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Portal Pseudoperfusion

An Angiographic Illusion

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Much confusion regarding the hemodynamics following interposition mesosystemic shunts prevails. Many authorities have claimed that portal venous perfusion continues following interposition mesocaval shunts. In 1971, a prospective, randomized trial comparing the distal splenorenal shunt with a variety of interposition mesosystemic shunts (primarily mesocaval or mesorenal) was begun. Visceral angiography was utilized to assess the early and late postoperative hemodynamic changes following both selective and nonselective shunts. None of the patients with patent interposition shunts retained portal perfusion present preoperatively. Searching for an explanation for this hemodynamic discrepancy, we examined two patients of the randomized trial angiographically. Both patients had excellent portal perfusion preoperatively, yet following interposition shunting (one mesocaval and one splenocaval), neither maintained portal perfusion of the liver. Celiac artery injections produced opacification of the entire splenoportal axis; however, it is shown that such portal venous opacification occurred in a retrograde direction by selective hepatic arterial injections demonstrating hepatofugal portal venous flow. Additionally, two nonrandomized patients received interposition mesorenal shunts and exemplify this phenomenon, entitled "portal pseudoperfusion." The explanation for conflicting literature reports lies in the misinterpretation of venous phase celiac and nonselective SMA arteriography in determining the direction of portal flow. A narrative of preoperative and postoperative angiograms of four patients will clarify the mechanism of "portal pseudoperfusion" and demonstrate that interposition shunts totally siphon portal venous perfusion. Clues to the detection and techniques to avoid this phenomenon will be presented.

WIDE CLINICAL EXPERIENCE with the interposition mesocaval shunt popularized by Drapanas has documented its effectiveness in portal decompression by virtually eliminating the threat of recurrent variceal bleeding. Its technical simplicity compared to the distal splenorenal shunt, and claims by Bismuth,[1] Drapanas,[2] Webb,[14] Stipa,[10] and Thompson[11] of preservation of portal perfusion following the mesocaval shunt, further entice the surgeon to employ this more expeditiously performed shunt. The experience at the Emory University Affiliated Hospitals contrasts with the above authors and has demonstrated that interposition mesosystemic shunts are functionally and hemodynamically identical to the side-to-side portacaval shunt; *i.e.*, the cost of performing these shunts is total deprivation of portal venous perfusion.

Recently a prospective, randomized trial comparing the distal splenorenal shunt with a variety of nonselective portasystemic shunts was completed. The

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majority of patients in the nonselective group underwent either interposition mesocaval or mesorenal shunts. One criterion required for entry into the trial was the presence of hepatopetal portal perfusion demonstrated by venous phase superior mesenteric or splenic arteriography or by splenoportography. No patient following interposition mesocaval or mesorenal shunting demonstrated preservation of portal perfusion that was demonstrated preoperatively. This loss of portal venous perfusion was abrupt, as demonstrated by early postoperative arteriography. As long as the shunt remained patent, no unequivocal portal perfusion could be demonstrated angiographically at any interval following surgery. This hemodynamic discrepancy among different authors warrants explanation. The purpose of this report is to examine by angiography the portal hemodynamics following interposition mesosystemic or splenocaval shunting and to demonstrate that the mesocaval, mesorenal, and splenocaval shunts are truly nonselective or total shunts. An explanation of how other authors might have misinterpreted abdominal angiography following their interposition mesocaval shunts will be proposed.

Materials and Methods

Cases 1 and 2 are patients electively admitted to the Clinical Research Facility at Emory University Hospital for yearly longitudinal metabolic and hemodynamic assessment as both are members of the randomized portasystemic shunt trial begun in 1971.[7] These patients were selected to illustrate the "portal pseudoperfusion" phenomenon as they were to undergo visceral angiography as a routine follow-up procedure and were deemed safe candidates to receive the small amount of additional contrast necessary.

Case 3 underwent routine postoperative visceral angiography to document shunt patency prior to discharge and was also considered a safe candidate for the additional contrast. Angiograms from Case 4 were extracted from the Radiology teaching file to further demonstrate this phenomenon. All patients underwent visceral angiography with informed consent. No patient was preselected because of any known anatomic or radiographic peculiarity demonstrated previously; therefore, we feel these patients at varying intervals following surgery are representative of the entire group of patients of interposition portasystemic shunts.

Case Reports

Case 1. A 35-year-old Caucasian man with Laennec's cirrhosis underwent an elective dacron interposition mesocaval shunt for recurrent massive variceal hemorrhage in March, 1976. His early postoperative convalescence was benign; however, two years following surgery he has suffered infrequent episodes of portasystemic encephalopathy, but no evidence of recurrent variceal bleeding, jaundice, ascites, or peripheral edema. Recently his fasting NH_3 level was 125 μg/dl (normal $\leq$ 50 μg/dl) with NH_4Cl index >14,000 (normal <1,000 μg-min/dl). Quantitative liver function tests; *i.e.*, galactose elimination capacity, antipyrine clearance and half-life, and maximal rate of urea synthesis, have demonstrated marginally preserved liver function despite normal liver enzymes and minimally deranged coagulation profile and serum proteins.

This patient's sequence of angiography is as follows: Preoperatively, the venous phase of the superior mesenteric artery injection demonstrates hepatopetal portal flow (Fig. 1). The SMA injection (Fig. 2) on venous phase (Fig. 3), performed two years postoperatively, demonstrates opacification of the superior mesenteric vein, Dacron® graft, and inferior vena cava. Note that the entire mesenteric flow is diverted through the shunt. There is no contrast within the portal vein or liver.

A selective splenic artery injection (Fig. 4) was performed next, with the venous phase of this injection (Fig. 5) demonstrating opacification of the splenic vein and inferior vena cava. The graft itself is not well visualized due to the diluted contrast's overlying a background of the radiodense vertebral column, but note that there is no portal vein or liver parenchymal opacification to suggest prograde portal flow. There is no evidence that gastrosplenic or mesenteric compartment blood continues to perfuse the liver following this mesocaval shunt.

The selective hepatic arterial injection is critical in understanding the "portal pseudoperfusion" phenomenon. The catheter has been placed just proximal to the gastroduodenal artery (Fig. 6), as more peripheral placement was judged unwise because of the risk of thrombosis and, thus, possible total hepatic blood flow deprivation. Delayed venous phase films (Fig. 7) demonstrate opacification of the portal vein, and the curtain of contrast can be followed in an hepatofugal direction emptying into the shunt. This is unequivocal evidence that the portal vein has been converted to an outflow tract, as seen following side-to-side portacaval shunts in the Budd-Chiari syndrome, as well as occurring spontaneously in cirrhosis.[4,6,8,9,12] The portal flow is siphoned through the shunt and thus cannot contribute to nutrient portal perfusion.

The wedged hepatic vein injection (Fig. 8) further confirms the finding that the portal vein is patent and flow in this patient is hepatofugal.

Most important, however, is the celiac axis injection, which will demonstrate the "portal pseudoperfusion" mechanism. Withdrawal of the catheter into the celiac axis with contrast injection opacified both the hepatic and splenic arteries (Fig. 9). The delayed venous phase films (Fig. 10) demonstrate simultaneous opacification of both splenic and portal veins. The opacification of the splenoportal axis following celiac injection suggests hepatopetal flow; however, the previous selective splenic and hepatic artery injections invalidate this interpretation. Clearly, the hepatofugal portal venous flow admixing with hepatopetal splenic venous flow gives the illusion of net hepatopetal portal perfusion. This demonstrates that the celiac axis injection is not a reliable method of determining portal perfusion following portasystemic shunts. Celiac axis injections have led to widespread fallacious interpretations of the hemodynamic status following shunting procedures and have compounded the difficulty of comparing various shunts with regard to their effect upon portal flow.

Comment

Case 1 is a classical example of the "portal pseudoperfusion" phenomenon. A celiac axis injection alone would have led to the erroneous conclusion of the presence of prograde portal flow. The selective splenic and

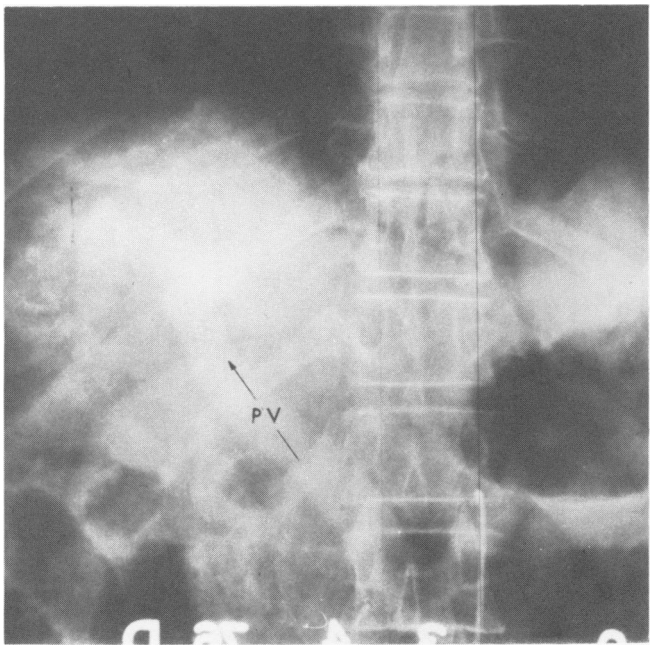

FIG. 1. Case 1: preoperative SMA venous phase angiogram demonstrates prograde portal flow (portal vein = PV).

