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The Polytetrafluoroethylene (PTFE) Graft for Portacaval Interposition: An Experimental Observation†

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In an attempt to determine the efficacy of the polytetrafluoroethylene (PTFE) graft as a portacaval interposition shunt, 26 mongrel dogs were randomly selected to receive a side-to-side shunt with a 6 mm, 8 mm, or 10 mm PTFE graft after portal hypertension had been created by hepatic vein ligation. The dogs were clinically observed, and if they showed signs of graft occlusion, they were re-explored surgically. The 6 mm graft had a 0% patency rate; the 8 mm graft had a 28.6% patency rate; and the 10 mm graft had an 87.5% patency rate. Histological examinations revealed adequate incorporation of the graft, formation of an endothelial layer, and absence of a thick intimal layer. In this experimental model, the PTFE graft served as a satisfactory portacaval interposition shunt when the 10 mm graft was used.

Polytetrafluororethylene (PTFE) grafts have been extensively used clinically during the last several years as arterial substitutes (1,2) and in isolated instances as venous substitutes (3-6). However, their use as venous substitutes has never been universally accepted because of the low patency rates, due primarily to the lower pressure and slower blood flow that characterizes the venous system. Drapanas and Lord have reported on their successful use of the teflon and dacron prosthesis for portacaval interposition shunts in cases of portal hypertension (7-11), and Rosenthal recently reported on the clinical use of the PTFE graft as a mesocaval shunt in seven patients with portal hypertension (12). However, there are no published reports on the experimental use of the PTFE graft as an interposition portacaval shunt for portal hypertension. Therefore, we decided to design an experimental animal model that would both create acute portal hypertension and test the effectiveness of the PTFE graft. We were also interested in evaluating the effect of different sizes of grafts on the adequacy of the portal decompression, the duration of the shunt patency, and the histological characteristics of the implant.

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Materials and Methods

Twenty-six mongrel dogs of both sexes, weighing between 19 and 29 kg, were anesthetized with sodium thiamylal for induction and halothane (0.1-1.5½) for maintenance. Through a midline abdominal incision, the liver, portal vein, and inferior vena cava were exposed. The portal vein and inferior vena cava pressures were determined intraoperatively so that normal base line values could be obtained. The hepatic veins were carefully dissected and individually ligated using a technique similar to that described by Orloff, et al (13-15). After the last hepatic vein had been ligated, the venous congestion of the liver and intestines was immediately evident. Creation of portal hypertension was documented and recorded by measuring portal venous pressure directly (Fig. 1).

The 26 dogs were then randomly assigned to four groups. Group I received a standard side-to-side portacaval shunt. Groups II, III, and IV underwent a portacaval interposition shunt with 6 mm, 8 mm, and 10 mm PTFE grafts, respectively. The length of the graft for all groups was kept constant at about 1.5 cm. The portal decompressing effect of the PTFE graft interposition shunt was measured by determining the postshunt portal venous pressure (Fig. 1). Postoperatively, the dogs were observed clinically on a daily basis. Serum bilirubin, alkaline phosphatase, serum glutamic-pyruvic transaminase (SGPT), and complete blood counts were obtained on a predetermined schedule. The development of ascites was clinically assessed in all animals. Venograms were selectively taken to determine the patency of the graft.

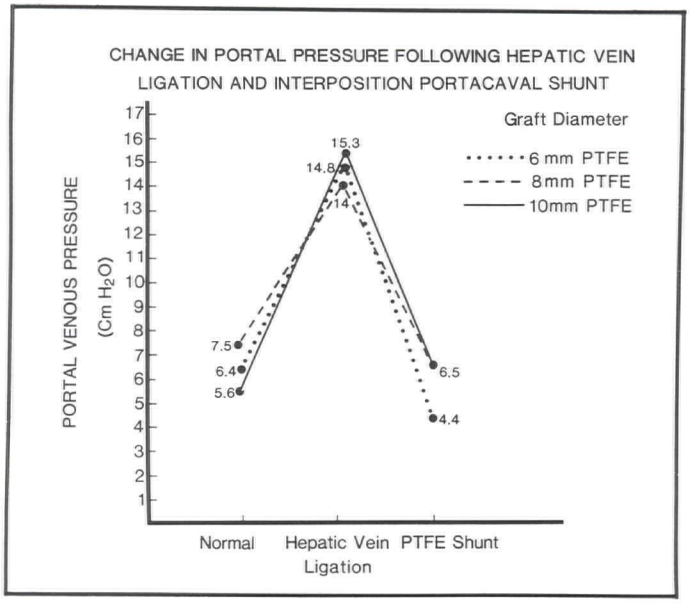

Fig. 1
Portal pressure increases with ligation of the hepatic veins and returns to normal after the PTFE interposition shunt.

