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Reconstruction of the Vena Cava with the Peritoneum: The Effect of Temporary Distal Arteriovenous Fistula on Patency (An Experimental Study)

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Objective: To determine the effect of increasing inferior vena cava blood flow by means of distal arteriovenous fistula on the patency of a peritoneal tube graft.

Materials and methods: In 16 mongrel dogs, a 3–4 cm long circular defect was created at the infrarenal inferior vena cava. The defect was interposed with peritoneal tube graft. A temporary distal femoro-femoral arteriovenous fistula was also constructed in 8 dogs just after the caval interposition. Graft patency was evaluated by Doppler ultrasonography and angiography. Histological evaluation was also performed.

Results: Seven dogs in each group survived. All control grafts occluded within the first week, compared to no occlusions in fistula group (Fisher's exact test, $p < 0.005$). However one 'fistula' dog with a still patent graft was sacrificed on the 18th day due to ultrasonographically occluded arteriovenous fistula.

Conclusion: In dogs, the peritoneum may be used as graft material for reconstruction of the inferior vena cava, provided a distal arteriovenous fistula is constructed.

Key Words: Peritoneum; Inferior vena cava; Temporary arteriovenous fistula.

Introduction

The reconstructive surgery for the injured large veins like inferior vena cava with autologous or prosthetic grafts has been discouraging because of the high incidence of early occlusion due to thrombosis which has been attributed to the low blood flow velocity and the low driving pressure in veins and to 'antigravitational flow' in veins of the lower part of the body.¹ Also thrombogenicity and inflammatory reaction of the graft material seem to be major causes of graft failure.^{2,3} So far no ideal graft material for large veins has been found. The peritoneum is readily available in large quantities for construction of an inferior vena cava repair and can

be considered as a useful alternative to other autologous graft materials. However, the peritoneum has thrombogenicity that eventually lead to early occlusion of graft. There are several reports in the literature on that basis recommending the use of anticoagulant and antithrombotic drugs to maintain the patency of repaired vena cava.^{4,5} However, it was reported that the use of temporary arteriovenous fistula to increase the blood flow and pressure might be beneficial in preventing the thrombotic occlusion of the vein seen after surgery for ilio-femoral venous reconstruction or thrombectomy.⁶ As a continuation of our preliminary works on this topic, the aim of the present study was to evaluate the effectiveness of a temporary distal femoro-femoral shunt to prevent the early thrombotic occlusion and to maintain the patency of the inferior vena cava reconstruction performed with an isodiametrically constituted peritoneal graft. So we developed an animal model of vena cava reconstruction with a peritoneal tube graft with/without distal arteriovenous fistula to demonstrate its clinical applicability.

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Materials and Methods

The experimental protocol was approved by the Local Ethical Committee. The experiments were conducted in accordance with the Guide for the care and use of laboratory animals published by the US National Institutes of Health (NIH Publication Number 85-23, revised 1985). Sixteen adult mongrel dogs of both sex weighing 22–29 kg each were used in this study as below.

Control group

Inferior vena cava reconstruction with peritoneal tube graft.

Study group

Same as control group, additionally a temporary distal femoro-femoral arteriovenous fistula was performed.

The duration of the experiment was 4 weeks. The food was withdrawn 12 hr before the surgery but free access to water was permitted. Antibiotic was given at just before the operation and administered until the PO 6th day (0.5 g/day IM Sefotaxim). Anaesthesia was induced with intramuscular xylazine 2 mg/kg followed by succinylcholine chloride 1 mg/kg infusion and endotracheal intubation was performed. Anaesthesia was further maintained by using 1–1.5% Halothane in 50% oxygen and 50% room air.

Surgical technique

The animals had been performed right paramedian laparotomy incision followed by infrarenal vena cava was dissection through the bifurcation level. A piece of peritoneum and posterior sheath of rectus abdominis muscle from the anterior abdominal wall were cleared from fat and excised as in desired size. Mesothelial surface was meticulously protected without any traumatic injury. This patch was wrapped around a silastic tube which has an appropriate diameter with inferior vena cava by using uninterrupted horizontal mattress sutures with 6-0 polypropylene keeping the mesothelial surface of the patch inside. So, a 3–4 cm long tubular graft was obtained (Fig. 1(A)). After the infusion of intravenous heparin 3–4 cm of the vena cava was excised following the placement of vascular clamps at proximal and distal site.