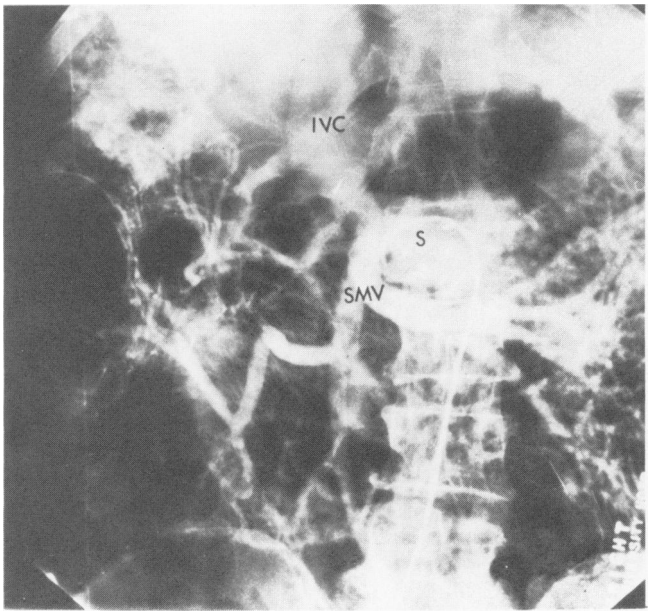

FIG. 3. Case 1: venous phase of SMA injection (Fig. 2). Mesenteric flow is totally siphoned through the shunt (superior mesenteric vein = SMV; shunt = S; inferior vena cava = IVC).

hepatic injections demonstrate the true direction of blood flow as the hepatofugal portal vein contrast admixes with the hepatopetal splenic vein contrast over the opaque vertebral column with both effluents flowing through the shunt.

Case 2. A 52-year-old Caucasian woman with primary biliary cirrhosis and recurrent bleeding esophageal varices, upon receiving a nonselective randomization status, underwent an elective interposition splenocaval shunt. Preoperatively, venous phase splenic arteriography demonstrated hepatopetal flow (Fig. 11). Angiograms performed in the early (<6 months) and late (>6 months) postoperative period have confirmed the shunt-induced deprivation of portal perfusion. Following a late postoperative SMA injection (Fig 12), contrast is seen filling the shunt and inferior vena cava on venous phase films (Fig. 13). Selective splenic arterial injection (Fig. 14) demonstrates the splenic vein and patency of the shunt (Fig. 15). Neither the SMA nor splenic injections opacify the portal vein.

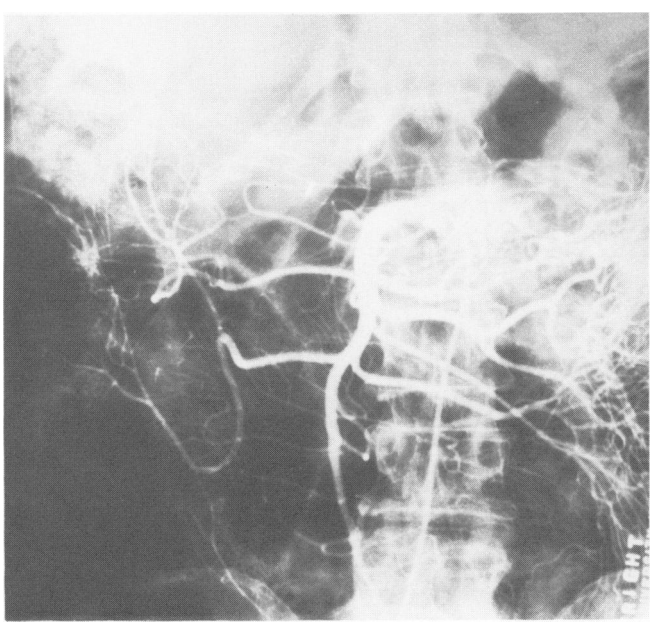

FIG. 2. Case 1: SMA injection two years following interposition mesocaval shunt.

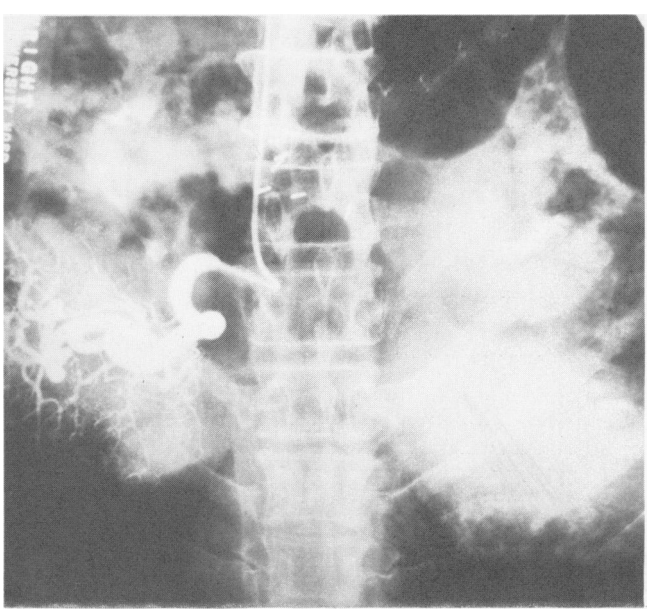

FIG. 4. Case 1: Selective splenic arteriogram two years following mesocaval shunt.

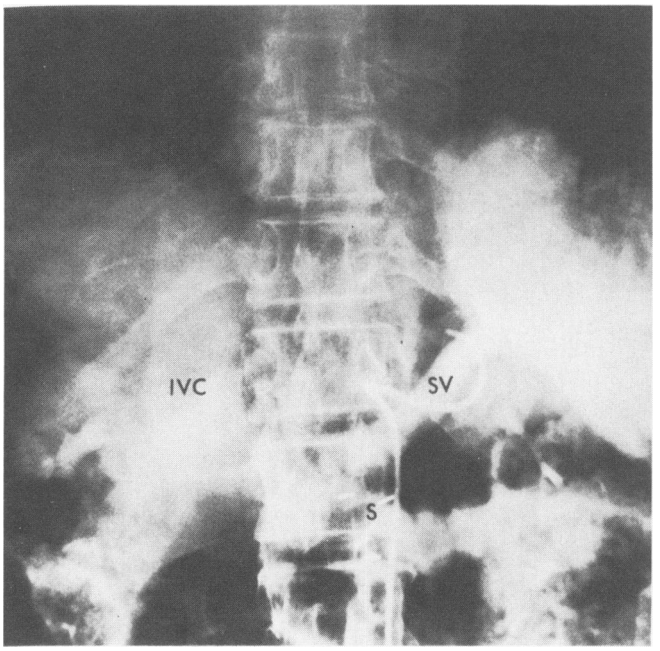

FIG. 5. Case 1: venous phase of splenic artery injection (Fig. 4), demonstrating a patent shunt. Note absence of prograde portal venous flow (splenic vein = SV; shunt = S; inferior vena cava = IVC).

A logical argument would be that secondary portal venous thrombosis had occurred, precluding portal flow; however, selective hepatic arterial injection (Fig. 16) is noted to opacify the portal vein with the curtain of contrast proceeding in an hepatofugal direction (Figs. 17 and 18); conclusive evidence of both portal vein patency and hepatofugal flow. This is further substantiated by a late postoperative hepatic wedge injection (Fig. 19). Although no celiac axis injection was performed in this patient, one can readily see how a celiac flush injection might have been misinterpreted as hepatopetal splenoportal axis flow.

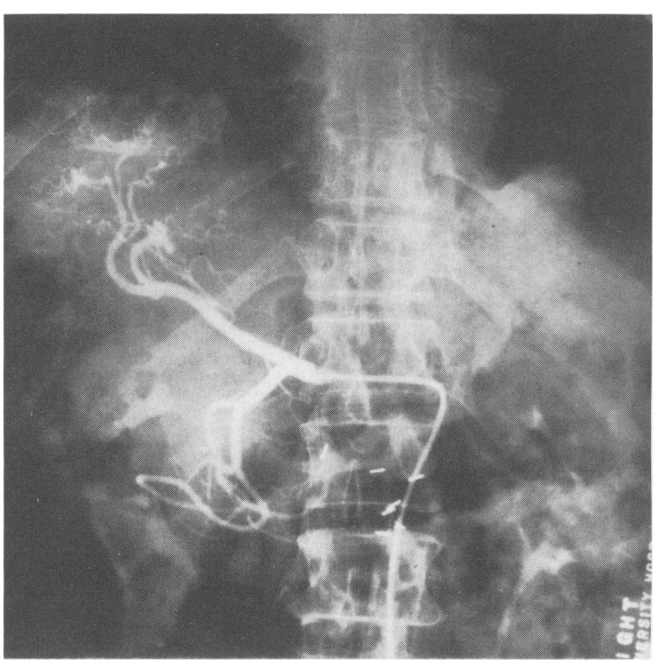

FIG. 6. Case 1: common hepatic arteriogram two years following mesocaval shunt.

