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REVIEW ARTICLE

Techniques for Surgical Conversion of Aortic Endoprosthesis

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Introduction

Conversion from endoluminal to open repair of abdominal aortic aneurysms (AAA) may be required at the original operation (primary conversion) or at a later operation (secondary conversion). A review of the literature reveals that little has been written on conversion or the techniques of performing this procedure.

We have previously reported[1] the high mortality rate (43%) in patients rejected for open abdominal aortic aneurysm repair in whom endoluminal repair was undertaken and primary conversion required. We have also noted that the incidence and indications for conversion from endoluminal to open repair of abdominal aortic aneurysms have changed.[2] This paper examines our continuing experience with conversion and discusses techniques that may be used for performing the primary and secondary forms of this operation.

Incidence and Causes of Conversion

Between May 1992 and May 1998 at the Royal Prince Alfred Hospital, the endoluminal method was used to repair 221 abdominal aortic aneurysms. Excluded from the present study were 13 secondary endoluminal repairs and four patients in whom the pathology was that of false aneurysm. Primary conversion at the original operation was required in 17 patients, and secondary conversion at a subsequent operation was required in a further 17 patients.

Patients were divided into two groups who had their operations in two consecutive periods of 3-year duration. Group I consisted of 70 patients who underwent endoluminal repair of abdominal aortic aneurysms between May 1992 and May 1995. Group II consisted of 151 patients who underwent endoluminal repair of abdominal aortic aneurysms between May 1995 and May 1998.

Primary conversion

Endoluminal repair was achieved in 204 patients. Conversion to open repair was required in the remaining 17 patients. The majority of primary conversions occurred in Group I (Table 1). In this group, 17% required conversion compared with 3% in Group II. The causes of failure have been described in detail previously[3] (Table 2).

There were eight perioperative deaths (overall mortality 3.6%), five of which occurred in the 204 patients undergoing successful endoluminal repair (2.5%). The remaining three occurred in 17 patients requiring conversion from endoluminal to open repair (18%). All three patients in the latter group

Table 1. Primary conversion rates for the two groups of patients undergoing endoluminal repair of abdominal aortic aneurysm.

	Operations	Primary conversions
Group I	70	12 (17%)
Group II	151	5 (3%)
Total	221	17

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Table 2. Causes of failure leading to primary conversion.

	Group I	Group II
Access problems	2	
Aortic/iliac rupture	1	1
Balloon malfunction	1	
Migration	3	2
Endograft thrombosis	1	
Bifurcated deployment failure	4	2
Totals	12	5

had co-morbidities that led to them being rejected for open repair at other medical centres. There were four deaths in 70 operations (5.7%) in Group I and four deaths in 151 operations (2.6%) in Group II. The mortality rates for the various subgroups are summarised in Table 3. The cause of the eight perioperative deaths was myocardial infarction ($n=3$), renal failure ($n=3$), multisystem failure ($n=1$) and sigmoid volvulus after discharge but less than 30 days postoperatively.

Comparative figures reported in the literature for primary conversion and perioperative mortality are summarised in Table 4.

Secondary conversion

Secondary conversion to open repair was required in 17 patients. The causes of these secondary conversions were persistent endoleak in 12 patients, increasing abdominal aortic aneurysm diameter in the absence of endoleak in two patients, inadvertent covering of the renal arteries by the endograft in two and migration without endoleak in one patient (Table 5). The covered renal arteries were not detected at the original operation. The patients presented with anuria in the first 24 hours postoperatively. The diagnosis was confirmed by aortography in one and plain X-ray in the other (Fig. 1). The latter investigation was able to be performed more rapidly, by less experienced staff, and avoided further contrast load. Of the 12 patients undergoing conversion for persistent endoleak, five had intact aneurysms while seven with known endoleaks presented with ruptured aneurysms (Fig. 2). All patients who presented with rupture but one survived secondary conversion to open repair, despite the presence of severe co-morbidities in six of the group. This unexpectedly high survival rate has been reported in detail.[18]

Late deaths occurred in 10 patients due to myocardial infarction ($n=6$), liver failure ($n=2$), ruptured

Table 5. Causes of failure leading to secondary conversion.

Persistent endoleak (presenting with rupture, $n=7$)	12
Increasing diameter/no endoleak	2
Inadvertent covering of renal arteries	2
Migration of prosthesis/no endoleak	1

Table 3. Mortality rates for subgroups of patients undergoing endoluminal repair.

