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# Treatment of Short-necked Infrarenal Aortic Aneurysms with Fenestrated Stent-grafts: Short-term Results

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***Introduction.*** *A proximal neck of 15 mm length is usually required to allow endovascular repair of abdominal aortic aneurysms (EVAR). Many patients have been refused EVAR due to a short neck. By customising fenestrated grafts to the patients' anatomy, we can offer an endovascular solution, especially for patients who are unsuitable for open repair.*
***Methods.*** *Eighteen patients were selected for fenestrated stent-grafting if they presented with an abdominal aneurysm of at least 55 mm in diameter, a short neck (less than 15 mm), plus contra-indications for open repair (cardiopulmonary impairment or a hostile abdomen). The stent-graft used was a customised fenestrated model based on the Cook Zenith® composite system. We used additional stents to ensure apposition of the fenestrations with the side branches.*
***Results.*** *All endovascular procedures were successful. Out of the 46 targeted side branches (10 superior mesenteric arteries, 36 renal arteries), 45 were patent at the end of the procedure. One accessory renal artery became occluded by the stent-graft. There was one possible proximal type I endoleak, which later proved to be a type II endoleak. There was no mortality, but complications occurred in six patients: two cardiac complications, three urinary complications and one occlusion of a renal artery. At follow-up (mean 9.4 months, range 1–18), there were no additional renal complications and all the remaining targeted vessels stayed patent.*
***Discussion.*** *By customizing fenestrated stent-grafts, it is possible to position the first covered stent completely inside the proximal neck, thus achieving a more stable position. The additional side-stents may also contribute to a better fixation. This technique may become a valuable alternative for patients who are at high risk from open surgery.*

*Key Words: Fenestration; Stent-graft; Aortic aneurysm; Short neck.*

## Introduction

It is now more than 10 years since Parodi reported the first EVAR, initially with tube-grafts and later with bifurcated grafts.[1] Since then, many patients have been treated with different endovascular devices.[2–6] For each of these devices, there are comparable anatomical requirements for a successful endovascular repair of abdominal aortic aneurysm (EVAR). One of the necessary anatomical features is a good proximal neck, i.e. a non-tapered cylindrical portion of at least 15 mm below the renal arteries.[7–9] Several devices now present with transrenal/suprarenal fixation, to enhance the stability in the proximal neck.[10–16] Nevertheless, in general, patients with proximal necks shorter than 15 mm are regarded as unsuitable for endovascular repair. An additional reason for concern is proximal neck dilatation after EVAR.[17–23]

These problems can be solved by using a customized stent-graft design including fenestrations for the aortic side branches above such a short neck (i.e. the renal arteries and the superior mesenteric artery). It enables the first sealing portion of the stent-graft to be positioned in a more stable part of the aorta with the customized fenestrations at the exact origin of the targeted vessels. This approach makes it possible to treat patients with short necks and perhaps patients with some juxtarenal aneurysms.[24–26]

This paper reports the early experience from a European centre with a large endovascular experience, and discusses the possible benefits of this technique.

## Patients and Methods

Between November 2001 and April 2003, 18 patients with an AAA greater than 55 mm in diameter

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**Table 1. Patient and fenestrated stent-graft characteristics with targeted vessels and procedural outcome**