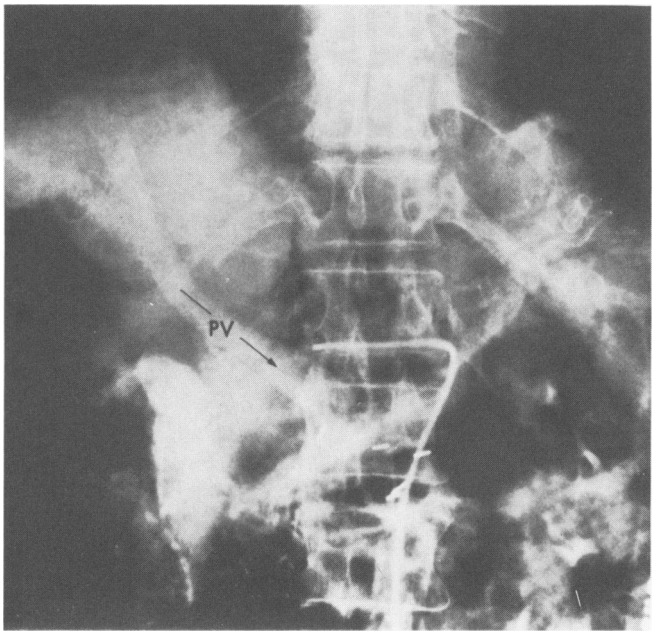

FIG. 7. Case 1: venous phase of common hepatic arteriogram (Fig. 6), demonstrating retrograde (arrow) portal venous flow (portal vein = PV).

Comment

Case 2 unfortunately had no celiac axis injection, but the critical finding is the flow of the curtain of con-

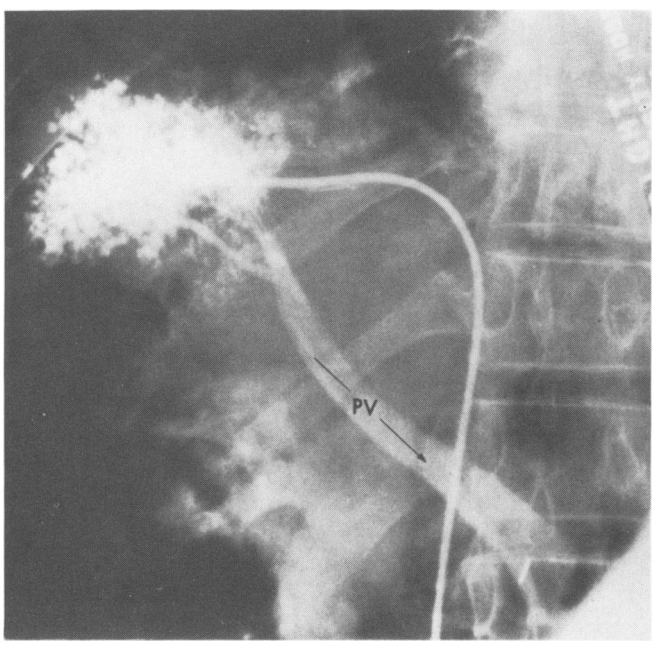

FIG. 8. Case 1: wedged hepatic venous injection corroborating impression that the portal vein has been converted to an outflow tract (portal vein = PV).

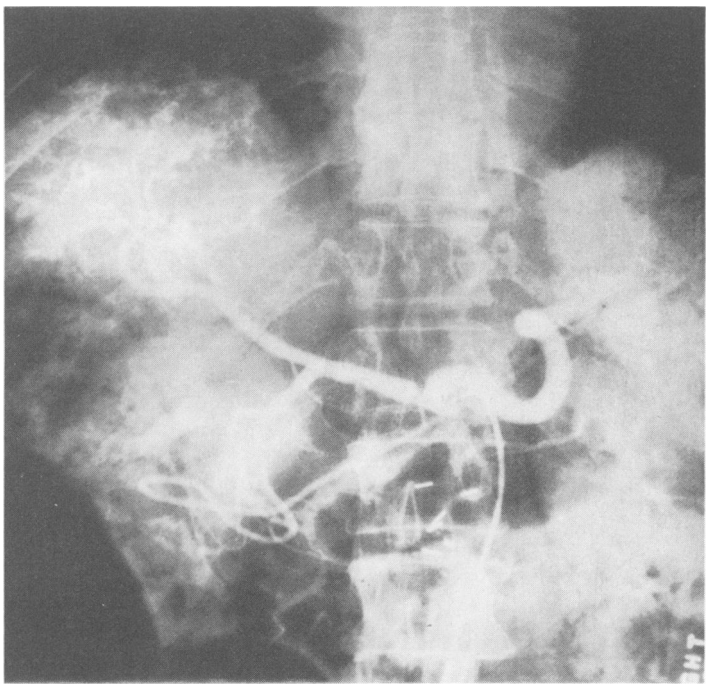

FIG. 9. Case 1: celiac axis injection two years following mesocaval shunt.

trast away from the liver following selective hepatic arteriography.

Case 3. A 68-year-old Caucasian man with Laennec's cirrhosis and a history of bleeding esophageal varices underwent an elective interposition mesorenal shunt after preoperative SMA arteriography with

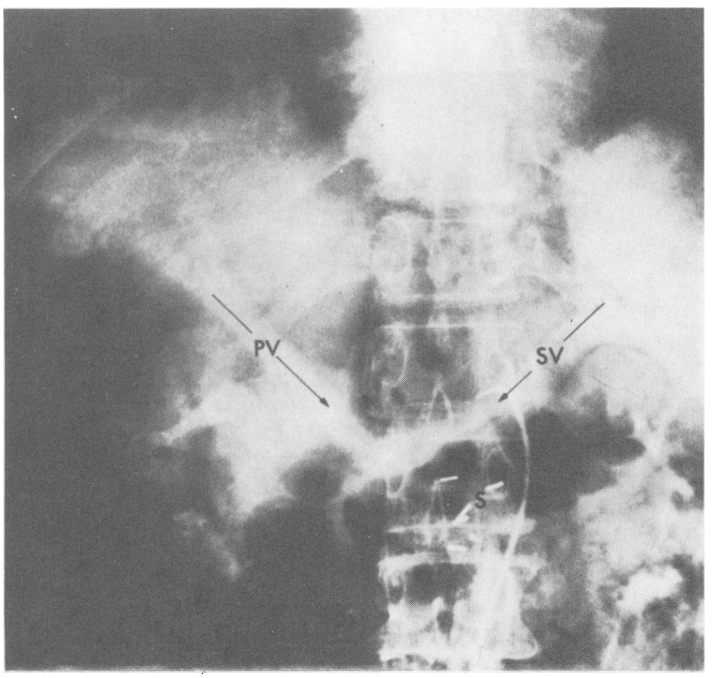

FIG. 10. Case 1: venous phase of celiac axis injection (Fig. 9), demonstrating the "portal pseudoperfusion" phenomenon—the illusion of net prograde splenoportal axis flow. Note the true direction of portal (PV) and splenic (SV) vein flow (arrows) demonstrated in Figures 5 and 7 (shunt = S).

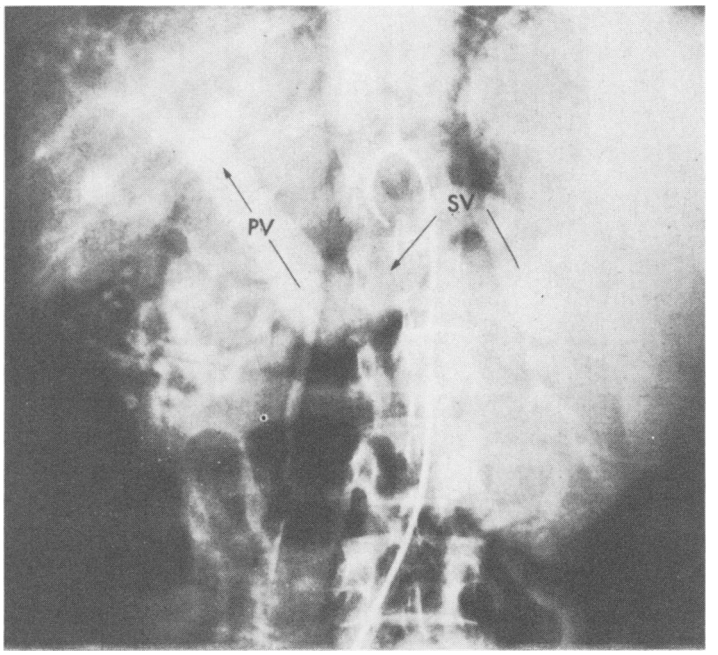

FIG. 11. Case 2: Preoperative venous phase of splenic arteriogram demonstrating hepatopetal portal flow (portal vein = PV; splenic vein = SV).

