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Magnetic Resonance Imaging and MR Angiography of Endoluminally Treated Abdominal Aortic Aneurysms

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Objectives: *To evaluate magnetic resonance imaging (MRI) with gadolinium-based contrast medium-enhanced MR angiography (MRA) for the follow-up of endoluminally treated abdominal aortic aneurysms.*
Design: *MRI/MRA, angiography and computed tomography (CT) were performed 1 month after endoluminal stent-graft placement. MRI/MRA was repeated at 6 and 12 months and angiography and CT were added to confirm unexpected findings.*
Materials: *Fifteen male patients with endoluminally treated abdominal aortic aneurysms.*
Methods: *MRI with MRA, spiral CT with transverse images and angiography were performed.*
Results: *MRI/MRA demonstrated changes of stent-graft morphology, aortic neck- and aneurysmal diameter, stent-graft blood flow, stent-graft leakage, blood flow in lumbar arteries, intra-aneurysmal thrombus, periaortic inflammation and vertebral body infarction. For most of these features MRI/MRA provided more information than angiography and/or CT. MRI was the only method demonstrating thrombus reorganisation and vertebral body infarction.*
Conclusions: *MRI with MRA provides the relevant information needed for follow-up of endoluminally treated abdominal aortic aneurysms (AAA). This may be the method of choice because of its use of contrast media with very low nephrotoxicity, lack of ionising radiation and non-invasiveness.*

Key Words: Abdominal aortic aneurysm (AAA); Endoprosthesis; Endoluminal stent-graft, MRI; MR angiography.

Introduction

Transfemoral endovascular stent-graft placement is a minimally invasive alternative for the treatment of infrarenal abdominal aortic aneurysms (AAA),[1–9] but only 6 years have elapsed since the first reported procedure.[2] In order to establish the long-term clinical value of this technique, it is important to regularly follow the patients with techniques providing detailed information about morphology and function of the stent-graft,[10] with the lowest possible risk. Intra-arterial angiography, computed tomography (CT) and CT angiography are the most commonly used methods for follow-up of patients treated with endoluminal stent-grafts.[7,8,11,12] These methods expose the patient to ionising radiation and potentially nephrotoxic iodine-based contrast media. Magnetic resonance imaging (MRI) has been used for the follow-up of patients surgically treated with aortic grafts.[13] MRI provides good soft-tissue contrast, is non-invasive and does not expose the patient to ionising radiation. The recently introduced gadolinium-based contrast medium-enhanced MRA of the aorta[14–16] provides high quality 3D angiograms after an i.v. injection of a contrast medium that is significantly less nephrotoxic than iodinated contrast media.[17–19] However, MRI with MRA has not previously been reported as a method for follow-up of patients treated with endovascular stent-grafts for AAA. CT has proven to be a useful method,[11,12] and has therefore been accepted as the required investigation in the EUROSTAR registry.[20]

The aim of this study was to assess the value of MRI with gadolinium-based contrast medium-enhanced MRA in the follow-up of endoluminally treated AAA.

Patients

Fifteen consecutive patients with an infrarenal abdominal aortic aneurysm treated with an endovascular stent-graft, were included. All patients were male and

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had a mean age of 68 years (range 53–81 years). A nitinol-polyester endoprosthesis (Mialhe Stentor™, MinTec, Bahamas) was used in 13 patients; in one a straight stent-graft and in 12 a bifurcated stent-graft. In the last two patients the recently introduced modification (Vanguard™, Boston Scientific, Oakland, N.J., U.S.A.) was used. The surgical procedure included preparation of one or both common femoral arteries. In two cases a percutaneous approach was used in one groin. In one case an additional femoral aneurysm had to be replaced by an ePTFE graft. In some cases a blood pressure reduction was recorded during the insertion of the introducer or the device.[9,21] No intentional blood pressure reduction was attempted in any case. Two patients suffered a neurological injury with partial paresis of one leg. This was interpreted as a sign of microembolisation to the lumbosacral plexus. Full restitution was achieved in one patient, the other has persistent weakness of the leg. Postoperative fever was a common finding, continuing in some cases up to 10–14 days.

One patient was operated on after 6 months due to ischaemia of the large bowel, apparently unrelated to the endovascular procedure. One patient was treated with conventional emergency surgery due to a large bleed from a suture rupture and subsequent aneurysm rupture one year after implantation. Two patients were treated with complementary endovascular procedures after 11 and 21 months, respectively, due to leakage.

Methods

The follow-up was performed from February 1995 through November 1996 with MRI/MRA, CT and angiography 1 month after endoluminal stent-graft placement and with MRI/MRA at 6 and 12 months (Table 1).