The dogs that survived the operation were randomly sacrificed during the next ten months. Those that manifested signs of late graft thrombosis, such as ascites, were re-explored. Three dogs were followed for at least ten months in order to evaluate the long-term patency and histological characteristics of the graft. All grafts were retrieved during the postmortem examinations and sent for microscopic pathological evaluation.

Results

Table I gives the results for the first group of dogs with side-to-side portacaval shunts, which served as the control group. One dog died postoperatively within the first 24 hours. The four remaining animals all had patent shunts up to a maximum period of five months of follow-up.

In Group II, composed of dogs with 6 mm PTFE interposition shunts, all six PTFE grafts occluded during the first 24 hours after surgery (Table II). At autopsy, severe liver and mesenteric venous congestion had resulted in scattered areas of intestinal ischemia and infarction.

Among the seven dogs randomly assigned to the 8 mm PTFE group, two died on the first postoperative day (Table III). Again, the autopsy showed severe intestinal venous congestion with areas of bowel necrosis. The grafts were occluded. A third dog developed progressive ascites which started two weeks postoperatively. This dog was re-explored on the 21st postoperative day, and approximately 4.5L of ascitic fluid was removed. The graft was collapsed and occluded. The liver was grossly congested, but there

Table I
Group I
Side-to-Side Shunt

Dog	Ascites	Shunt Patency	Follow-up (Weeks)	Final Outcome
1	None	Open	8	Sacrificed
2	None	Open	20	Sacrificed
3	None	Closed	<1 day	Died
4	None	Open	20	Sacrificed
5	None	Open	16	Sacrificed

Table II
Group II
6 mm Diameter PTFE Shunts

Dog	Ascites	Shunt Patency	Follow-up (Hours)	Final Outcome
1	None	Occluded	<12	Died
2	None	Occluded	<12	Died
3	None	Occluded	<12	Died
4	None	Occluded	<12	Died
5	None	Occluded	<12	Died
6	None	Occluded	<12	Died

Table III
Group III
8 mm Diameter PTFE Shunts

Dogs	Ascites	Shunt Patency	Follow-up (Weeks)	Final Outcome
1	None	Occluded	16	Sacrificed
2	None	Occluded	<1 day	Died
3	None	Occluded	<1 day	Died
4	None	Open	8	Sacrificed
5	Yes	Occluded	3	Sacrificed
6	None	Occluded	27	Sacrificed
7	None	Open	8	Sacrificed

were no signs of intestinal ischemia or necrosis. The portal pressure was elevated at 14 cmH_2O. During the first operation on this dog the portal pressure was 16 cmH_2O, but it had been reduced to 3 cmH_2O after the shunt. Closure of the graft undoubtedly was responsible for the later increase in portal pressure from 3 to 14 cmH_2O.

Two other dogs were re-explored on the 60th and 67th postoperative day, and both were found to have an open graft. Two more dogs were followed for four and nine

Table IV

Group IV
10 mm Diameter PTFE Grants

Dog	Ascites	Shunt Patency	Follow-up (Weeks)	Final Outcome
1	Yes	Occluded	8	Sacrificed
2	None	Open	14	Sacrificed
3	None	Open	44	Sacrificed
4	None	Open	44	Sacrificed
5	None	Open	1	Died (Distemper)
6	None	Open	11	Sacrificed
7	None	Open	4	Sacrificed
8	None	Open	12	Sacrificed

