REVIEW

Abdominal Aortic Aneurysm Surgery in Renal, Cardiac and Hepatic Transplant Recipients

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Abstract With advancements in transplantation and improved long-term allograft survival, the once rare clinical scenario of an abdominal aortic aneurysm (AAA) in a patient with a functioning allograft has become much more frequent. In transplant recipients, AAA repair has the potential to cause irreversible ischaemic injury to the transplanted organ. Different case series and case reports have mentioned a variety of techniques to offer protection to the transplanted organs during aneurysm repair such as cold perfusion, shunting, temporary surgical bypass and extracorporeal circuits etc. Critical review of these adjuncts seems to suggest that they do not give any better results than just using a “clamp and go” approach. Endovascular aneurysm repair (EVAR) may offer some advantages for transplant patients who have suitable anatomy for endovascular stent deployment. In addition to these surgical techniques, various aspects of medical management for renal, cardiac and hepatic transplant recipients undergoing AAA repair are discussed.

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Introduction

With increasing numbers of transplants being performed, the prevalence of transplant recipients with an abdominal aortic aneurysm (AAA) has increased. Transplantation is now offered to a wider age group of patients, and recipients are surviving longer with advances in immunosuppression therapy. The hypertensive, diabetic and pro-atherogenic side effects of immunosuppressive agents promote vascular disease in these patients, making the management of these patients complex. The combination of an AAA and transplanted organ creates unique management challenges:

- Renal transplants derive their blood supply from the iliac arteries below the AAA. In the past, maintaining adequate renal perfusion during open AAA repair has been achieved by several methods, with no clear consensus on which is most effective.
- The de-enervated transplanted heart needs careful monitoring during AAA repair.
- Previous hepatic transplantation may leave a relatively "hostile abdomen" with the potential for a high risk complex open repair.

Different case series and case reports have mentioned a variety of medical and surgical techniques to offer protection to transplanted organs during AAA repair. This article is a critical review of these techniques.

Methods

A systematic literature search of the related articles published between January 1975 and January 2008 was carried out using Pubmed and Embase databases by two independent researchers (US and KV). The keywords used for literature search included “aneurysms”, “abdominal aortic aneurysm”, “ruptured aortic aneurysms”, “endovascular aneurysm repair”, “open aneurysm repair”, “renal transplant”, “kidney transplant” “liver transplant”, “hepatic transplant” “cardiac transplant”, heart transplant” and “lung transplant”. Relevant medical journals such as The Journal of Vascular surgery, European Journal of Vascular and Endovascular Surgery, Transplantation, American Journal of Transplantation and Transplant Proceedings were also hand searched. Each relevant article retrieved had its references searched for missed reports.

Aortic Aneurysm Repair in Renal Transplant Patients

Most of the case series reporting AAA repair in renal transplant recipients focus on the strategies used to preserve renal function. Such strategies can be divided into two broad categories: aneurysm repair without transplant protection and repair with prophylactic protective measures.

Aorto-iliac reconstruction without renal transplant protection

Kidneys can tolerate a warm ischaemia time of approximately 50 min. Therefore if blood flow is re-established within this time, renal function theoretically should return to normal with minimal deficit. It is possible that ischaemia does result in some irreversible damage, but this is tolerated because of functional reserve in the kidney. This becomes a significant issue in transplanted organs as some of that functional reserve is lost during the transplantation process. In spite of this, success without graft protection has been achieved and reported. Back flow may also provide some blood supply to a transplanted kidney to protect against ischaemia.

After supra-aneurysmal cross-clamping, aortic back pressure was found to be more than 35 mmHg in the elective setting. Kidneys perfused by an arterial pressure of only 25 mmHg may remain viable for 2–3 h. There have been several reports of AAA repair without protection of the kidney transplant. In Lacombe’s experience of 5 patients, a temporary creatinine rise was seen in only one patient. This patient, in addition to an AAA, had bilateral iliac artery aneurysms involving external and internal iliac arteries, and had an aorta to external iliac graft with reimplantation of the renal transplant artery. The aortic clamp time was 50 min. Although none of these patients produced any urine during the clamping time, adequate urine output was restored by the end of the operation. Of the 4 cases reported by Moon, two underwent aorto-bi-iliac bypass without any surgical protection. The warm ischaemia time was 37 min and 25 min respectively and transient rises in serum creatinine were observed (the remaining two patients had renal protection by aorto-iliac bypass and cold perfusion). Harris and May and Mately and Immelman have also favoured slight modifications to their operative techniques rather than using shunts or other advanced techniques: In a patient with atherosclerotic stenosis of the right common iliac artery and of the right internal iliac artery, which supplied the transplanted kidney, a bifurcated Dacron graft (16 mm/8 mm) was used for the aortic reconstruction. The origin of the graft was from the infra-renal abdominal aorta. The right limb of the bifurcated graft was anastomosed to the transplanted renal artery, divided immediately beyond the stenotic segment. The left limb was anastomosed to the right common femoral artery.