| Patient | Age | Sex (M;F) | ASA | AAA size* (mm) | Neck length (mm) | Anesthesia (GA;EA;LA) | RRA | LRA | Acc. RA | SMA | Number of side branches Perf/Targ | Endoleak (type) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 71 | M | 4 | 62 | 6 | EA | 1 | 1 | 0 | 0 | 2/2 | |
| 2 | 73 | F | 3 | 55 | 10 | EA | 1 | 1 | 0 | 0 | 2/2 | |
| 3 | 76 | M | 3 | 57 | 8 | EA | 1 | 1 | 1 | 1 | 3/4 | |
| 4 | 77 | M | 3 | 60 | 8 | GA | 1 | 1 | 0 | 1 | 3/3 | |
| 5 | 73 | M | 3 | Type I | 4 | GA | 1 | 1 | 0 | 1 | 3/3 | |
| 6 | 60 | M | 3 | 55 | 7 | EA | 1 | 1 | 0 | 1 | 3/3 | Type II |
| 7 | 75 | M | 3 | Type I | 10 | EA | 1 | 0 | 0 | 0 | 1/1 | Type I → type II |
| 8 | 79 | M | 3 | 55 | 9 | EA | 1 | 1 | 0 | 0 | 2/2 | Type II |
| 9 | 66 | M | 2 | 55 | 6 | EA | 1 | 1 | 0 | 1 | 3/3 | |
| 10 | 66 | M | 3 | Type I | 10 | LA | 1 | 1 | 0 | 0 | 2/2 | |
| 11 | 78 | M | 3 | 57 | 10 | EA | 1 | 1 | 0 | 0 | 2/2 | |
| 12 | 70 | M | 3 | 57 | 6 | EA | 1 | 1 | 0 | 0 | 2/2 | |
| 13 | 77 | M | 3 | 58 | 6 | EA | 1 | 1 | 0 | 1 | 3/3 | |
| 14 | 81 | M | 2 | 58 | 6 | LA | 1 | 1 | 0 | 1 | 3/3 | |
| 15 | 62 | M | 3 | 58 | 8 | LA | 1 | 1 | 0 | 0 | 2/2 | |
| 16 | 85 | F | 2 | 60 | 8 | EA | 1 | 1 | 0 | 1 | 3/3 | |
| 17 | 78 | M | 3 | 70 | 10 | EA | 1 | 1 | 0 | 1 | 3/3 | |
| 18 | 83 | M | 3 | 62 | 8 | EA | 1 | 1 | 0 | 1 | 3/3 | |

M, male; F, female; ASA, American Society of Anaesthesiologists Physical Classification; AAA, abdominal aortic aneurysm; *, diameter of aneurysm or type I endoleak after EVAR; GA, general anaesthesia; EA, epidural anaesthesia; LA, local anaesthesia; RRA, right renal artery; LRA, left renal artery; Acc. RA, accessory renal artery; SMA, superior mesenteric artery; Perf, perfused; Targ, targeted.

underwent EVAR with a fenestrated stent-graft. All patients had proximal necks unsuitable for standard EVAR (Table 1). All patients had significant co-morbidity or a hostile abdomen that precluded open abdominal repair. Six patients had cardiac, five patients cardiac and pulmonary, and three patients pulmonary contra-indications. Two patients had hostile abdomens, one after an open cysto-prostatectomy and radiotherapy and one with a productive aorto-enteric fistulae. Finally, three patients (one already mentioned with a hostile abdomen) had a type I endoleaks after previous stent-grafting with a neck that was too short. Informed consent was obtained from all patients.

### *Stent-graft configuration*

Detailed evaluation of the proximal neck was obtained by spiral CT with axial and perpendicular reconstructions. A calibrated angiogram was also performed. The stent-graft used was a composite endoluminal prosthesis based on the Zenith system (William A. Cook Australia Pty. Ltd., Brisbane, Australia), which has a self-expanding modular design with an uncovered Gianturco Z-stent (William Cook Europe, Bjaeverskov, Denmark) for proximal fixation in the standard configuration. The proximal anchor stent, which has multiple spikes at its upper end to enhance fixation, is designed for suprarenal implantation.

There was one major modification with regard to the Australian study.[25] In contrast to the previous bifurcated two piece fenestrated system, we used a composite system composed of a tube in which a bifurcated device is to be positioned (Fig. 1). A contra lateral limb completes the three-part configuration. The tube graft was also fitted with diameter reducing ties to allow only partial deployment prior to catheterisation of the side branches and final orientation of the stent-graft.

Customization of the stent grafts was based on each individual configuration. Three types of fenestrations were possible: scallops, large and small fenestrations (Fig. 2). Each fenestration was marked by three (scallop) or four (small or large fenestration) radiopaque markers to enable accurate alignment. Each tube graft was fitted with anterior and posterior markers to facilitate orientation during insertion and deployment.

### *Implantation technique*

Patients were treated under general, epidural or local anaesthesia according to the judgement of anaesthetist and surgeon, in concert with the patient. Two patients were treated under general anaesthesia, 13 under epidural anaesthesia, and three under local anaesthesia (Table 1). Patients were prehydrated with IV solution 12 h before the procedure and renal output was carefully monitored. All the procedures were performed in an operating theatre with the use of a mobile C-arm (OEC 9800, General Electric Medical Systems, Salt Lake City, Utah, USA).