and without Priscoline demonstrating the total absence of portal perfusion with a huge coronary vein filling gastroesophageal varices (Fig. 20). Two months following the shunt procedure, visceral angiography was repeated because of a history of recurrent gastrointestinal bleeding and possible shunt thrombosis. Following the SMA injection (Fig. 21), the venous phase mesenteric contrast flows through the shunt and left renal vein (Fig. 22). Similarly, the selective splenic arterial injection (Fig. 23) demonstrates total diversion of splenic compartment blood through the shunt (Fig. 24). Neither the SMA nor splenic injections provide evidence for portal perfusion. These

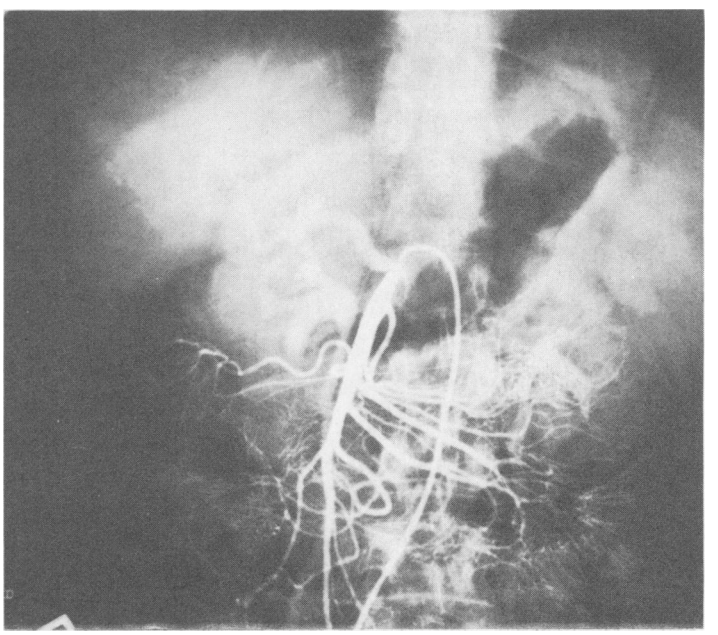

FIG. 12. Case 2: SMA injection approximately three years following interposition splenocaval shunt. Undesirable hepatic arterial reflux occurred, but was technically unavoidable in this case.

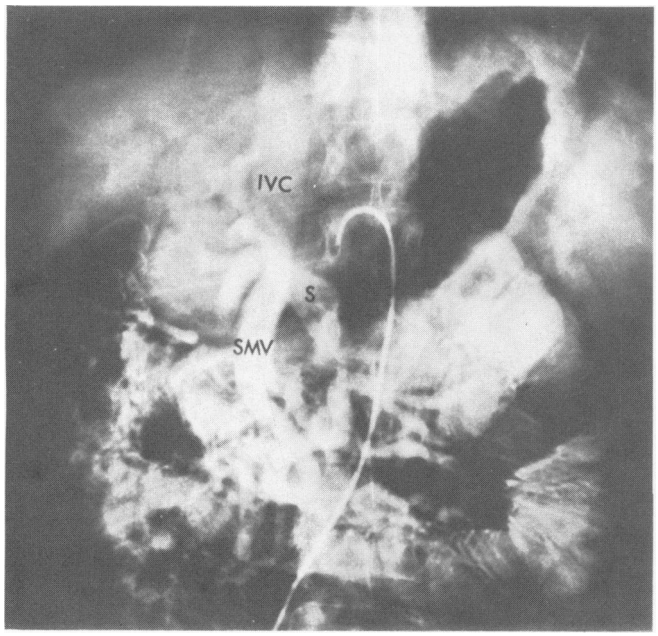

FIG. 13. Case 2: venous phase of SMA injection (Fig. 12), demonstrating shunt patency but no prograde portal flow (superior mesenteric vein = SMV; shunt = S; inferior vena cava = IVC).

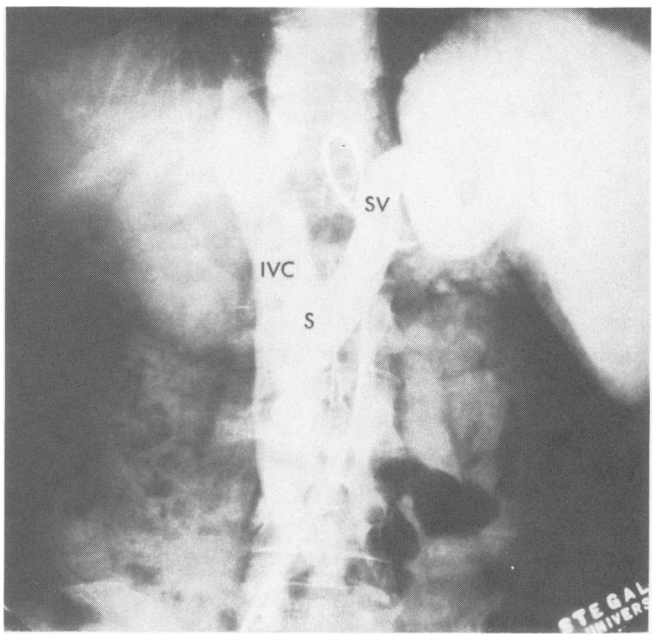

FIG. 15. Case 2: venous phase of splenic arteriogram (Fig. 14), demonstrating shunt patency but no portal perfusion as all splenic compartment blood is siphoned through the shunt (splenic vein = SV; shunt = S; inferior vena cava = IVC).

findings were anticipated because of the preoperative absence of portal perfusion. However, the postoperative celiac axis injection (Fig. 25) opacifies clearly both portal vein and splenic vein simultaneously on venous phase films (Fig. 26). Could the shunt procedure resurrect hepatopetal portal flow if none were demonstrated preoperatively by both angiography and wedged hepatic vein injections? This is most unlikely and is further supportive evidence of the inadequacy of celiac injections in determining the direction of postoperative portal venous flow. Thus, the illusion of hepatopetal flow may be demonstrated in a patient with preoperative complete absence of portal venous perfusion.

Comment

Case 3 demonstrates an interesting finding of a patient with no evidence of prograde portal flow preoperatively,

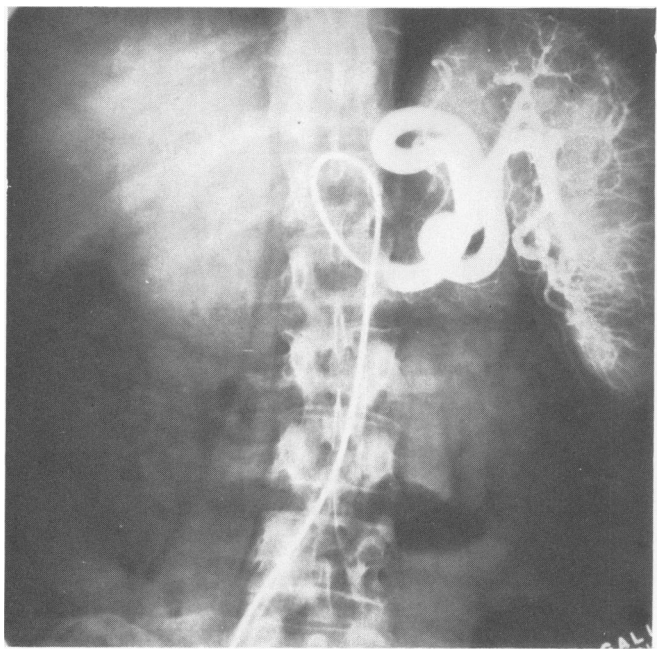

FIG. 14. Case 2: selective splenic arteriogram approximately three years following splenocaval shunt. Note the injection selectivity.

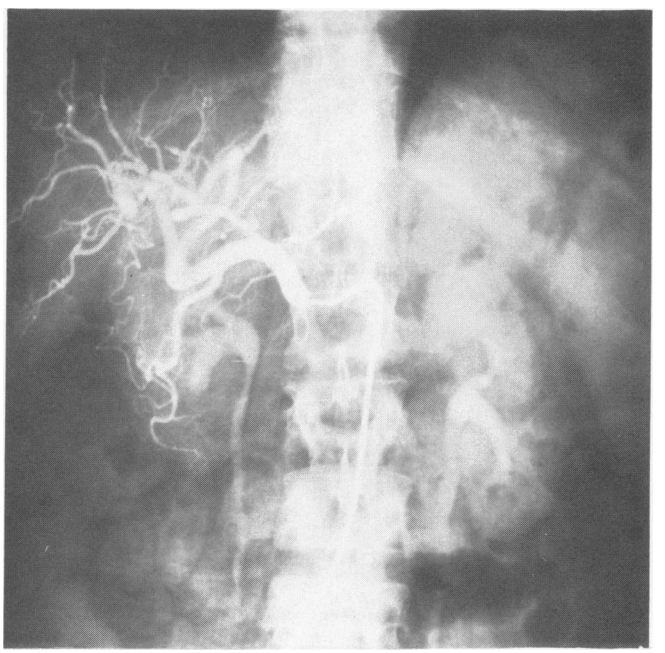

FIG. 16. Case 2: selective hepatic arteriogram three years following splenocaval shunt.