Aorto-iliac reconstruction with renal transplant protection

A range of techniques to protect the renal transplant have been reported. These include temporary surgical bypass, shunting, extracorporeal circuits and cold perfusion for the delivery of oxygenated blood.

Axillo-femoral bypass

Shons et al. reported the use of an axillo-femoral bypass during repair of an infra-renal mycotic aortic aneurysm following renal transplantation. An 8 mm woven Dacron graft was used for the left sided axillo-femoral bypass following which the mycotic aneurysm was resected. The proximal aorta just distal to the renal arteries was oversewn. The left common iliac artery was ligated proximal to the left hypogastric artery and at the site of the end-to-side transplant renal artery/external iliac artery anastomosis. There was a significant increase in serum creatinine to
4.6 mg/100 ml, which decreased to normal by the 15th postoperative day. The patient died two months after surgery from an aortic rupture due to progression of the underlying infecting process.

Temporary externally-routed axillary artery to common femoral artery bypass was used by Roach et al. to protect renal transplants in three patients. The renal transplant was perfused in a retrograde manner while aortic and/or iliac clamps were used to exclude the aneurysm during the operation. The maximum aortic cross-clamp time was 65 min with a minimum of 45 min. Although there was an increase in the operating time by 45–60 min the technique provided complete protection of the renal transplant from warm ischaemia. There was no postoperative deterioration in renal function of either of these patients. Gibbons et al. have published similar results in two patients.

Aorto-femoral shunting
There are reports of temporary aorto-femoral shunting (i.e. Gott shunt) to provide temporary renal transplant perfusion. The proximal end of the shunt is used to cannulate the aorta through 2 purse string sutures (Fig. 1). Similar use of temporary shunting during aorto-iliac repair has been described. A modification of this has also been described by Kashyap and Quinones-Baldrich. Instead of using separate aortic cannulation, an inline shunt was fashioned by placing a 20 French chest tube through the iliac limb of the bifurcated graft into the supra renal aorta. It was then guided into the right common iliac artery and held in place with Rumel tourniquets (Fig. 2). The proximal anastomosis was then completed followed by iliac anastomosis, with the removal of the shunt just before the completion of the iliac anastomosis. The patient had an uneventful recovery with no renal dysfunction postoperatively.

Sterioff et al. have also described the use of polyvinyl tubing as a shunt, which was placed between the upper abdominal aorta and the common iliac artery. Renal perfusion pressure was only 15 mmHg less than systemic pressure. The transplanted kidney functioned normally during 71 min of aortic cross-clamping, and there was no evidence of postoperative renal failure. Similar benefits have been reported by O’Mara and colleagues.

Pump oxygenator
Campbell and colleagues first described the use of a pump oxygenator in 1982 for transplant protection.
et al.\textsuperscript{16} and Wolfe et al.\textsuperscript{17} have also reported two cases in which femoro-femoral bypass with a pump oxygenator was used. Clamping time was 40 min and a perfusion pressure of 60–80 mmHg was maintained throughout the procedure.\textsuperscript{17} Panneton et al. have described the use of atrio-femoral extracorporeal shunting in a patient undergoing descending thoracic aortic aneurysm repair.\textsuperscript{18} The utility of such extracorporeal bypass shunts is restricted however by their limited availability outside cardiothoracic units.