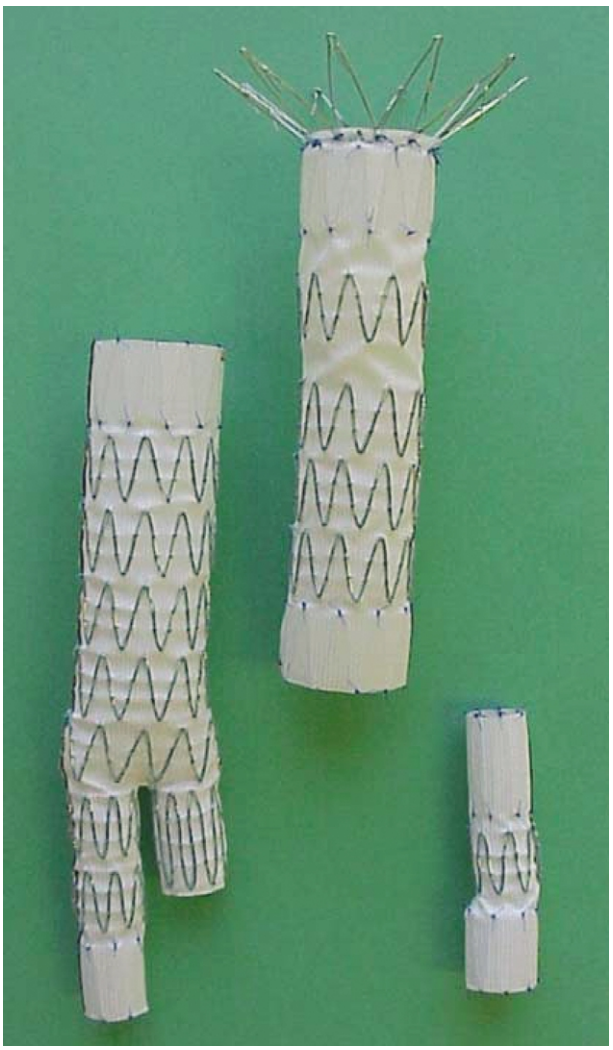

**Fig. 1.** The Cook Zenith composite 3-part system: fenestrated tube, bifurcated graft, and contra-lateral limb.

The technique used was very similar to the set-up of our Australian colleagues in Perth and Adelaide.[24–26] The complete deployment of the stent-graft was always carried out after catheterisation of the side branches and after adjusting the position by means of inflated balloons. Stenting of small fenestrations was routinely performed. The idea of stenting being to secure the orifice of the side branch but also to accurately appose the fenestration with the ostium of that side branch. After completion of the procedure with the bifurcated system and the contra lateral limb, a completion angiography was carried out to confirm vessel patency and complete exclusion of the aneurysm. If necessary multiplanar angiography was performed.

*Follow-up*

All patients were followed-up with abdominal X-rays, duplex and CT-scan at 6 weeks, 6 months and 1 year. In addition, their renal function and blood pressure were monitored.

## Results

All endovascular procedures were successful. There were no conversions to open surgery. Completion angiography showed complete exclusion of the aneurysm in 15/18 patients (Table 1). There were three endoleaks: one possible small type 1 endoleak and two type 2 endoleaks. At the end of the procedure, 45/46 targeted side branches were clearly patent and one accessory renal artery was occluded (patient number 3). In total, we used two large fenestrations, 20 small fenestrations and 24 scallops for 10 superior mesenteric arteries, 35 renal arteries and one accessory renal artery. Additional stent placement was carried out in 18 of the 20 small fenestrations. The two small fenestrations not stented were for the main renal artery and an accessory renal artery, both on the left side in patient number 3. Here, the final angiogram showed a good perfusion of the main renal artery, but an occlusion of the accessory renal artery. We met with three types of technical problems in eight different patients. In three patients, the sheaths leaked continuously due to the simultaneous catheterisation with different wires, catheters and balloons, causing additional blood loss (1000, 1100 and 1700 ml, respectively). In three patients, catheterisation of the right renal artery proved difficult and time consuming. In two patients, the iliac access was very difficult. Each of these technical problems was eventually solved.