The peritoneal graft was anastomosed as an interposition graft to the vena cava by uninterrupted suture technique (Fig. 1(B)).

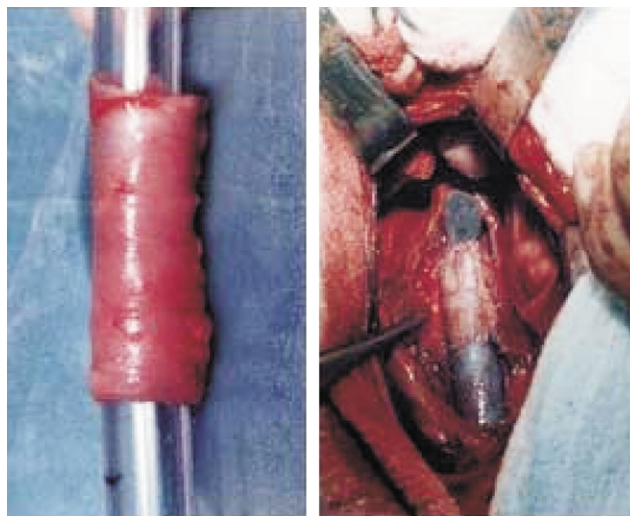


Fig. 1. Cavoplasty technique. (A) The preparation of the graft by wrapping around the silastic tube. (B) The anastomosis of the fascio-peritoneal tube to inferior vena cava by uninterrupted sutures.

The vascular clamps were opened and blood flow was maintained. The external surface of the graft was covered with retroperitoneum and laparotomy was closed without drainage. Half of the animals were further separated and a 6–8 cm long vertical incision was performed in right groin. Femoral artery and vein were prepared and then arteriovenous shunt was constructed by using 7(0) polypropylene suture in a side-to-side fashion.

Postoperative follow-up

The animals were given subcutaneous low molecular weight heparin until the end of observation period. The animals were also checked daily by Doppler ultrasonography to evaluate the graft and shunt patency in the postoperative period. All the animals in which the graft occlusion was demonstrated by Doppler ultrasonography were re-anaesthetized and a 20 G catheter was introduced into the right femoral vein by using open technique. Phlebography was then performed with contrast medium to confirm the occlusion. These animals were then performed relaparotomy and operational area was explored. Macroscopic findings were noted. After the animals were sacrificed with a high dose of pentobarbital sodium, some part of inferior vena cava was excised and fixed for microscopic examination within 10% neutral formaline. The prepared sections were dyed with haematoxyline–eosine for examination under light microscope.

Additionally in arteriovenous fistula performed

group the proximal part of the arterial side of the fistula was cannulated in order to obtain the images of reconstructed vena cava and arteriovenous fistula at the same view. The animals, which completed the study period, were performed relaparotomy at the end of the 4th week. They were then sacrificed with a high dose of pentobarbital sodium injection following macroscopic examination. In this group microscopic examination was performed with the same technique.

Fisher's exact test was used to compare the groups. Any p value <0.05 was considered as statistically significant.

Results

There was one postoperative fatality for each group due to infection. The peritoneal tube grafts in all dogs of the control group occluded due to thrombosis within the first week, in mean 3 days (Fig. 2). On macroscopic evaluation, peritoneal tube grafts were severely contracted and filled with fresh thrombus formation. Accordingly on microscopic examination, significant inflammatory infiltration was detected as accumulation particularly at the graft-vessel border. Capillary proliferation, edema, and inflammatory cells were detected at the media-adventitia layer of inferior vena cava. Also intimal thickening, microfibrin and histiocyte accumulation were detected. However, mesothelial surface (peritoneum) of the graft side showed widespread fibrin and leukocytic exudative infiltration and necrosis (Fig. 3(a)).

