

Original Article

Inferior Vena Cava Reconstruction with a Flap of Parietal Peritoneum: An Animal Study

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Background: The development of reconstructive venous surgery has been hampered by the lack of suitable grafts. Patency rates with grafts in the venous system are commonly less satisfactory than in arterial system, mainly due to nonpulsatile flow velocity and the low pressure in veins. Grafting of the inferior vena cava may be necessary in cases of trauma and major tumor surgery involving the vein. Several types of grafts have been evaluated. Reconstruction of the vena cava with autologous vein is so time-consuming and requires extra incisions. Prosthetic material is associated with a higher risk of infection and thrombosis. We, therefore, created an animal model of inferior vena cava reconstruction using a flap of parietal peritoneum.

Methods: A tube, 5 cm in length and 1cm in diameter, was constructed from the parietal peritoneum of the anterior abdominal wall of ten dogs. It was anastomosed end-to-end as an interposition graft to the inferior vena cava. The observation period was two months.

Results: Eight of ten grafts were macroscopically and venographically patent, while the other two were occluded. Eight out of ten specimens (for pathologic examination) which revealed patent lumens were completely endothelialized. No infection or other problems were noted.

Conclusion: The peritoneum is an accessible and safe substitute for reconstruction of the inferior vena cava.

Archives of Iranian Medicine, Volume 12, Number 5, 2009: 448 – 453.

Keywords: Inferior vena cava • peritoneum • vein reconstruction

Introduction

Lack of suitable graft materials to replace large-caliber veins considerably delayed the development of reconstructive venous surgery. There is a need for reconstruction of major veins in cases such as advanced tumor and major venous trauma.¹⁻⁴

Grafting and reconstruction of the inferior vena cava (IVC) is required after resection of invasive retroperitoneal tumors,^{5,6} gynecologic tumors,⁵⁻⁷ hepatocellular carcinomas,⁵⁻⁷ renal cell carcinomas,⁵⁻⁹ and also major trauma; but so far no

ideal graft material has been found.

Autologous peritoneum seems suitable enough for replacement of the IVC as a venous graft and is readily available in large quantities.

The aim of the present study was to evaluate a flap of parietal peritoneum for replacement of the IVC as an interpositional tube graft in dogs (the animal in which the behavior of prostheses most closely parallels that in humans), during an observation period of two months.

Materials and Methods

Ten randomly selected, healthy dogs of both sexes and various ages weighing 15 to 20 kg were used as cases.

Anesthesia was induced with intravenous thiopental sodium (Pentotal, Abbot, Sweden). Endotracheal intubation was done and the anesthesia maintained with oxygen and halothane, by a mechanical ventilator.

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Accepted for publication: 27 May 2009

Eight hundred thousand units of penicillin G plus procaine (Penicillin G Mixture, Haian, Iran) injected intramuscularly and two doses prescribed after the operation. The dogs were on supine position during the surgery.

Surgical procedures

Surgery was performed under sterile conditions. Through a midline laparotomy, the intestines were set aside to the left (and moisturized with gauze swab) to expose the IVC from the renal veins to the caval bifurcation. The IVC distal to the renal veins was dissected free.

A tube was constructed with parietal peritoneum from the anterior abdominal wall with a length of 5 cm and a diameter of 1 cm.

This was performed using a thoracic catheter (10.7 mm diameter) as a stent, and continuous everting 5 – 0 polypropylene (Prolene, Ethicon, UK) sutures (Figure 1A). Then, it was carefully dissected from the abdominal wall (and the surrounding fat tissue was removed), till it could be easily placed close to the IVC (Figure 1B).

After intravenous injection of 50 units/kg of heparin (Heparin, IPDIC, Iran), the IVC cross-clamped by vascular clamps, below the renal veins and above the confluence of the iliac veins, and a 4 – 5 cm of the IVC was excised.

The peritoneal tube graft was anastomosed as an interposition graft to the IVC with end-to-end anastomosis (Figure 2). The anastomosis was performed with continuous everting 5 – 0 Prolene sutures. Patency was awaited for ten minutes after which the laparotomy wound was closed. The duration of the operation was two and a half to three hours and clamping time was about 50 minutes. Two doses of heparin were injected intramuscularly after the surgery. Each dog was kept in a separate cage and there was an unlimited access to food and water.