*Operative details*

The mean duration of the procedure was 166 min (range 110–270) and the mean blood loss was 450 ml (range 100–1700). The mean amount of contrast used was 170 ml (range 80–240). The mean radiation time was 16 min (range 9–28), using pulse fluoroscopy whenever possible.

*Mortality and morbidity*

There was no surgical mortality. There were complications in six patients. Patient number 13 suffered from cardiac decompensation, possibly related to a minor myocardial infarction, with subsequent pneumonia.

**Fig. 2.** Different types of fenestrations: scallop, large fenestration, and small fenestration.

Patient number 17 developed atrial fibrillation, which was treated with medication. Three patients (1, 5 and 7) suffered from urinary complications (two urinary retentions and one urinary tract infection). Patient number 7 also suffered from a retroperitoneal haematoma, which was treated conservatively. In patient number 3, we noted moderate perfusion of the left upper pole and bad perfusion of the left lower pole of the kidney after occlusion of the accessory renal artery. A spiral CT scan showed an excluded aneurysm, with an occluded accessory renal artery and a severe stenosis of the left renal artery. We were unable to catheterise the tight stenosis and eventually lost the left kidney, although the completion angiogram at the initial operation showed a perfect result.

Hospitalisation varied from three to 12 days with a mean of 6.4 days, including the preoperative admission day. Two patients went to the ICU: one as a precaution for one day, and patient number 13 with the cardiac complications.

### *Follow-up*

The mean follow-up was 9.4 months (range 1–18). Except for the one problem already mentioned, there were no other patency problems with the targeted vessels. All vessels appeared fully patent on spiral CT scan (routine endovascular follow-up at 6 and 12 months postoperatively). Renal function was normal in all patients and none developed hypertension.

The three suspected endoleaks were followed closely. In patient number 8, the type II endoleak from an open inferior mesenteric artery persisted and was successfully treated by supraselective embolisation. In patient number 6 the type II endoleak from lumbar arteries disappeared, with the aneurysm shrinking. Therefore, no treatment was required. In patient number 7, we suspected a small type I endoleak but the spiral CT scan and subsequent angiogram suggested a type II endoleak caused by lumbar arteries. This endoleak persisted and the aneurysm did not shrink. Finally, we decided to do a laparotomy for final diagnosis and treatment. After careful opening of the sac (without clamping) and removal of the thrombus, we discovered four patent lumbar arteries, which were all oversewn. The aneurysmal sac was then wrapped around the stent-graft. The patient recovered well from the laparotomy.

Patient number 3, who lost his left kidney, died after 8 months due to metastatic adenocarcinoma (no primary tumour found). All the other patients are doing well.

## Discussion

The technique originally devised by the combined efforts of Cook Australia (David Hartley) and the endovascular teams of Perth (Michael Lawrence-Brown) and Adelaide (John Anderson) aimed at dealing with AAA's with proximal necks shorter than 15 mm in length.[25,26] By customizing fenestrations and/or scallops for the renal arteries and, if required, the superior mesenteric artery, the proximal covered stent can be positioned in a more proximal and, therefore, straighter part of the aorta. It seems logical that this will improve the stent-graft's stability. However, the technique is complex, since it requires simultaneous catheterisation, ballooning and sometimes stenting of the targeted vessels. The procedure is significantly longer than a standard EVAR procedure (166 min vs. 110 min in our hospital). This makes general anaesthesia or IV sedation in addition to epidural or local anaesthesia often necessary. We also used more contrast medium compared to the standard EVAR procedure (170 ml vs. 100 ml). Until now our only precaution to avoid nephrotoxicity was to prehydrate the patients overnight before the procedure. An additional measure is possibly the use of $CO_2$ angiography for part of the procedure. Radiation times appear low with a mean of 16 min (range 5–28). However, one has to take in account that we used pulse fluoroscopy whenever possible and accepted the sometimes lower quality of the image. The pulse fluoroscopy reduced the mean radiation time in standard EVAR procedures from 29 to 4 min. The radiation time during fenestrated stent-grafting is significantly higher than standard EVAR procedures (16 min vs. 4 min).

