it to the inability of the left renal vein to accommodate the increased flow without an elevation of pressure. Our studies would seem to indicate that the flow through the interposition mesocaval shunt is not a function of the large graft diameter for there was only a 3 mm pressure gradient across the shunt, but rather a function of the outflow pressure determined by the vena cava capacitance.

Numerous investigators have recently shown a lack of

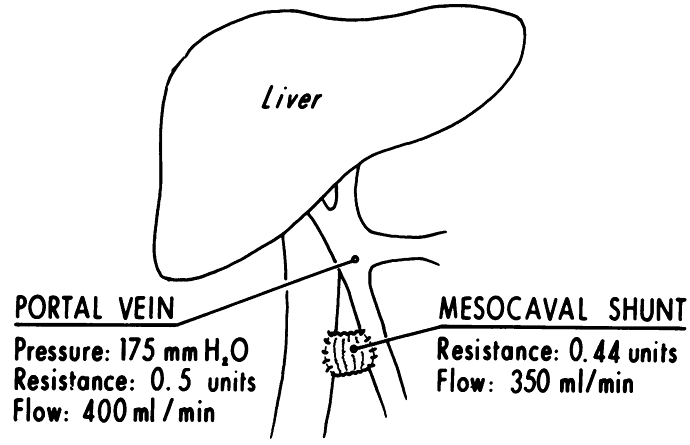
FIG. 11A. Pressure and flow measurements are depicted in a patient with cirrhosis prior to shunt.






*TOTAL PORTAL RESISTANCE = 0.07 units*

FIG. 11B. Measurements obtained following standard side-to-side portacaval shunt.




*TOTAL PORTAL RESISTANCE = 0.23 units*

FIG. 11C. Measurements obtained from another patient following interposition mesocaval shunt. It will be noted that total portal resistance following interposition mesocaval shunt (0.23 units) is considerably higher than following side-to-side portacaval shunt (0.07 units) but lower than the patient prior to the performance of the shunt (0.05 units).

correlation between the magnitude of portal pressure before portacaval anastomosis and the volume of portal flow. Moreno and his associates,[11] in studying 85 patients with cirrhosis, found an average portal flow of 6.5 ml/min/kg, measured by the square wave electromagnetic flowmeter. They concluded that the portal flow correlated poorly with portal pressure for some of the highest portal pressures are encountered in patients with the highest flows and *vice versa*. They also noted that portal flows ranged from static flow with only a slight to and fro motion during respiration to as high as 25 ml/min/kg, the latter figure well within the range of total portal blood flow encountered in normal subjects. If we apply these mean portal flow measurements to our patients following interposition mesocaval shunt we conclude that approximately 50% of total portal flow is diverted through the shunt. We can further conclude that shunt flow essentially represents superior mesenteric venous flow. On the other hand, it is also likely in those patients with balanced or stagnant portal flow resulting from very high sinusoidal resistance that total portal diversion might occur even at the flow rates measured through the shunt.

In a recent report by Moreno, *et al.*,[12] it was further concluded that there was no analytical or clinical relationship between changes in pressures on the hepatic end of the occluded portal vein (hepatic occluded portal pressure) and preshunt portal flow, nor could any correlation be found between the occluded portal pressures and postoperative survival. Similar conclusions have been reached by Smith[18] and by Orloff and his associates.[13]

Maintenance of portal perfusion of the liver following interposition mesocaval shunt measured by angiographic technique has also been confirmed by Thompson and Read,[22] by Lord and his associates,[9] and by Stipa.[21] Reichle[14] has measured portal blood flow in a series of patients pre- and postoperatively using an unique quantitative technique of infusing droplets of lipiodol directly into the portal vein *via* the cannulated umbilical vein. He demonstrated that following interposition mesocaval shunt in a small number of patients, approximately half of the portal flow continued to perfuse the liver. Mean preshunt portal flow was 529 ml/min and this was reduced to 246 ml/min postshunt. By extrapolation, the average mesocaval shunt flow in his patients was 283 ml/min which agrees closely with our average measured shunt flows of 293 ml/min. Interestingly, the reduction of portal flow following interposition mesocaval shunt was of the same magnitude as the reduction in portal flow measured by him in a parallel series of patients who had undergone a distal splenorenal shunt according to the technique of Warren.[24]