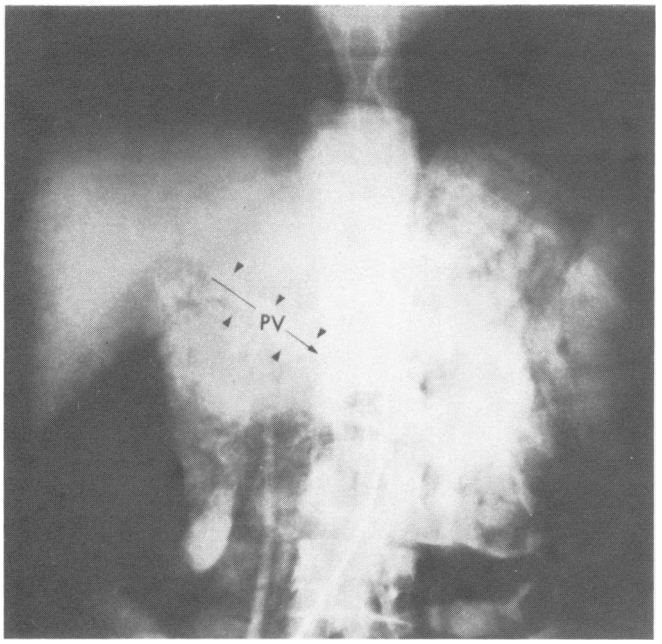

FIG. 17. Case 2: venous phase of hepatic arteriogram (Fig. 16), demonstrating opacification of the extrahepatic portal vein (arrows). Note the dense parenchymal opacification following the arterial injection and the large regenerative nodule projecting inferiorly (portal vein = PV).

even with priscoline used to augment mesenteric arterial flow. However, some would claim that prograde portal flow was present two months postoperatively on the basis of the celiac axis injection. A selective hepatic artery injection would certainly have demonstrated

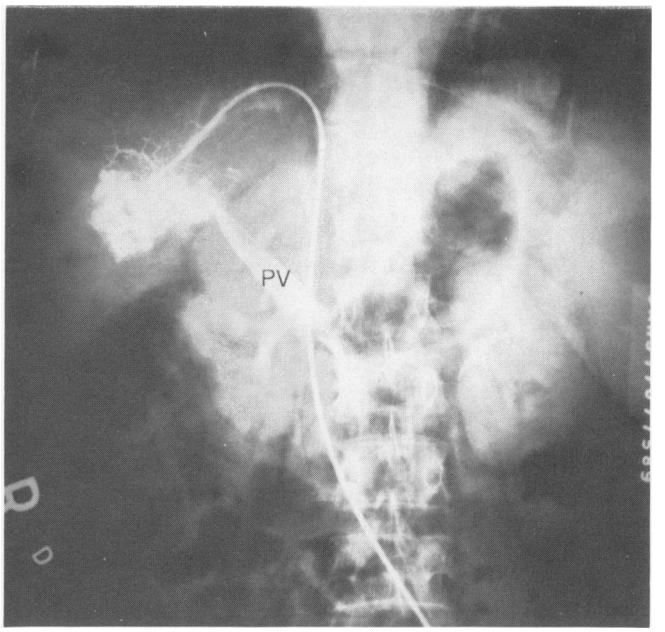

FIG. 19. Case 2: wedged hepatic venous injection confirming patency of portal vein (PV) and also demonstrating hepatofugal flow.

hepatofugal portal venous flow; however, none was available for this presentation.

Case 4. A 45-year-old Caucasian female with Laennec's cirrhosis underwent an elective dacron mesorenal interposition shunt for recurrent variceal hemorrhage. A total shunt was chosen because of tardy portal venous flow on the venous phase of the SMA injection (Fig. 27), as well as technical difficulties encountered at surgery.

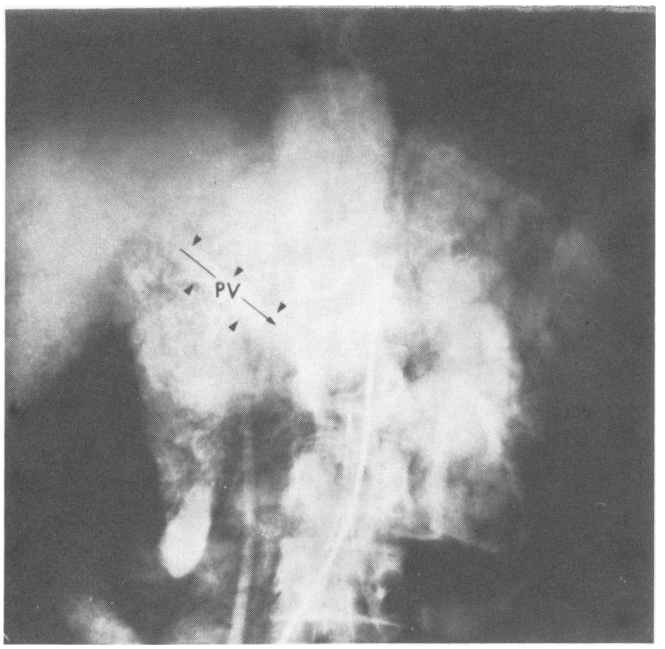

FIG. 18. Case 2: two seconds after film of Figure 17; note curtain of portal vein contrast proceeding in an hepatofugal direction (arrows) toward the splenocaval graft (portal vein = PV).

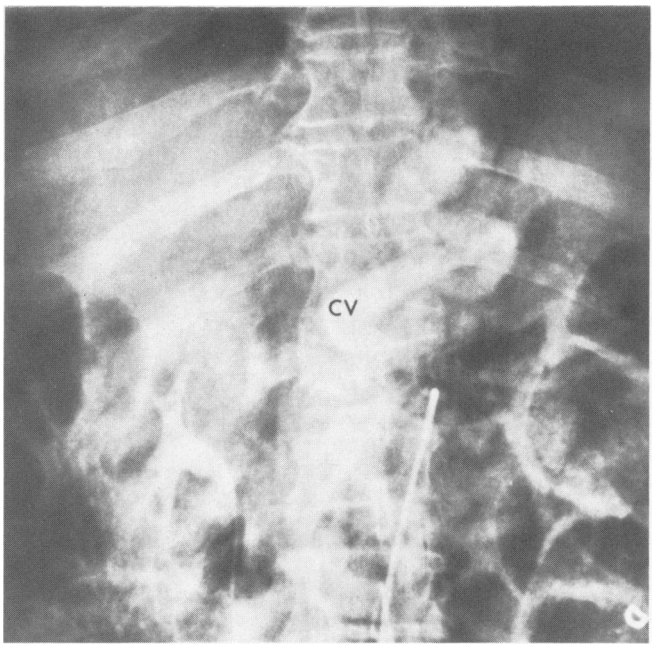

FIG. 20. Case 3: preoperative venous phase SMA injection after Priscolone, demonstrating absence of portal perfusion. Note the filling of a huge tortuous coronary vein (CV).

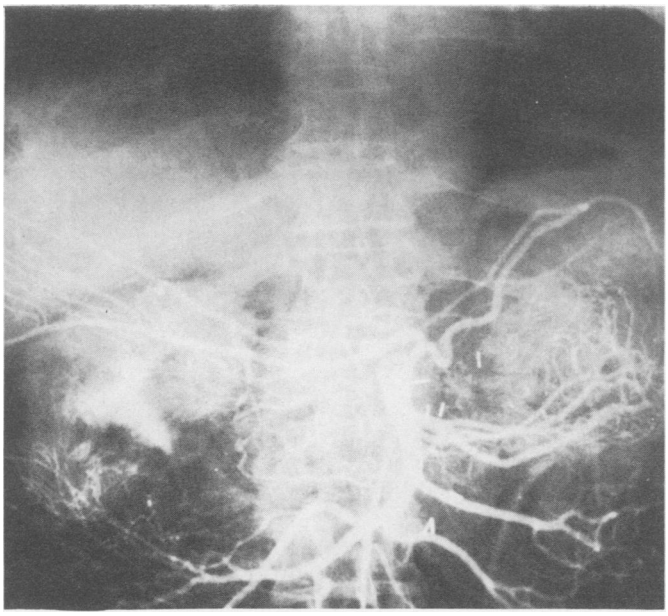

FIG. 21. Case 3: SMA arteriogram two months following interposition mesorenal shunt.