**Cold perfusion and topical cooling**

Continuous hypothermic renal perfusion during aneurysm repair was first reported by Nghiem and Lee.\textsuperscript{19} They used continuous perfusion of 4 °C Ringer’s lactate directly into the iliac artery anastomosed to the renal graft (Fig. 3). Panneton\textsuperscript{18} has also described this method of renal protection. Chacko and colleagues described using sterile ice slush for external cooling of the renal transplant during aortic surgery. After removal of the ice slush and clamps, urine production resumed and creatinine levels remained unchanged.\textsuperscript{20}

**Systemic hypothermia**

Lacombe has described systemic hypothermia as an adjunct for transplant protection. Although there was no urine output during the period of aortic clamping, adequate urine output was restored by the end of the operation.\textsuperscript{3} The duration of vascular clamping was 25 min, with a pre-operative serum creatinine value of 1.1 mg/dl, a maximum postoperative value of 1.2 mg/dl and a long-term value of 1.1 mg/dl.

From the above description of various techniques, it can be seen that most investigators have used some form of allograft protection. But the outcomes of using these techniques are comparable to those of some surgeons who just used a “clamp and go” approach. Clearly protective techniques increase operative time. A “clamp and go” technique may be an efficient method of AAA repair in experienced hands. Hypothetically, clamping and declamping proximal to a transplant organ would also have the potential of protecting it from ischaemia reperfusion injury due to direct ischaemic preconditioning. However, to our knowledge, there have been no trials of preconditioning in transplanted kidneys. A large-scale trial, looking at the effect of remote ischaemic preconditioning at the time of transplant as a means of reducing early graft dysfunction (REPAIR Trial), is underway and may provide a definitive answer.\textsuperscript{21}

**Endovascular Aneurysm Repair**

Endovascular stenting provides a minimally invasive method of repairing AAAs with frequently decreased operative times. In 2000, Sawhney et al.\textsuperscript{22} treated 2 patients with pelvic renal transplants and AAA using an aorto-uni-iliac system with femoro-femoral bypass grafting (Fig. 4). As the renal transplant derived its blood supply from the external iliac in both cases, tapered aorto-uni-iliac grafts were fashioned with their distal landing site in the common iliac artery. Both patients had an uneventful recovery and there was no endoleak or other complication related to their aneurysm repair. Forbes et al.\textsuperscript{23} reported the use of EVAR in treating an asymptomatic 7.0 cm abdominal aortic aneurysm, in a patient with a renal transplant fed by the right external iliac artery, using a bifurcated system. The aorto-iliac component was introduced through the left femoral artery. The right limb of the graft and iliac extension were inserted in a retrograde fashion from the right common femoral artery so that the graft terminated in the common iliac artery. Fifteen case reports have now been published since 2000 confirming that endovascular repair is safe in patients with previous renal transplants. There is no consensus regarding the safe dose of contrast medium that can be used during EVAR in transplant recipients. But as recommended for non-transplant patients, the amount of contrast used should be kept to a minimum. There is no increased risk of contrast induced nephropathy (CIN) in transplant kidneys and normal kidneys are equally susceptible to CIN.\textsuperscript{24,25} CIN can be prophylactically treated by good hydration, diuresis and anti-oxidants such as N-acetylcysteine.\textsuperscript{24,26,27}

**Simultaneous AAA and Renal Transplantation**

This is a very rare management choice. Only a small number of simultaneous renal transplant and AAA repairs have been reported. The first description was by Cerilli and colleagues in 1977.\textsuperscript{28} According to Adamec et al.,\textsuperscript{29} the single-staged operation has its advantages in that there is only one anaesthesia involved and patients require only one hospital admission. There are however, obvious disadvantages such as the urgent nature of the procedure when the allograft becomes available, the known increased risk of aneurysm...
repair in a renal failure patient and potential effects on the grafted kidney should the patient have episodes of haemodynamic instability following an operation of such magnitude. A renal patient optimized for surgery by dialysis is still at high risk of surgical complications. A combined operation in this setting invites systemic complications.

The use of fresh arterial allografts (FAGs) for AAA repair combined with renal transplantation has also been reported. Adamec et al. have reported the largest case series of simultaneous aortic reconstruction using FAG and kidney transplantation. In each case FAG and the kidney were harvested from the same patient. All patients were immunosuppressed with cyclosporin or tacrolimus, mycophenolate mofetil (MMF) and steroids. Of the five patients in this series, there was one death at 6 weeks after the operation. One patient had ischaemic colitis which required partial colonic resection.