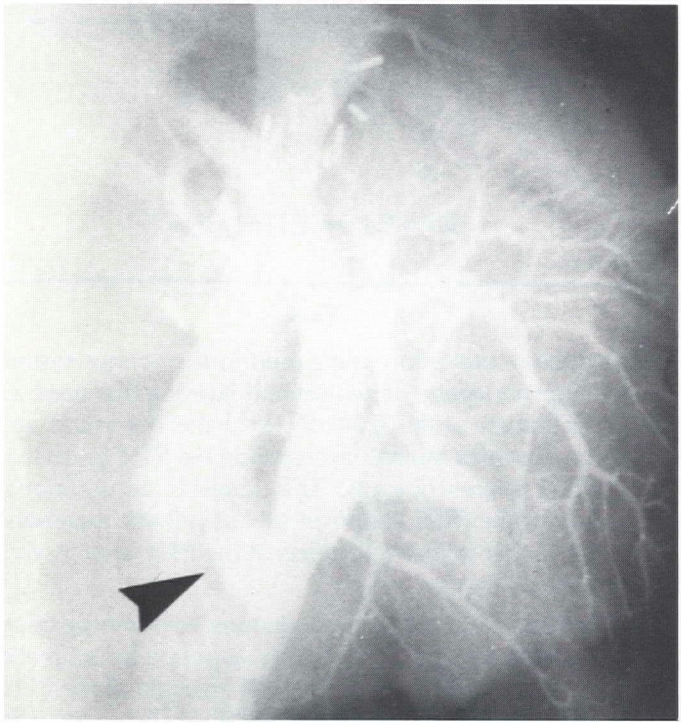

Fig. 2
Venogram showing patent portacaval PTFE graft (10 mm) at 80 days after implantation.

months, respectively. The grafts in both these dogs were found to be occluded on re-exploration, but no ascites or other signs of liver or intestinal congestion were found.

In Group IV, none of the 10 mm grafts closed immediately, and none of the dogs died during the early postoperative period (Table IV). One dog developed ascites three weeks after the first operation. Abdominal paracentesis had to be performed twice to relieve the tense, enlarging abdomen before re-exploration on the 53rd postoperative day. The operative findings were similar to those found in the 8 mm graft dog with ascites: the graft was completely occluded. All other dogs with 10 mm PTFE grafts had open grafts. Venograms were performed selectively to demonstrate shunt patency (Fig. 2).

When the grafts were recovered within four months or less, no significant gross changes were detectable. Microscopic examination revealed some red blood cells and a few monocytes and leukocytes within the wall. After the 90th postoperative day, microscopic examination revealed proliferation of spindle-shaped fibroblasts and small blood vessels within the graft wall, as well as scattered mononuclear cells of histiocytic origin with rare Langhan foreign body giant cells. All ten patent grafts were endothelialized with a layer of acquired fibrous intima of variable thickness. One also showed microscopic foci of calcification.

After the fourth month of implantation, areas of patchy and extensive calcium depositions in the wall of the grafts were seen grossly and were more evident in the older grafts. The older grafts also appeared thick, hard, and gritty on cut sections. Microscopic examination revealed a more extensive cellular reaction consisting of fibroblastic cells and endothelial proliferations with collagen and fibrous tissue deposited within the wall of the grafts. A single layer of flat endothelial cells (Fig. 3) was seen among the 10 mm grafts that were followed for up to ten months. None of the long-

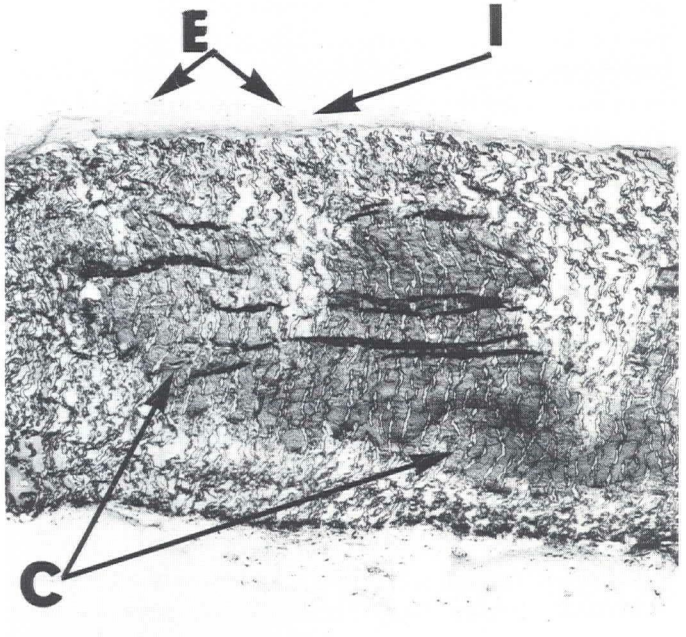

Fig. 3
Photomicrograph of 10 mm PTFE graft ten months after implantation showing the endothelial layer (E), intimal layer (I), and calcifications (C). 72 X (H & E)

term grafts demonstrated any histologic evidence of a thick pseudo-intimal layer.

No significant changes in the serum bilirubin, alkaline phosphatase, or total serum protein became evident during the study.

Discussion

To carry out the aims of our study on PTFE grafts, it was necessary to develop an animal model of portal hypertension. This was accomplished by complete ligation of the hepatic veins, which, in turn, immediately resulted in severe hypertension in all dogs. During the same operation, the PTFE portacaval interposition was performed because the acute hypertension would lead to mesenteric thrombosis and death, as seen in the immediately closed grafts. This method also eliminated any morbidity associated with subjecting the animals to two separate operations.