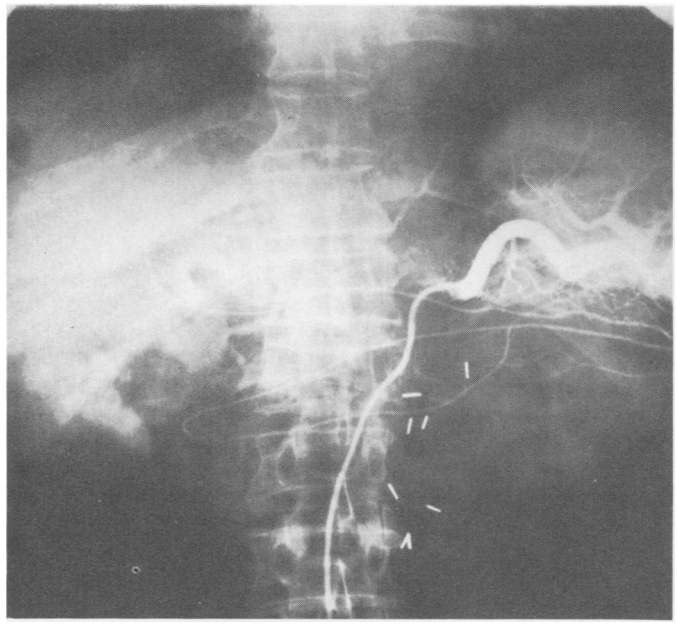

FIG. 23. Case 3: selective splenic artery injection two months following mesorenal shunt.

Visceral angiography seven days following surgery demonstrated another mechanism of the "portal pseudoperfusion" phenomenon: reflux opacification of the hepatic artery arising from the SMA. The SMA injection allowed reflux of contrast into the hepatic artery (Fig. 28) and venous phase films opacify the shunt, IVC, as well as the portal vein, producing the illusion of hepatopetal portal flow while confirming shunt patency (Fig. 29). That the portal vein is opacified in retrograde fashion is substantiated by the following injections: The selective splenic artery injection (Fig. 30) demonstrates opacification of the splenic vein with contrast diverted through the shunt with no evidence of portal flow (Fig. 31). Following the selective hepatic artery injection (Fig. 32), the venous phase (Fig. 33) demonstrates retrograde portal flow filling the shunt; conclusive evidence that the portal vein is now an outflow conduit. The catheter was then repositioned more peripherally in the SMA and immediately

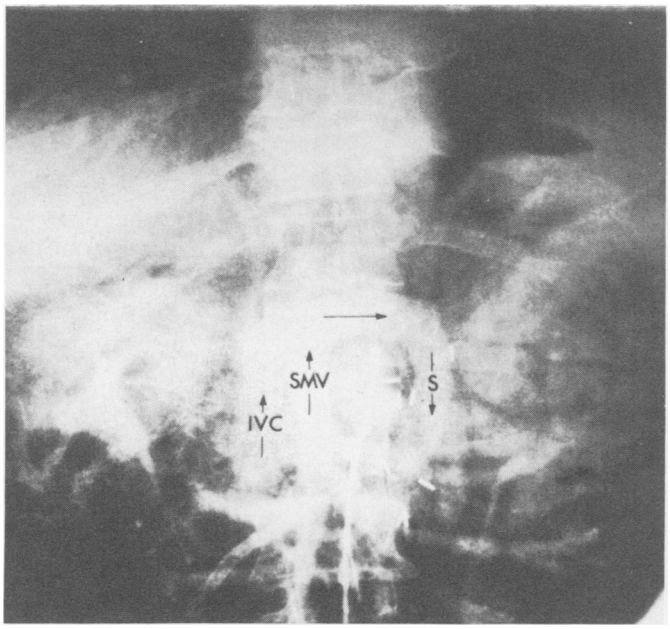

FIG. 22. Case 3: venous phase of SMA injection (Fig. 21), opacifying superior mesenteric vein (SMV), shunt (S), and inferior vena cava (IVC). There is no evidence for portal venous perfusion as all mesenteric blood flows into the shunt.

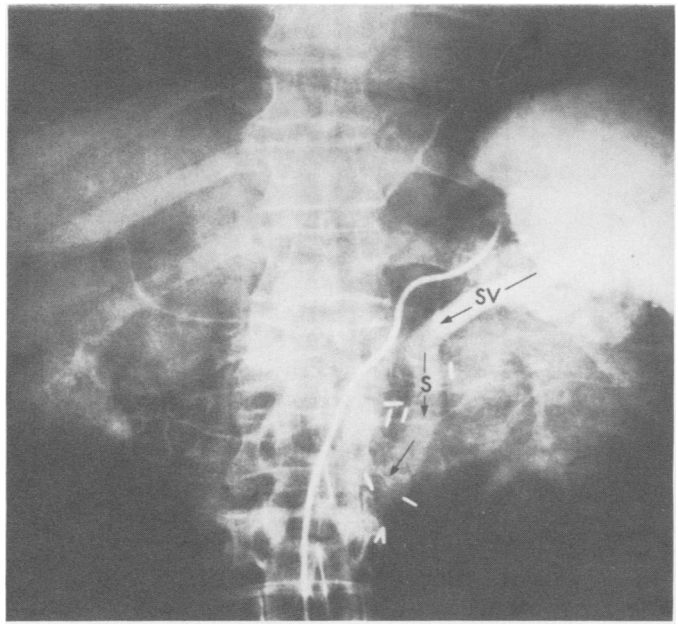

FIG. 24. Case 3: venous phase of selective splenic arteriogram (Fig. 23). No splenic compartment blood perfuses the liver as splenic venous (SV) blood is totally diverted through the shunt. Note the intense opacification of the spleen following arterial injection (shunt = S).

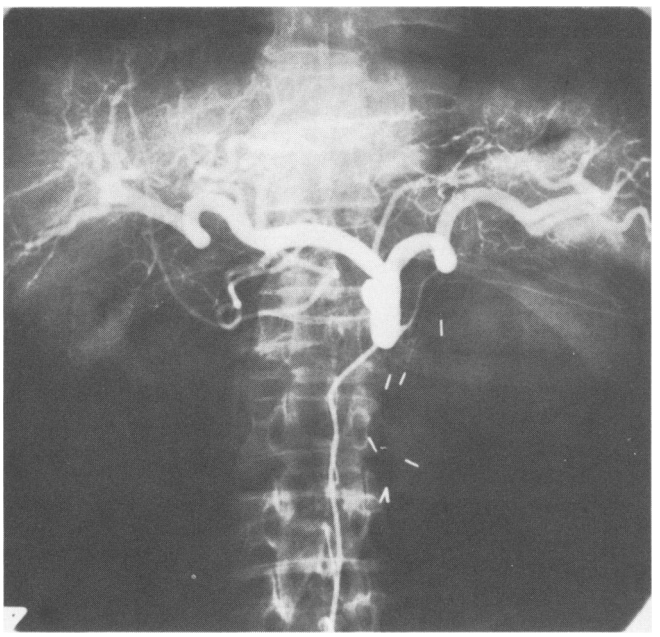

FIG. 25. Case 3: celiac axis injection two months following mesorenal shunt.

prior to contrast injection, 25 mg of Priscoline was injected to prevent reflux of contrast into the hepatic artery (Fig. 34). Reflux was successfully prevented by this maneuver and the venous phase of this second SMA injection indicates total diversion of mesenteric flow through the shunt with no demonstrable portal flow (Fig. 35). The critical importance of injection selectively should be easily appreciated, as another mechanism for producing "portal pseudoperfusion" has been demonstrated.

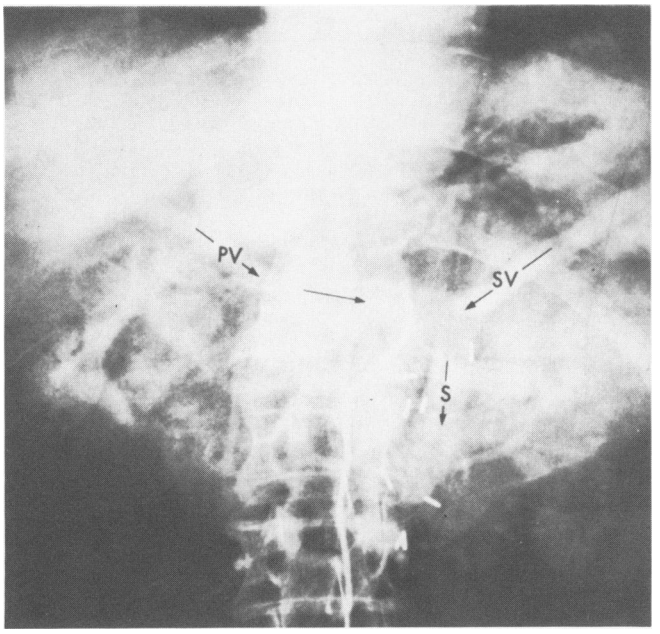

FIG. 26. Case 3: venous phase of celiac axis, creating the illusion of net portal perfusion. The curtains of contrast from the portal vein (PV) and splenic vein (SV) meet over the radiodense vertebral column with the flow from each diverted through the shunt (S).