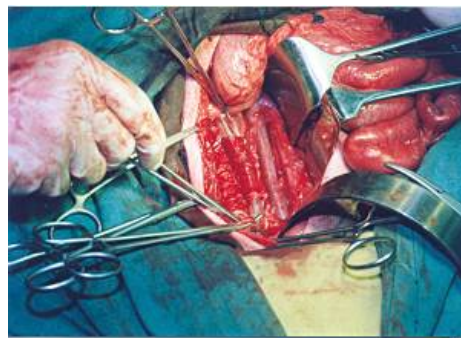
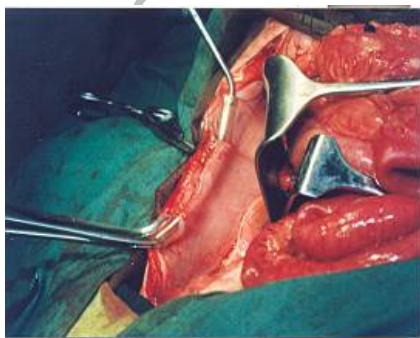


Figure 1. A) The peritoneal tube, constructed with a thoracic catheter as stent, using continuous, everting 5 – 0 Prolene sutures. **B)** The peritoneal tube, dissected from the abdominal wall and fat, compared with the IVC in its level.

After at least two months, the dogs were re-anesthetized as previously described, and phlebography was done for them; patency was evaluated by inspection after which the graft area was excised and sent for pathologic examination, and the dogs were sacrificed painlessly.

Phlebography

At the end of the study, all animals re-anesthetized as previously described and, via a right groin incision, a catheter entered into the right femoral vein. Phlebography was then performed in the antero-posterior position using 20 mL of contrast medium (Meglumine Compound 76%, Darou Pakhsh Pharmaceutical Mfg, Iran).

Just for one case, phlebography had been done intraoperatively.

Pathologic examination

The grafted peritoneum and its surrounding soft tissue were examined macroscopically. Any possible lumen was marked by an appropriate cannula. Then, the whole grafted region excised en-bloc and put in 10% buffered formalin.

After proper fixation, serial cross-sections were made at the level of cannula and any other possible lumens. A mean of two paraffin blocks were prepared from each case. A 3 µm thick slide was made from each block and stained by hematoxylin and eosin, and finally examined microscopically.

Results

All the animals survived the operation and the subsequent observation period.

None of the animals developed lower extremity edema, but some engorgements of superficial veins were detected in the abdomen of three animals (dogs 7, 9, 10). We started to sacrifice the animals after two months.

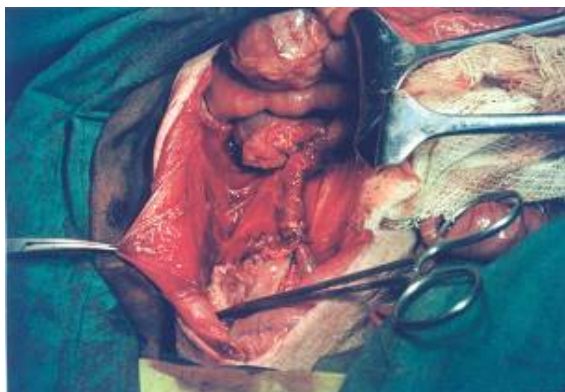


Figure 2. The peritoneal tube graft anastomosed as an interpositional graft to the IVC, with end-to-end anastomosis.

Phlebography

The phlebography two months after the surgery showed that eight grafts were patent (dogs 1 to 8). In two of the patent grafts (dogs 7, 8), there were some degrees of stenosis (especially at the cranial anastomosis) and there was filling in one or two collaterals.

Two of the grafts were occluded. In the animals with occluded grafts, the venous flow drained within a few collaterals.

Macroscopic evaluation

None of the animals showed any signs of infection at relaparotomy; but some degrees of adhesion adjacent to the graft area were presented.

Macroscopically, seven grafts (dogs 1 to 7) were patent at the end of study, while two grafts (dogs 9, 10) were occluded. One graft (dog 8) seemed highly stenotic.

The occluded grafts were totally obliterated and could be identified mainly as a fibrous strand with remaining sutures.

Pathologic examination

Macroscopically, seven of them revealed patent lumen which was confirmed microscopically (dogs 1 to 7) (Figure 3).

The wall of lumens was composed of a fibrofatty tissue with no definite and recognizable three-layer pattern (intima, media, adventitia) of true vessels (Figures 3 and 4). The lumens were endothelialized completely (Figures 4A and 4B). No thrombosis identified.