Immediate occlusion of the graft always led to early death, because the sudden increase of portal pressure without the decompressing effect of an interposition shunt could not be tolerated. The development of ascites from the second to about the eighth week postoperatively was a strong indication of delayed graft thrombosis. Two dogs developed ascites in their second and third postoperative week, and both of these grafts were occluded. However, when the dogs were followed for more than four months, late occlusion of the graft did not produce ascites. The formation of adequate collateral circulation was undoubtedly responsible for the animal's ability to tolerate late graft occlusion without ascites formation. Of four dogs that were followed from four to ten months, two had an open graft of the 10 mm graft size, and two had occluded grafts of the 8 mm size but without ascites (Table IV).

Of the three sizes of grafts used, the 10 mm graft performed best (Fig. 4). Only one of the eight dogs in this group occluded after the second postoperative week. All other grafts continued to remain patent for as long as ten months. The excellent patency rate for this group parallels that of our control group, which had a side-to-side portacaval shunt and no interposition graft. Performance of the 6 mm graft was very disappointing, with all animals in this group dying due to early graft occlusion. This graft invariably occluded within the first 24 hours postoperatively.

The significance of the increasing deposition of calcium in the walls of the graft according to its length of implantation is difficult to determine. However, the presence of an endothelial layer certainly is encouraging because of its well-known ability to resist thrombus formation. With a large diameter PTFE graft, such a layer should lead to a favorable long-term patency rate.

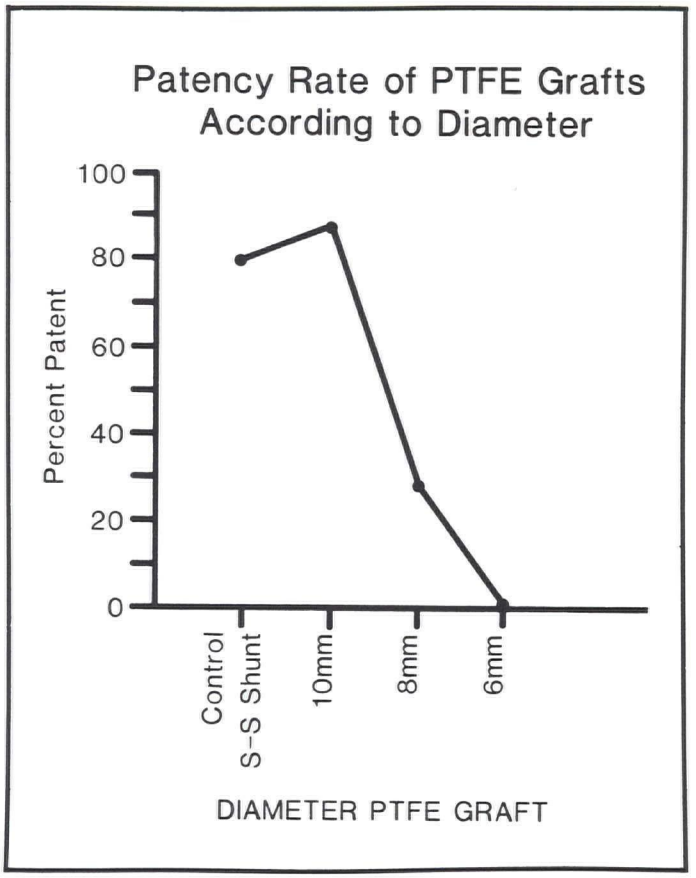

Fig. 4

While dacron and teflon grafts used in the venous system have a high incidence of neo-intimal layering that narrows the inner lumen of the graft (8), we have not found any evidence of a thick intimal layer among the PTFE grafts that we studied microscopically. This suggests an additional advantage of the PTFE graft over other synthetic materials; however, longer follow-up studies of the PTFE graft in vivo will be necessary.

There is little doubt that an autogenous vein interposition graft, such as the jugular vein, is superior to synthetic materials (16,17). However, if the effectiveness of the PTFE graft can be shown to compare favorably to that of the vein graft, then the PTFE graft would have an advantage in most clinical situations, since operative time and surgical stress would be reduced by eliminating the vein harvesting.

Conclusions

Our findings have demonstrated that the larger the size of the interposition graft, the better the patency rate. The 10 mm diameter PTFE graft had a 87.5% patency rate when followed either on a short or longer-term basis. We therefore conclude that the PTFE graft performs adequately as a portacaval interposition shunt in the dog if a 10 mm diameter graft is used.

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