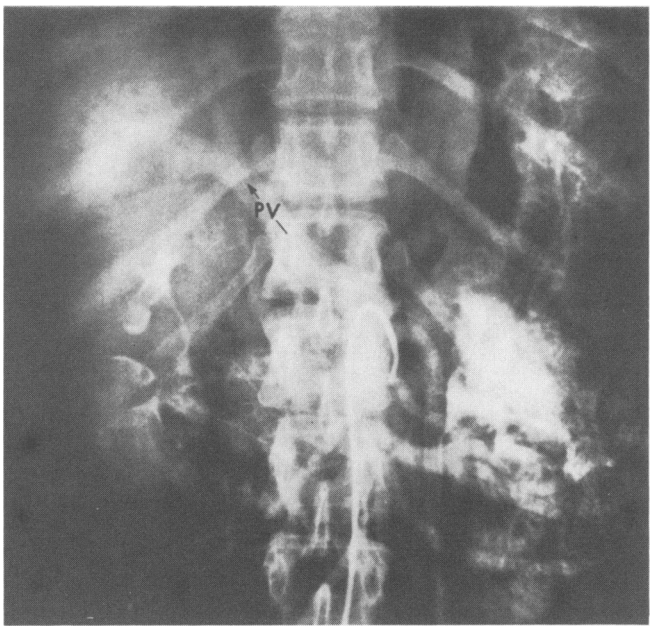

FIG. 27. Case 4: preoperative SMA venous phase angiogram demonstrating only fair portal flow (portal vein = PV).

Comment

Case 4 emphasizes the importance of injection selectivity and avoidance of hepatic arterial injection which can confuse venous phase interpretation. That the portal vein opacification occurred in retrograde direction (Fig. 29) is substantiated by the selective hepatic injection (Fig. 32), as well as the truly selective SMA injection (Figs. 34 and 35).

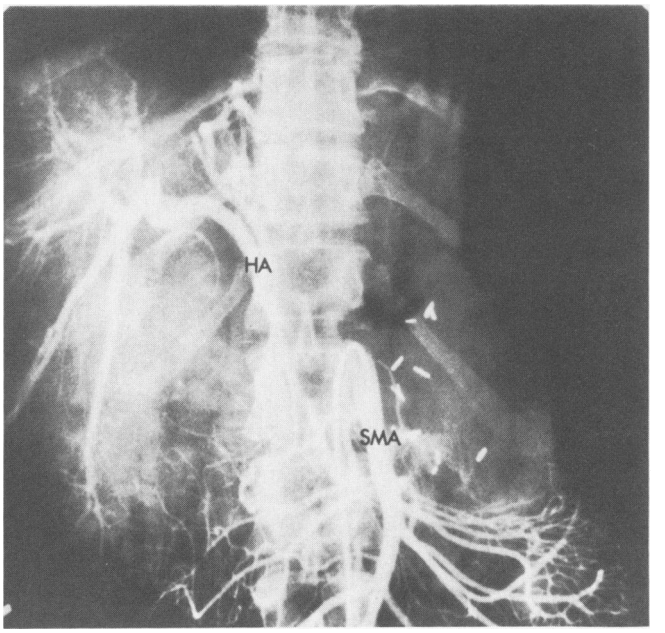

FIG. 28. Case 4: SMA injection seven days following interposition mesorenal shunt. Contrast refluxes into the hepatic artery (HA) due to catheter recoil with injection.

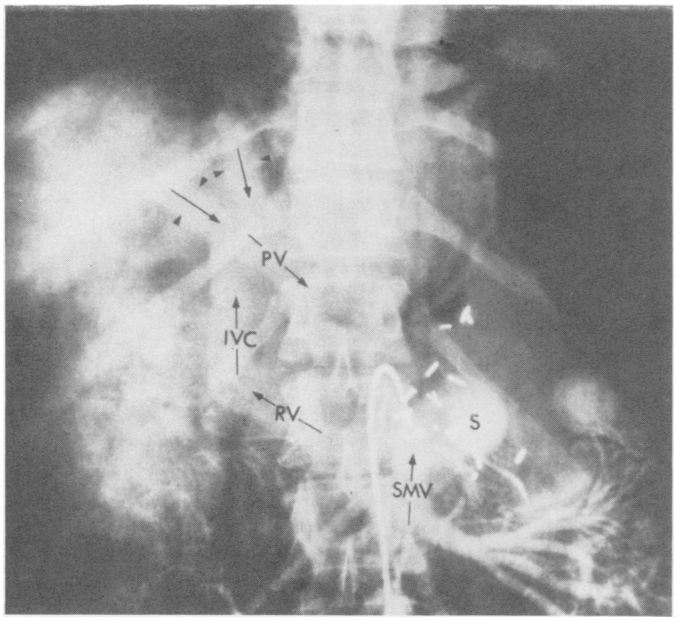

FIG. 29. Case 4: venous phase of the SMA reflux hepatic arteriogram (Fig. 28) opacifying the portal vein (PV, arrows) as well as the superior mesenteric vein (SMV), shunt (S), renal vein (RV), and inferior vena cava (IVC). Is there prograde portal perfusion or is the portal vein an outflow tract, as indicated (arrows)? The following figures will clarify this question.

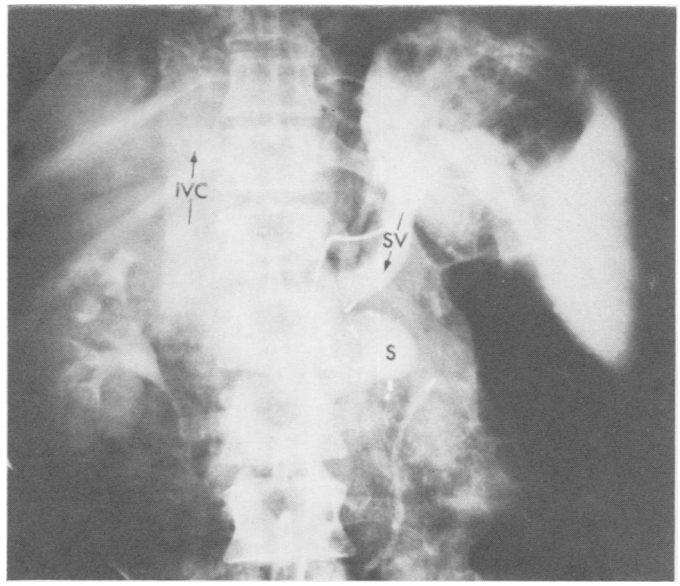

FIG. 31. Case 4: venous phase of selective splenic arteriogram (Fig. 30) demonstrating all contrast flowing through the shunt (S) to the inferior vena cava (IVC). Note the dense opacification of the spleen following the arterial injection, and no portal vein opacification (splenic vein = SV).

Discussion

The randomized trial begun in 1971 comparing the selective distal splenorenal shunt with a variety of nonselective shunts, mainly interposition mesocaval or mesorenal, has documented the >90% efficacy of both shunts in the prevention of recurrent variceal bleeding. The significant metabolic superiority of portal perfusion over nonperfusion has been confirmed by quantitative liver function tests such as the maximal rate of urea

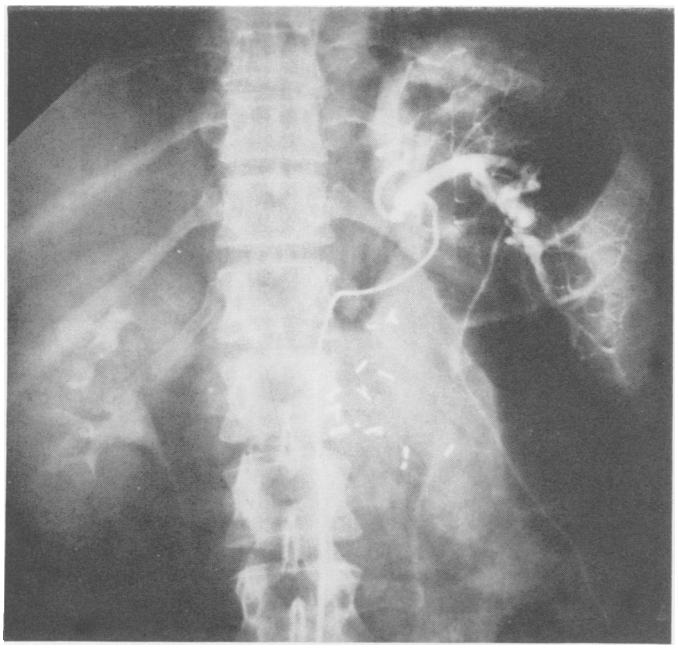

FIG. 30. Case 4: selective splenic arteriogram seven days following mesorenal shunt. No extra splenic arterial reflux occurs.