A general trend has developed over the years. Permanent bypass procedures have been replaced by temporary bypass/shunting procedures, which have given way to EVAR in suitable cases. Although there is considerable evidence in the literature that renal transplants can withstand ischaemia for moderate periods (2–3 h) without perfusion, this strategy has not gained popularity. EVAR has also resolved this, as it provides the best chance of avoiding renal ischaemia.

**Aneurysm Repair in Heart (HT) and/or Lung Transplant Patients**

The natural history of AAAs in this subgroup is that of rapid expansion and rupture following the transplant procedure. Although the precise precipitating factor for this behaviour has not been identified, different multivariate logistic regression models have identified pre HT ischaemic heart disease, male gender and old age as the common risk factors for developing post HT abdominal aortic aneurysms. Aggressive surveillance is therefore warranted in HT patients with these risk factors. There is evidence that aneurysm expansion is slower in diabetic patients than in patients without diabetes. This observation suggests aneurysm formation and expansion may not be solely a manifestation of atherosclerosis but rather may be due to other comorbid factors that promote degradation of the connective tissue within the aortic wall. Perhaps diabetic patients with transplanted organs are at lower risk for AAA growth than transplant patients without diabetes and may undergo surveillance on a schedule similar to patients without a transplant. The role of immunosuppression remains unclear. A reduction in the immunosuppression therapy to slow the aneurysm expansion is not recommended. Other factors related to AAA specific to heart transplantation are: the circulatory anomaly resulting from cardiac denervation at the time of transplant and size difference between the donor aorta and the recipient aorta. Such factors may result in altered biomechanical stresses that influence aneurysm formation and expansion. Also most patients develop hypertension after heart transplantation. This may result from a significant increase in ejection fraction or the proatherosclerotic effects of immunosuppressants. Use of antihypertensive medications, which would lead to the reduction in afterload, could be potentially beneficial in this regard.

**Aneurysm Repair in Liver Transplant (LT) Patients**

Orthotopic liver transplantation remains the standard of care for decompensating cirrhosis. There are case reports where open aneurysmectomy was performed in patients with previous LTs. Most reports describe adhesions which had to be dealt with before the main procedure. These may have resulted from previous surgery, spontaneous bacterial peritonitis, sclerosing peritonitis and fibrosing retroperitoneum associated with the resolution of portal-hypertension varices. Endovascular techniques allow this problem to be avoided in selected cases. The current recommendations for AAA repair by the Joint Council of the American Association for Vascular Surgery and Society for Vascular Surgery favour the use of EVAR in LT patients who are at high risk for an open repair and have suitable
anatomy. According to Mekeel et al., most LT recipients are in the high risk category for an open repair due to previous abdominal surgery and maintenance on immunosuppressants. On the other hand, EVAR is contraindicated in patients with arterial flow to the liver from an aortic jump graft. As with other transplant recipients the theoretical risk of infection is increased in LT patients as they are immunocompromised. However, to date no infectious prosthesis-related complications have been reported in LT patients following AAA repair.

Conclusions

Critical review of various techniques, that have been used traditionally for transplant protection, seems to suggest that that they do not give any better results than just using a "clamp and go" approach. EVAR has theoretical advantages in the renal transplant patient presumably because the periods of reduced flow in the iliac arteries are relatively short. There is also a significant reduction in the surgical stress to the patient. In the case of open surgery for renal transplant patients, if the period of clamping is predicted to be less than 50 min, then little protection may be required and a "clamp and go" approach can be adopted. Renal cooling, mannitol and fluid loading have all been used to provide renal protection in this setting. Distal perfusion with a shunt after the proximal anastomosis allows time for the distal lower anastomosis or anastomoses. If the proximal aortic anastomosis will be complex then some form of shunt after the proximal anastomosis allows time for renal protection in this setting. Distal perfusion with a shunt after the proximal anastomosis allows time for the distal lower anastomosis or anastomoses. If the proximal aortic anastomosis will be complex then some form of shunt or extracorporeal bypass can be used. In any case of transplant, medical optimization is usually required during aortic aneurysm surgery which involves adequate blood pressure control and optimal immunosuppressant and steroid therapy.

Conflict of Interest

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Ethical Approval

NA.

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