With regard to sealing of the aneurysm and patency of the targeted side branches, accurate positioning is mandatory. We decided not to stent scallops, nor large fenestrations. In our view scallops should be used for the upper-targeted vessels like the superior mesenteric artery or the higher of two asymmetric renal arteries. The goal here is to maintain patency. Sealing is not the issue. This means that the fenestrations/scallops can be made larger to ensure good patency. In addition, stenting of large fenestrations can be very difficult due to the fact that they present with struts crossing the fenestration. Smaller fenestrations are reserved for the crucial lower renal vessels but inaccurate positioning is not easily detectable with angiography. We prefer to stent every small fenestration to ensure correct position at the orifice of the artery and to give additional fixation of the stent-graft. In one case (patient number three) we did not stent the small fenestration to the left renal artery. Having stented the

right renal artery, we tried to stent the left side but lost access and abandoned the stenting in view of a perfect angiographic image. Nevertheless, after one month, the renal artery orifice became severely stenosed. Attempts to recanalise and stent the artery failed and the left kidney was lost. We now stent every small fenestration.

The stent-graft we used is a three-piece device. Therefore, there is increased risk of type III endoleaks due to disconnection. We regard a long overlap zone between the proximal tube and the bifurcated second piece mandatory, as we are aware of two non-published disconnections between the two upper parts. The contra-lateral stump can be positioned on the aortic bifurcation to add to the stability of the remaining connection with the contra-lateral limb.

This procedure, which we carried out in high risk patients, is a lengthy and difficult one. This probably contributed to the morbidity: two cardiac and three urinary complications as well as a retroperitoneal haematoma, probably due to anti-coagulation therapy throughout the whole procedure. This has to be taken in account when one considers the different options (i.e., open vs. fenestrated) for any patient.

In conclusion, as previously shown by John Anderson,[25] this technique is feasible but it requires great experience in endovascular stent-grafting and renal stenting due to its complexity. In our view, it should be reserved for patients who are at a high risk from open repair and in whom a normal endovascular procedure is precluded because of a short proximal neck.[27–29] However, the stability of this stent-graft system and the patency of the stented fenestrations remains to be proven in the mid- and long-term.