Two out of ten cases did not show any grossly recognizable lumen (dogs 9, 10). On histopathologic examination, the lumens of the artificially made channels were totally obliterated and fibrosed. No definite endothelialization

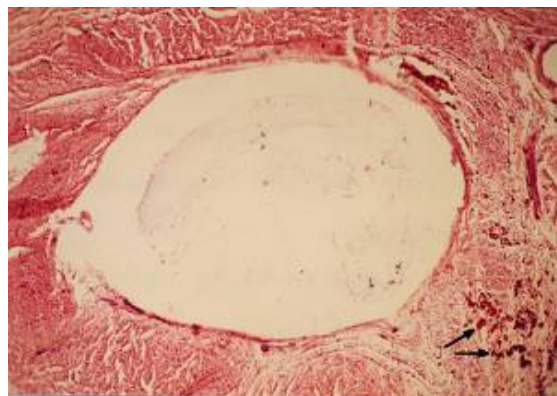


Figure 3. Low-power view of patent vascular channel. There is no well-formed intima or media of true vessels. Hemosiderin in the wall has been marked by the arrows (H&E×60).

identified. Beside them, chronic inflammation and foreign body giant cell reaction to suture materials were the only abnormal pathologic findings.

Histopathologic examination of one of the specimens did not reveal any artificially produced peritoneal channel at all, which could be due to improper sampling during autopsy.

Discussion

Venous grafting procedures imply a challenge in vascular surgery. Grafts in the venous system do not perform as well as their counterparts in the arterial system because of several unique characteristics of the venous environment:

1) A capacity for recanalization of native vessels with frequent formation of intraluminal adhesions.

2) Low intraluminal pressure.

3) Slow flow against a hydrostatic pressure gradient.

4) Low oxygen tension.

5) Irregular flow as a result of phasic nature and turbulence around valves.

6) Thin, fragile vessel walls.

7) A propensity for formation of large, profuse collateral pathways that can compete with and diminish flow in an implanted graft.¹⁰⁻¹²

Venous grafts are desirable clinically for large veins involved by obstruction, neoplastic invasion, congenital anomalies, and extensive laceration.

IVC reconstruction is required in cases of major trauma or obstruction, and also after resection of invasive hepatic malignancies, leiomyosarcoma, renal cell carcinomas, and adrenal carcinomas.^{6,7,9}

IVC reconstruction can improve survival particularly of patients with slow-growing tumors.

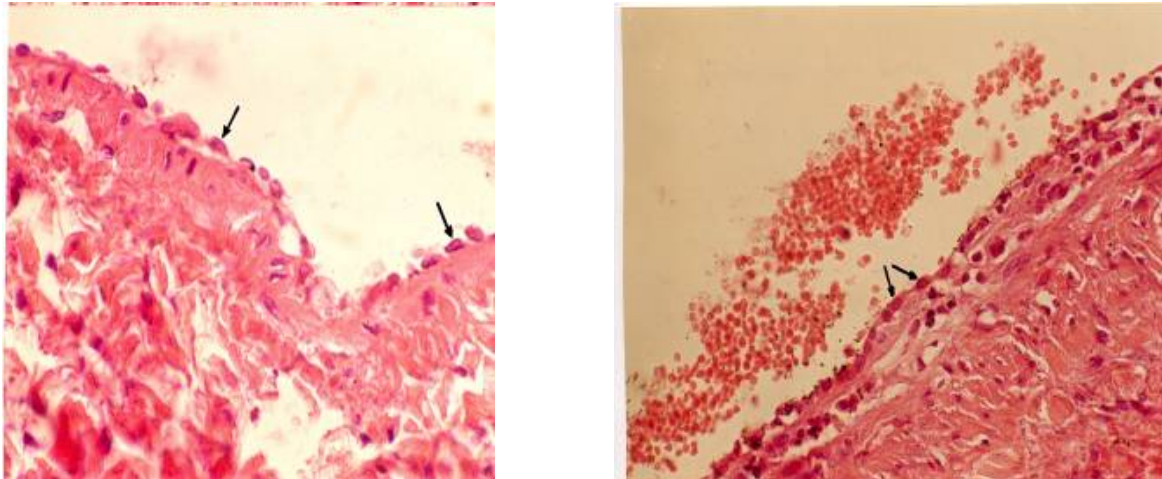


Figure 4. A) High magnification of the same field. The arrows show endothelial cells. No media is present (H&E×400). **B)** High-power view of the lumen side of the peritoneal tube graft. RBCs are seen. Endothelial lining has been marked (H&E×200).