	Overall	Successful endoluminal repair	Conversion to open repair (primary)	Group I	Group II
Patients	221	204	17	70	151
Deaths	8	5	3	4	4
Mortality (%)	3.6	2.5	18	5.7	2.6

Table 4. Reported results of conversion and mortality following endoluminal repair of AAAs.

Series	Prosthesis	*n*	Conversion to open repair	30-day mortality
Blum[4]	Vanguard	154	3 (2%)	1 (1%)
Parodi[5,6]	Parodi device	109	4 (4%)	5 (5%)
Chuter[7,8]	Chuter–Gianturco	54	3 (6%)	3 (5%)
Moore[9]	EVT	46	7 (15%)	0
Balm[10]	EVT	31	1 (3%)	1 (3%)
Yusuf[11]	Ivancev–Malmo	30	5 (17%)	2 (7%)
Lawrence-Brown[12]	HLB–Perth	21	0 (0%)	1 (4%)
White[13]	White–Yu	76	8 (11%)	3 (4%)
Thompson[14]	Bell–Leicester	25	5 (25%)	2 (8%)
Zarins[15]	AneuRx	190	0 (0%)	5 (2.6%)
Beebe[16]	Vanguard	258	5 (2%)	3 (1.2%)
Criado[17]	Talent	70	5 (7%)	1 (1.4%)

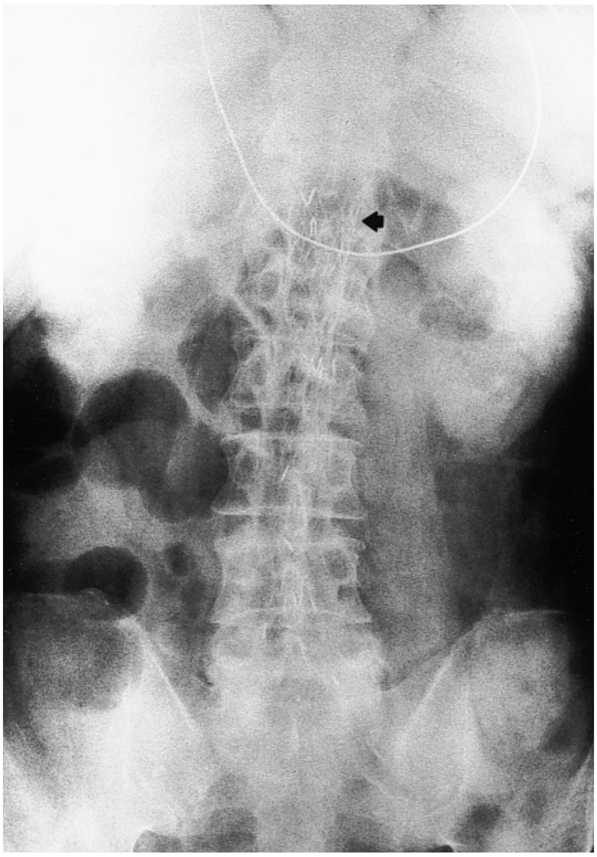

Fig. 1. Plain X-ray of an anuric patient taken eight hours after endoluminal repair of AAA. Note the superior end of the prosthesis (arrow) opposite the twelfth thoracic vertebra and well above the level of the renal arteries.

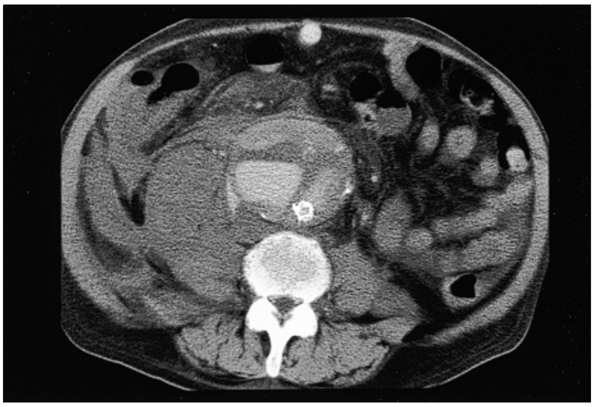

Fig. 2. One of seven patients with known endoleaks following endoluminal repair of AAA, who presented with rupture and required conversion.

oesophagus ($n=1$) and bacterial endocarditis/septicaemia ($n=1$).