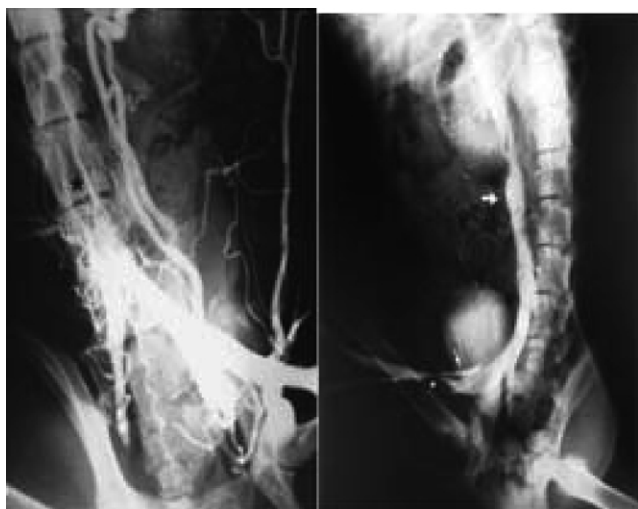


Fig. 2. The phlebography of reconstructed area in control (left) and study (right) group animal. The lumen of the tube graft was completely occluded (asterix) in control group animals whereas arteriovenous fistula (thin arrow) and graft lumen (thick arrow) were patent in study group animals.

In contrast to control group, any tube graft occlusion was not observed in study group at study period ($p < 0.005$). However, one of the subject in this group was sacrificed at 18th day due to ultrasonographically documented occlusion in arteriovenous fistula. But peritoneal tube graft was patent in this subject too.

Phlebography and Doppler ultrasonography revealed that both arteriovenous fistula and peritoneal tube graft were patent in these animals (Fig. 2 right). On macroscopic examination there was only minimal contraction at the edges of anastomosis line. On microscopic examination endothelial structure was normal other than minimal thickening at the intima of inferior vena cava. Mononuclear cells but not tissue necrosis were detected at the outer side of the graft (fascial side). Any sign of inflammation and mesothelial cell proliferation were not detected at the inner part of the graft which consisted the lumen (peritoneal side) (Fig. 3(b)).

Discussion

Inferior vena cava is the most frequently injured vein during the blunt or penetrating abdominal trauma. The type and the location of the injury affect the mortality rate. A more extensive injury to the inferior vena cava such as avulsion and laceration larger than 5 cm were associated with the highest mortality rate. While infrarenal injuries were associated with the lowest mortality rate (23%), suprarenal and retrohepatic injuries were associated with the highest mortality rate (70%).^{7,8} The definitive repair of caval injuries is the aim of the treatment and should be adapted to the individual needs of the patient. There are several methods of repair for inferior vena cava injuries. In the majority of the cases primary suture repair or patch cavaplasty with autologous or prosthetic grafts can be achieved successfully to repair the defect. Caval ligation, end-to-end anastomosis or graft interposition should be considered in selected cases. Although infrarenal caval ligation can be performed in emergency situations or in cases in which the repair of the injury is not possible, it has significant mortality and morbidity rates.⁸ The options available for reconstruction of vascular injuries with graft include autologous materials including primarily great saphenous vein, and various synthetic materials including primarily polytetrafluoroethylene grafts.⁹ However, severe contamination in penetrating abdominal injuries has been cited as a limiting factor for the use of synthetic grafts.¹

Since the mesothelium and endothelium exhibit similar functional and structural properties peritoneum