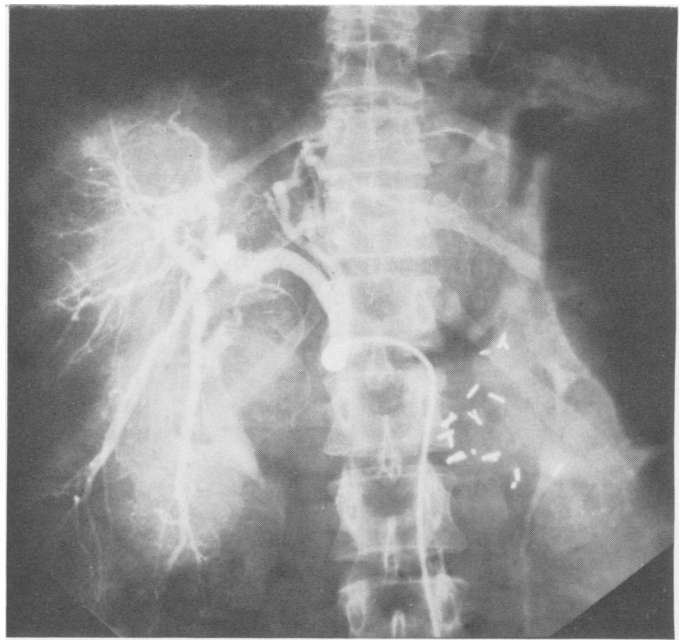

FIG. 32. Case 4: selective hepatic artery injection one week following mesorenal shunt. Note there is no reflux of contrast into the superior mesenteric or splenic artery, which might confuse venous phase interpretation.

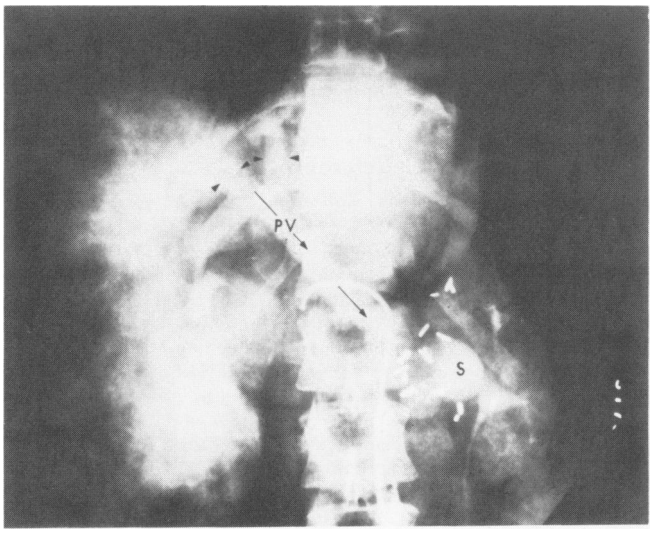

FIG. 33. Case 4: venous phase of selective hepatic arteriogram (Fig. 32), demonstrating retrograde portal blood flow and opacification of the shunt (S). Note the intense staining of the liver following the arterial injection (portal vein = PV).

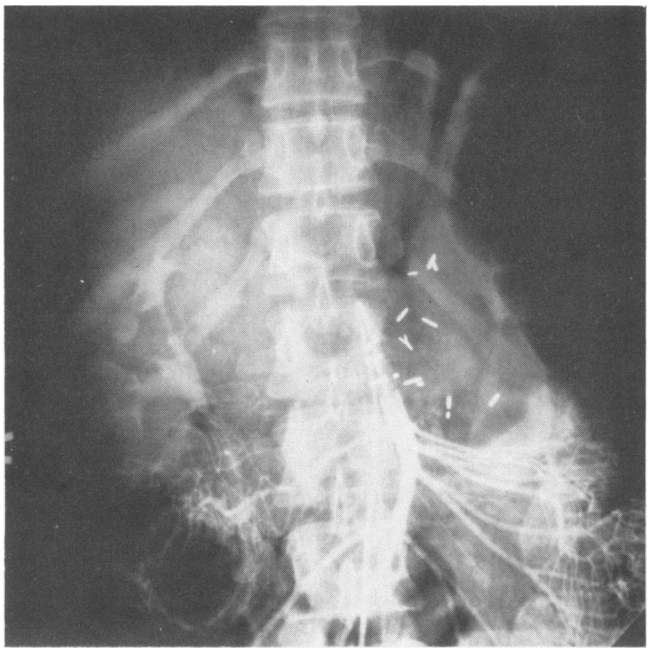

FIG. 34. Case 4: one week postoperative selective SMA arteriogram with Priscoline allowing no hepatic arterial reflux.

synthesis, ammonium chloride tolerance score, galactose elimination capacity, and antipyrine clearance and half-life. These biochemical advantages have been paralleled by a markedly diminished incidence of encephalopathy following the distal splenorenal shunt (11% vs 52%), which is the only shunt in our experience which preserves portal perfusion;[3,7,9,13] a critical determinant of the quality of life following portasystemic shunt surgery. We attribute this markedly lesser incidence of encephalopathy to the preservation of portal blood flow following selective shunting in contrast to the abrupt deprivation of portal flow following nonselective shunting procedures. None of our patients with patent interposition portasystemic shunts have maintained portal blood flow if it were present preoperatively. In fact, demonstration or portal venous flow following these total shunts is indicative of high-grade or total shunt occlusion, at which time the patient is in jeopardy of variceal rebleeding since adequate portal decompression could no longer exist. Functionally and hemodynamically, all interposition shunts are identical to the side-to-side portacaval shunt, which converts the portal vein to an outflow tract while achieving most efficient nonselective portal decompression.

After three decades, we still have no reliable means to quantitate portal or total liver blood flow and must depend upon qualitative venous phase splanchnic angiography or splenoportography to indicate direction and give an impression of magnitude of portal flow. The technique of venous phase splanchnic angiography, particularly the SMA injection, has proved clinically valuable in selecting patients considered for the distal splenorenal shunt, which is our shunt procedure of choice if intrahepatic portal flow is present angiographically.

We do not deny that the graft interposition mesosystemic shunts have been effective procedures in the

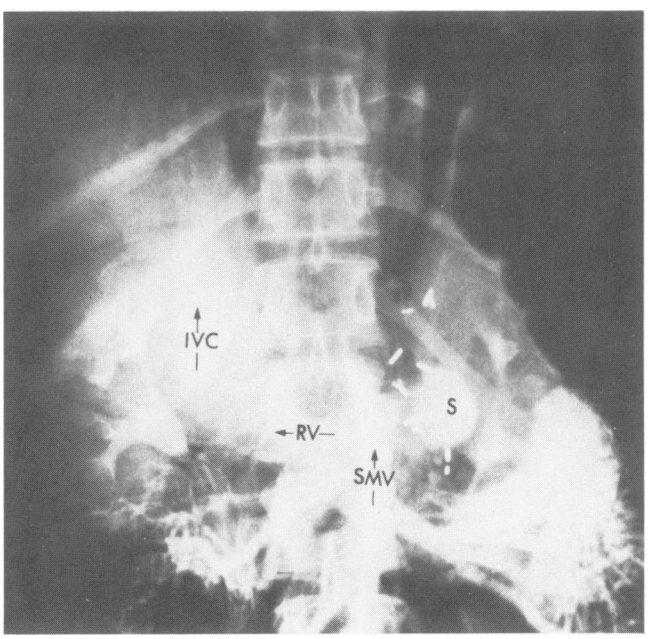

FIG. 35. Case 4: venous phase of SMA injection without hepatic arterial opacification. Note that no contrast appears in the portal vein and all mesenteric flow is diverted through the shunt (S); therefore, the portal vein was opacified in Figure 29 by contrast delivered by the hepatic artery and portal vein flow must be hepatofugal (inferior vena cava = IVC; renal vein = RV; superior mesenteric vein = SMV).

attack upon variceal bleeding, although some authorities on late follow-up examinations are noting occlusion rates as high as 32%.[5] We do, however, disagree with those who claim that interposition portasystemic shunts maintain portal blood flow and propose that gross misinterpretation of the angiograms has occurred in that portal venous opacification led to the conclusion that there was prograde portal venous flow. In fact, this portal venous opacification occurred because of retrograde flow of contrast delivered to the liver by the hepatic arterial limb of the celiac injection. This is easily demonstrable with the selective hepatic arterial injections, as shown by the patients presented.

Several points are important for those desirous of avoiding the pitfalls leading to angiographic misinterpretation. One cannot overemphasize the critical importance of injection selectivity precluding reflux into the hepatic artery which may opacify the portal vein in retrograde direction. Hepatic arterial reflux may be suspected whenever the hepatic parenchyma is densely stained. This density will often obscure the intrahepatic portal venous radicles, resulting in a deeply opacified liver and extrahepatic portal vein. When this picture occurs, one can be certain that the portal vein filled retrograde from the hepatic artery and has been converted to an outflow tract. When the portal vein fills in prograde fashion, the liver is never densely opacified and the intrahepatic portal vein arborizations are clearly delineated if such flow exists. Our preference for assessing pre- and postshunt portal flow is the selective SMA venous phase angiogram—never the celiac axis injection so frequently misused by others.

Our conviction is that hepatopetal portal venous flow ceases abruptly following interposition portasystemic shunting, and that these shunts should be reserved for those with absent or minimal portal flow. The concept that interposition shunts preserve portal flow is erroneous and should be abandoned. Meticulous attention to the technique and interpretation of splanchnic angiography is urged.

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