Techniques for Surgical Conversion

A clear distinction must be drawn between primary conversion and secondary conversion. Primary conversion usually occurs in patients who have undergone 2–3 hours of intervention and have received a large quantity of contrast agent. Patients undergoing secondary conversion have neither of these risk factors mitigating against their recovery.

There is frequently a difference between the two procedures in the degree of urgency. Primary conversion may need to be performed expeditiously in the presence of aortic or iliac artery perforation, or the entrapment of the delivery catheter above the renal arteries[1] and in situations where the endoprosthesis has blocked the iliac outflow. Secondary conversion for persistent endoleak which could not be corrected by supplementary endovascular intervention is an elective procedure unless the patient presents with rupture. Secondary conversion may also be required urgently when the renal arteries are found to have been inadvertently covered.

It is advisable to have the patient in the operating room draped for open repair in all cases of endoluminal repair should this become necessary. If the procedure is being performed in an angiographic suite, arrangements for surgical conversion should be available and close at hand.

Four techniques may be used for conversion. The technique chosen depends on the type and position of the prosthesis being used and the indication for conversion.

Conventional open AAA repair

This may be used in patients in whom the endoluminal approach had been abandoned due to access problems where there is no endograft present in the aorta or in situations where the endograft is contained entirely within the aneurysmal sac. In this group it is possible to apply the proximal aortic clamp immediately below the renal arteries and the iliac clamps midway along the common iliac arteries without risk of injuring the vessels by clamping an artery with an underlying metal stent. The aneurysm is able to be opened and the endograft removed with no more blood loss than would be expected with a standard open repair.

Modified conventional open AAA repair

This technique may be used in patients requiring conversion who had endografts deployed in the correct position immediately below the renal arteries and/or where part of the endograft was within one or both common iliac arteries. Clamps are applied to the aorta and common iliac arteries as with a standard open AAA repair, but are opened and closed in sequence to allow removal of the underlying endograft within the jaws of the clamp. Following initial clamping, the aneurysm is opened and thrombus removed to reveal the endograft (Fig. 3). The distal ends of the endograft,

Fig. 3. The aneurysm sac has been opened at a conversion operation following perforation of the common iliac artery. The contralateral limb (thin arrow) was deployed outside the contralateral stump (thick arrow) and attempts to dislodge it from the native common iliac artery, to enable a second limb to be deployed correctly, resulted in perforation. Orientation: the patient's head is to the left and feet to the right.

be they tube, aortoiliac or bifurcated, are lifted out of the open sac after opening the appropriate iliac clamp if this is necessary. The main trunk of the endograft is then cross-clamped within the opened aneurysmal sac to assist with manipulation and reduce blood loss when the aortic clamp is temporarily released. The proximal end of the endograft is removed after opening the aortic clamp. Endografts may be removed by traction alone with no attempt being made to reduce the diameter of the graft, dis-impact hooks or cool endografts with a thermal memory. Any of the above manoeuvres are likely to lead to excessive blood loss. Surprisingly little damage is noted when the aorta and iliac arteries are inspected for damage following removal of the endografts. In the authors' experience, there have been no instances where there was any concern for the integrity of the arterial walls or their ability to hold sutures.

Supracoeliac control of the aorta

This will usually be required where endografts have been deployed over the renal arteries, or in patients who sustain rupture of the proximal neck of the aneurysm during deployment of the endograft by balloon inflation. This approach may also be required if a one-piece bifurcated endograft is deployed with a twist in the trunk, thus trapping the delivery catheter in the aorta above the level of the renal arteries. Patients with known endoleaks presenting with rupture of the aneurysm may also require temporary supracoeliac control, until the infrarenal aortic neck of the aneurysm is defined within the retroperitoneal haematoma. Supracoeliac control may also be required following removal of an infected endoprosthesis, to enable the infrarenal aorta to be oversewn.

The technique of gaining control of the supracoeliac segment of the aorta has been described in detail by the authors previously.[19] Essentially, it involves division of the gastrohepatic omentum to display the right crus of the diaphragm. The fibres of this muscle are separated to enable the index and middle fingers of the right hand to pass through the right crus, identify the underlying distal thoracic aorta, and guide the jaws of an aortic clamp around it.

Amputation of the infrarenal portion of the endoprosthesis by cutting the metal frame of para- and suprarenal attachment systems

Endografts which are anchored superiorly by attachment systems which are at the level of the renal arteries or above (Fig. 4) can usually be removed in their entirety during primary conversion, but the above technique may be required during secondary conversion where the endoprosthesis is incorporated in the aortic wall. Good-quality wire cutters are used to sever the endoprosthesis from its attachment system which remains intact and *in situ*. Alternatively, the fabric of the endoprosthesis may be divided between the stents, avoiding the need to cut the metal frame.