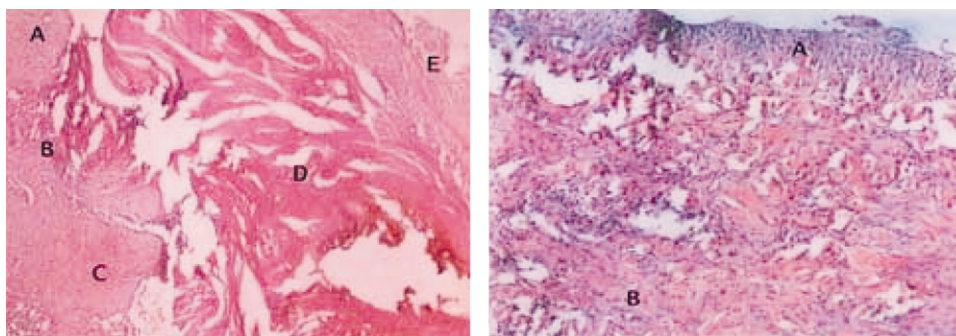


Fig. 3. (a) Control group. Light microscopic feature of the anastomotic line from control group (H&EX200). Left side of the picture is vascular tissue: Inflammatory infiltration is present in intima (A), media (B) and adventitia (C). Right side of the picture is graft tissue: Inflammatory infiltration and tissue necrosis (D) and fibrin accumulation are present (E). (b) Study group. Light microscopic feature of the graft tissue from arteriovenous fistula group (H&EX200). The mesothelium (A) is intact and sign of inflammation, proliferation and necrosis were not seen. There is a minimal inflammation on the outer part (B).

was recommended to serve as a proper venous graft.¹⁰ In experimental studies, peritoneum was demonstrated to be thrombogenic^{2,3} and its usage necessitates the use of anticoagulant⁵ and antithrombotic⁴ or antiinflammatory¹¹ therapy to maintain the lumen patency. In our present study we also observed that the peritoneal tube grafts were occluded completely in the absence of any preventive measures. However, Akimaru *et al.* reported that in cases of small caval defects peritoneal patch can be used successfully following fixation in alcohol for 10 min.⁹ Temporary arteriovenous fistula is known to be effective for long-term maintenance of venous graft patency by way of increased blood flow through the vein. But the mechanisms related with the beneficial effect of increased blood flow on thrombotic occlusion have not been elucidated completely yet. Gloviczki *et al.* reported in an experimental study that arteriovenous fistula decreased the platelet and fibrin deposition which lead to an early occlusion.¹² Neglen *et al.* reported that the use of temporary distal arteriovenous shunt improved the patency of thrombectomised segment even 2 years after the surgery in 80% of the patients.¹³ Similarly it was reported that in patients which were treated by synthetic graft for iliac vein replacement, distally created arteriovenous fistula preserved the patency of synthetic vein graft in 84% of the patients, whereas this ratio was 11.5% in arteriovenous fistula non-performed group.¹⁴ The venous reconstruction inevitably causes endothelial damage thus followed by secondary thrombosis. The arteriovenous fistula construction was suggested to improve the vessel patency period and to decrease the rate of postoperative thrombosis by help of increasing the venous blood flow.^{2,15} In our study we also observed that temporary arteriovenous fistula main-

tained the peritoneal tube graft patency in all survived animals at study group. Secondly the results of our study suggested that increased blood flow through the graft decreased the inflammatory reaction and maintained the mesothelial integrity. The loose neo-intima covering the graft surface play important role in intimal hyperplasia and thrombosis formation. The increased venous blood flow and pressure retarded the loose neo-intima formation in the graft surface (e.g. peritoneum) interposed to venous system. Since the complete endothelialization is important for prolonged patency¹⁶ this retardation enables the natural endothelium to cover the lumen. It is known that endothelialization process takes place at least in 30 days.¹⁷ The results of our present study suggested us that a temporary arteriovenous fistula decreased the inflammatory reaction without any antiinflammatory drug therapy and maintained the mesothelial integrity. Technically arteriovenous fistula should improve the graft patency without causing the high output cardiac failure. The output of the arteriovenous fistula should be between 100–300 ml/min to maintain graft patency.^{14,18} The creation of the fistula in a diameter of 0.4–0.6 cm will be adequate to obtain the efficient fistula output.

As a conclusion distally performed arteriovenous fistula maintained the graft patency by increasing the blood flow through inferior vena cava in which the reconstruction was performed with peritoneum.

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