In a significant experimental study in animals reported by Starzl and his associates[19] he found that perfusion of the liver by pancreatic venous blood flow was important in maintaining the integrity of the liver. Starzl has postulated that this important substance may be insulin and that it is important to preserve this portion of pancreatic blood flow to the liver. This evidence lends strong support to the need for maintenance of a portion of portal flow, particularly from the upper abdominal viscera as has been demonstrated in our patients following interposition mesocaval shunt.

Using our hemodynamic studies we have developed an electrical analogue of the portal system (Fig. 12). In this analogue we have shown in electrical terms the measurements derived in a patient with portal hypertension prior to a shunt; following a side-to-side portacaval shunt; and following an interposition mesocaval shunt. It

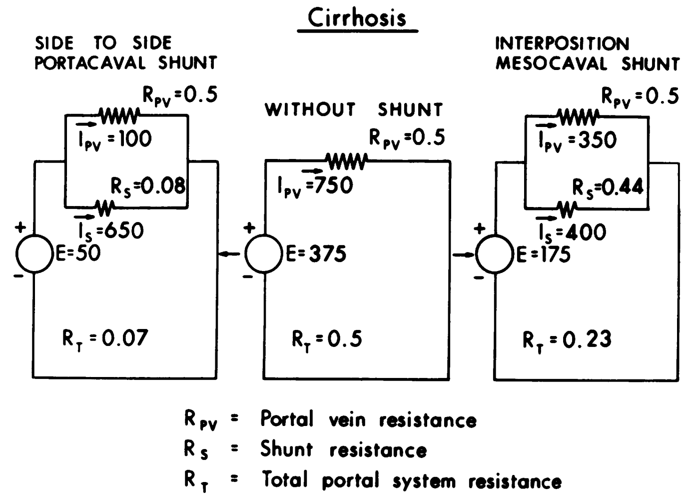



FIG. 12. Electrical analogue of portal system based on pressure and flow measurements in this series of patients.

can be seen that there is a good correlation between the predicted flows and pressures in the theoretical analogue and the actual measurements obtained in Fig. 11. We are now applying this analogue to intraoperative hemodynamic studies in order to evolve a better understanding of portal hemodynamics in cirrhosis.

Finally, it should be stated the results we have encountered in this series to date should not necessarily be attributed entirely to the type of shunt being performed. We feel that equally as important is the careful management of the patient preoperatively, control of hemorrhage by balloon tamponade, restoration of metabolic imbalances, potassium repletion and the use of aldosterone antagonists. Similarly, careful postoperative care is required in such patients including the administration of albumin, monitoring of serum electrolytes, particularly potassium, and the maintenance of nutrition. With better preoperative preparation of the patient and improved postoperative care in addition to a simpler operative technique which preserves at least a significant portal blood flow we feel that the whole outlook on the surgical management of portal hypertension has changed.

## Conclusions

We conclude from this study of 80 patients with interposition mesocaval shunt that the shunt is readily performed, carries a low operative mortality (8%), a low incidence of encephalopathy (11%) and that is can be applied to most, if not all patients with portal hypertension due to cirrhosis of the liver. In 44% of the patients continued perfusion of the liver was demonstrated by angiographic techniques. Shunt flow was measured at 293 ml/min, a figure which is approximately 50% that of calculated mean portal flow in these patients.

Cumulative life survival tables indicate an overall 75% 5-year survival in the entire group. It was 100%, 85% and 65% for the good, intermediate and poor risk patients, respectively.

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