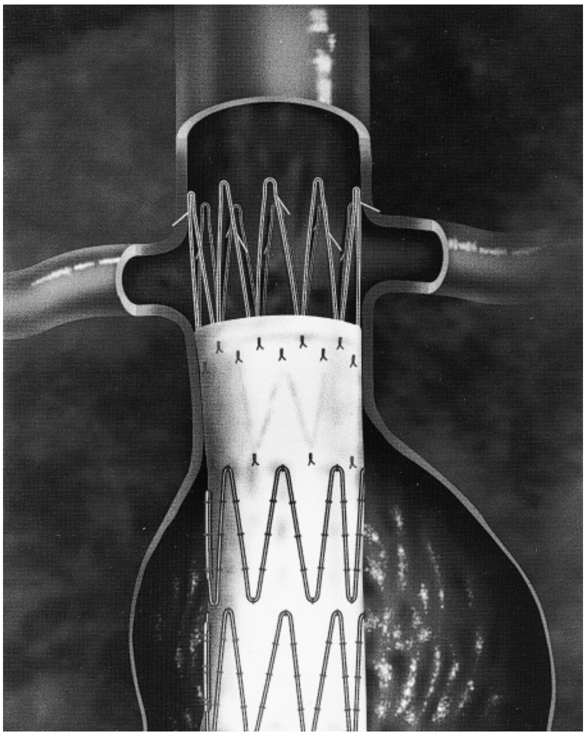

Fig. 4. Illustration of an endoprosthesis designed to be deployed with a barbed stent above the renal arteries. Adapted from a promotional brochure for the Zenith endoprosthesis (Cook Incorporated).

Table 6. Summary of indications and techniques for primary and secondary conversion from endoluminal to open repair.

	Indication for conversion	Technique
Primary conversion	Access not possible	Conventional repair
	Perforation of iliac arteries or AAA	Conventional repair
	Migration of prosthesis	Conventional repair
	Perforation of proximal neck of aneurysm	Supracoeliac control
	Delivery catheter trapped above renal arteries	Supracoeliac control
	Prosthesis with suprarenal attachment system	Supracoeliac control
Secondary conversion	Persistent endoleak	Modified conventional repair
	Increasing diameter/no endoleak	Modified conventional repair
	Chronic migration of endoprosthesis	Modified conventional repair
	Persistent endoleak with rupture AAA	Supracoeliac control
	Infected endoprosthesis	Supracoeliac control
	Prosthesis with suprarenal attachment system and endoleak	Amputation of infrarenal portion of endoprosthesis by cutting metal frame

The proximal remains of the amputated prosthesis are incorporated in the suture line which anastomoses the new graft to the neck of the aneurysm in the same way that Teflon felt is used to buttress a fragile arterial anastomosis. The authors have not had occasion to use this technique and are indebted to Dr Michael Lawrence-Brown for its inclusion. He considers it less traumatic than attempting to remove the entire prosthesis. The indications and techniques for primary and secondary conversion are summarised in Table 6.

Reconstruction following removal of the endoprosthesis

Although the configuration of the majority of the endoprostheses requiring conversion in the authors' experience have been bifurcated, most have been able to be reconstructed at open operation by using a tube prosthesis. In those instances where a bifurcated graft is required, advantage may be taken of the exposed common femoral arteries to perform an aortobifemoral reconstruction.

Adjunctive procedures for surgical conversion

Some endoprostheses have a balloon as part of the delivery catheter. In cases of perforation of the aorta or iliac arteries, during endoluminal repair, this balloon may be inflated and used to control haemorrhage while the abdomen is being opened and the aorta being controlled. Indeed the balloon may be used to enable completion of endoluminal repair and avoidance of conversion.[20]

Measurement of the intra-sac pressure prior to conversion is a useful manoeuvre in patients with an expanding aneurysm but no evidence of endoleak. Such cases usually demonstrate an intra-sac pressure which is near systolic pressure, thus confirming "endotension" and the need for conversion.

All conversion procedures expose the patient to an increased risk and are best avoided by careful case selection, appropriate preoperative investigation, accurate sizing of the endoprosthesis, thoughtful planning and good procedural technique.

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