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## References

1 Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vasc Surg* 1991; **5**:491–499.
2 Lawrence-Brown MMD, Hartley D, MacSweeney STR *et al.* The Perth endoluminal graft system: development and early experience. *Cardiovasc Surg* 1996; **4**:706–712.
3 White GH, Yu W, May J *et al.* Three-year experience with the White–Yu endovascular-GAD graft for transluminal repair of aortic and iliac aneurysms. *J Endovasc Surg* 1997; **4**:124–136.
4 Lawrence-Brown MMD, Sieunarine K, Hartley D *et al.* The Perth HLB bifurcated endoluminal graft: a review of experience and immediate results. *Cardiovasc Surg* 1998; **6**:220–225.
5 May J, White GH, Waugh R *et al.* Comparison of first- and second-generation prostheses for endoluminal repair of abdominal aortic aneurysms: a 6-year study with life table analysis. *J Vasc Surg* 2000; **32**:124–129.
6 Stelter W, Umscheid T, Ziegler P. Three-year experience with modular stent-graft devices for endovascular AAA treatment. *J Endovasc Surg* 1997; **4**:362–369.
7 Schumacher H, Eckstein HH, Kallinowski F *et al.* Morphometry and classification in abdominal aortic aneurysms: patient selection for endovascular and open surgery. *J Endovasc Surg* 1997; **4**:39–44.
8 Carpenter JP, Baum RA, Barker CF *et al.* Impact of exclusion criteria on patient selection for endovascular abdominal aortic aneurysm repair. *J Vasc Surg* 2001; **34**:1050–1054.
9 Woodburn KR, Chant H, Davies JN *et al.* Suitability for endovascular aneurysm repair in an unselected population. *Br J Surg* 2001; **88**:77–81.
10 Birch PC, Start RD, Whitebread T, Palmer I, Gaines PA, Beard JD. The effects of crossing porcine renal artery ostia with various endovascular stents. *Eur J Vasc Endovasc Surg* 1999; **17**: 185–190.
11 Bove P, Long G, Zelenock G *et al.* Transrenal fixation of aortic stent-grafts for the treatment of infrarenal aortic aneurysmal disease. *J Vasc Surg* 2000; **32**:697–703.
12 Burks JA, Faries PL, Gravereaux EC, Hollier LH, Marin ML. Endovascular repair of abdominal aortic aneurysms: stent graft fixation across the visceral arteries. *J Vasc Surg* 2002; **35**:109–113.
13 Desgranges P, Kobeiter K, Coumbaras M, Van Laer O, Melliere D, Mathieu D, Becquemin JP. Placement of fenestrated Palmaz stent across the renal arteries: feasibility and outcome in an animal study. *Eur J Vasc Endovasc Surg* 2000; **19**: 406–412.
14 Gawenda M, Winter S, Jaschke G, Brunkwall J. Stent jail of the renal arteries in stent graft exclusion of AAA. *J Cardiovasc Surg* 2002; **43**:857–863.
15 Greenberg RK, Fairman R, Sivastava SD *et al.* Endovascular grafting in patients with short necks. *J Cardiovasc Surg* 2000; **8**: 350–354.
16 Malina M, Brunkwall J, Ivancev K, Lindh M, Lindblad B, Risberg B. Renal arteries covered by aortic stents: clinical experience from endovascular grafting of aortic aneurysms. *Eur J Vasc Endovasc Surg* 1997; **14**:109–113.
17 Makaroun MS, Deaton DH. Is proximal neck dilatation after endovascular aneurysm exclusion a cause for concern? *J Vasc Surg* 2001; **33**:39–45.
18 Parra JR, Ayerdi J, McLafferty R, Gruneiro L, Ramsey D, Solis M, Hodgson K. Conformational changes associated with proximal seal zone failure in abdominal aortic endografts. *J Vasc Surg* 2003; **37**:106–111.
19 Prinsen M, Wever JJ, Mali WPTM, Eikelboom BC, Blankensteijn J. Concerns for the durability of proximal aortic aneurysm endograft fixation from a two and three year longitudinal computed tomography angiography study. *J Vasc Surg* 2001; **33**: 64–69.
20 Resch T, Ivancev K, Brunkwall J, Nirhov N, Malina M, Lindblad B. Midterm changes in aortic aneurysm morphology after endovascular repair. *J Endovasc Ther* 2000; **7**:279–285.
21 Sonesson B, Malina M, Ivancev K, Lindh M, Lindblad B, Brunkwall J. Dilatation of the infrarenal aneurysm neck after endovascular exclusion of abdominal aortic aneurysm. *J Endvasc Surg* 1998; **5**:195–200.
22 Wever JJ, de Nie AJ, Blankensteijn JD, Broeders IAMJ, Mali WPThM, Eikelboom BC. Dilatation of the proximal neck of infrarenal aortic aneurysms after endovascular aortic repair. *Eur J Vasc Endovasc Surg* 2000; **19**:197–201.
23 May J, White G, Ly CN, Jones MA, Harris JP. Endoluminal repair of abdominal aortic aneurysm prevents enlargement of the proximal neck: a 9-year life-table and 5-year longitudinal study. *J Vasc Surg* 2003; **37**:86–90.
24 Stanley BM, Semmens JB, Lawrence-Brown MMD, Goodman MA, Hartley DE. Fenestration in endovascular grafts for aortic

aneurysm repair: new horizons for preserving blood flow in branch vessels. *J Endovasc Ther* 2001; **8**:16–24.
25 Anderson JL, Berce M, Hartley DE. Endoluminal aortic grafting with renal and superior mesenteric artery incorporation by graft fenestration. *J Endovasc Ther* 2001; **8**:3–15.
26 Browne TF, Hartley D, Purchas S, Rosenberg M, Van Schie G, Lawrence-Brown M. A fenestrated covered suprarenal aortic stent. *Eur J Vasc Endovasc Surg* 1999; **18**:445–449.
27 Cuypers PWM, Gardien M, Buth J *et al.* Cardiac response and complications during endovascular repair of abdominal aortic aneurysms: a concurrent comparison with open surgery. *J Vasc Surg* 2001; **33**:353–360.
28 Bertrand M, Godet G, Koskas F *et al.* Endovascular treatment of abdominal aortic aneurysms: is there a benefit regarding postoperative outcome? *Eur J Anaesthesiol* 2001; **18**:245–250.
29 Chuter TA, Gordon RL, Reilly LM *et al.* Abdominal aortic aneurysm in high-risk patients: short- to intermediate-term results of endovascular repair. *Radiology* 1999; **210**:361–365.

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