Although in the area of venous reconstruction no graft material has been found superior to autologous veins, there is lack of suitable veins for large vein repair. Large-caliber autogenous vein grafts have been created by paneling several segments of vein into a composite tube and also by constructing spiral grafts.¹³ The superficial femoral veins and spiral jugular veins have been used for IVC reconstruction. In addition, there are other reports^{14,15} of using small-caliber veins for reconstruction of the IVC. The greater saphenous, left renal veins,⁶ and internal jugular veins¹⁶ have been used for portal vein reconstruction. The iliac vein has been used for hepatic vein reconstruction.¹⁷

These techniques to create large-caliber autogenous vein grafts are tedious and so time-consuming that patients may not be able to withstand the operative time (especially in major trauma)^{2,18} and they require additional incisions.

Synthetic grafts are used when vein grafts are unavailable because of prior use or disease, or inadequate size. Polytetrafluoroethylene (PTFE) grafts have been used as a synthetic alternative to autologous vein grafts for reconstruction of the IVC.

Although, as a result of some experimental studies,^{6,19,20} PTFE is the most promising solution for IVC reconstruction, there are still two major unresolved problems with such grafts:

1) A persistently higher thrombosis rate compared with autologous grafts when they are used in a low-flow runoff bed.

2) An increased risk of graft infection.

Although the clinical reports of IVC

reconstruction using a PTFE tube graft,^{6,19-22} did not mention infections as PTFE-associated complications, autologous materials are less susceptible to infection than prosthetic grafts. Furthermore, IVC reconstructions are often performed with hepatic surgery or intestinal resection. The material used for IVC reconstruction in these contaminated fields must be carefully selected to ensure a low risk of graft infection.

Use of autologous materials will probably have a lower thrombosis rate and greater resistance to infection than prosthetic materials in lower flow venous system.^{1-4,6,8,23,20}

Autologous peritoneum is an interesting material to be tried for venous grafting. Its mesothelium originates embryologically from the same stem cell as the endothelium. It also has properties to produce various regulator of fibrinolysis (such as t-PA, PAI-1, and PAI-2) and prostacyclin.^{3,23,24}

van Hinsbergh²⁴ and associates showed that epithelioid cells obtained from omental tissue are mesothelial in character and produce various regulators of fibrinolysis: t-PA, PAI-1, and PAI-2.

Akimaru⁶ and colleagues resected a 2.5×2.5 cm piece of peritoneum from seven pigs and made an oval window (long axis: 1.5 cm) in the infrarenal IVC, and then repaired that with the peritoneal patch fixed in alcohol. At the end, they concluded that the peritoneum is an accessible and safe substitute for reconstruction of the IVC.

In addition, Yoshioka²⁵ et al. used peritoneal patch fixed in alcohol for repairing the defect made in the anterior wall of the portal vein in pigs. They

suggested that their patch-graft technique using the peritoneum is a good and safe alternative for reconstruction after partial resection of the portal vein in clinical surgery.

As a whole, in this study, we chose parietal peritoneum as a vascular graft because:

1) Mesothelium in its surface has the same origin as the endothelium.^{3,23}

2) Its properties to produce various regulators of fibrinolysis and prostacyclin.^{3,23,24}

3) It is readily available and does not need any additional incisions.

4) It is readily available in large quantities.

Our results after two months showed that eight of the ten grafts were patent (although two of them were somehow stenotic), while two of them were completely occluded.

The reasons for stenotic grafts could be a reaction that had been augmented by the inclusion of the posterior abdominal wall muscle in the grafts (although we tried not to include the muscles in our tube graft).

One probable reason for the occlusions is that the graft wall is thin and soft and may be easily squeezed by external pressure as the intravascular pressure is low.

Another reason for the graft failures might be thrombotic occlusions. Clarke²⁶ et al. found in an *in vitro* model that uninjured mesothelium did not aggregate platelets whereas damaged mesothelium did. Complete endothelialization is important for prolonged patency,^{6,27} as we showed a good patency with the endothelial cells over the inner surface of the tube graft in the patent lumen.

Another possible reason for the occlusions of two grafts in this study might be the longitudinal suture line which might induce fibrosis. The changes found microscopically in our study (even in the patent grafts) indicated that major reactions occurred along suture lines.

Reconstruction of the IVC by peritoneal flap is safe, easy, and preferable to synthetic materials.

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