To confirm unexpected findings on MRI at 6 and 12 months, CT and angiography were also performed. The average length of follow-up was 8 months: range 1–12 months.

MRI

MRI was performed using a 1.5 T unit (Siemens Magneton Vision, Germany) with T1-weighted sagittal images of the lumbar spine, T1- and T2-weighted transverse images of the abdomen and gadolinium-based contrast-enhanced MRA[15,16] of the abdominal aorta. The sagittal images of the lumbar spine were performed with TR/TE = 600 ms/12 ms with 4 mm slice thickness. The transverse images of the abdomen had TR/TE = 580 ms/14 ms and 3800 ms/99 with 10 mm slice thickness. The first 21 investigations were performed with a non breath-hold sequence as the breath-hold sequence was not available. The non breath-hold MRA was performed in the coronal plane using a 3D FLASH sequence with TR/TE/FA = 21.0 ms/6.0 ms/30°, 256 × 512 matrix, FOV 400 mm, slab thickness 70 mm, effective slice thickness 2.5 mm, acquisition time 153 s. All patients received an i.v. hand injection of 40 ml gadolinium-based contrast medium: Magnevist® (Schering AG, Berlin, Germany) or Omniscan® (Nycomed A/S, Oslo, Norway). The injection time was 70 s. The last nine investigations were performed with breath-hold gadolinium-based contrast medium-enhanced MRA,[14] in the coronal plane using a 3D FLASH sequence with TR/TE/FA = 5.0 ms/2.9 ms/40°–50°, 192 × 256–512 matrix, FOV 500 mm, slab thickness individually adapted with effective slice thickness max. 3.0 mm, acquisition time 25–40 s. These patients also received an i.v. hand injection of 40 ml gadolinium-based contrast medium as above. The scan delay had been determined by a test bolus and the injection time was equal to the scan time. The non breath-hold MRA sequence was repeated in the transverse planes covering the iliac and the proximal femoral arteries. Multiplanar reconstructions (MPR) as well as maximum intensity projections (MIP) were performed from the MRA.

CT

Spiral CT (Toshiba Xpress/SX, Japan) was performed from above the renal arteries to the mid-pelvis ensuring the inclusion of the endoprosthesis. The examination was done with contrast enhancement only, using 90 ml Omnipaque® 300 mg I/ml (Nycomed A/S, Oslo, Norway), injected with a pressure injector (Medrad Mark IV, PA, USA) at a rate of 1.5–2.0 ml/s. The scans were reconstructed as 7 or 10 mm slices. Only transverse images were used for analysis and measurements.

Angiography

Angiography was performed on a Polydiagnost A (Philips, CT, USA) equipment with digital reconstruction. A 5 French pigtail catheter with six side-holes was used. Forty ml of Omnipaque® 300 mg I/

Table 1. Follow-up.

Patient	1 month	6 months	12 months	Remarks
1	MRI, CT, Angio	MRI/MRA	MRI/MRA	
2	MRI, CT, Angio	MRI/MRA, CT	MRI/MRA	Vertebral body infarction. Leakage – spontaneous remission
3	MRI, CT, Angio	MRI/MRA	MRI/MRA, CT	Leakage – compl. endovasc. procedure after 21 months
4	MRI, CT, Angio	MRI/MRA	MRI/MRA	
5	MRI, CT, Angio	MRI/MRA	MRI/MRA CT, Angio	Periaortic inflammation. Leakage – compl. endovasc. procedure after 11 months
6	MRI, CT, Angio	MRI/MRA, CT	Angio	Vertebral body infarction. Suture and aneurysm rupture – conv. surgery
7	MRI/MRA Angio	MRI/MRA	MRI/MRA	
8	MRI/MRA, CT	MRI/MRA	MRI/MRA, CT, Angio	
9	MRI/MRA, CT, Angio	MRI/MRA	MRI/MRA	
10	MRI/MRA, CT, Angio	MRI/MRA	MRI/MRA	
11	MRI/MRA, CT, Angio	MRI/MRA	MRI/MRA	
12	MRI/MRA, CT, Angio	MRI/MRA, CT		Periaortic inflammation
13	MRI/MRA, CT, Angio			Died of a malignant lymphoma after 4 months
14	MRI/MRA, Angio			
15	MRI/MRA, CT, Angio			

ml were injected with a pressure injector (Medrad Mark IV, PA, USA) at a rate of 20 ml/s. Films were obtained in posterior–anterior and oblique projections of the abdominal aorta. For evaluation unsubtracted and subtracted films were used.

Evaluation parameters

- *The stent-graft morphology* was evaluated on the MIP reconstruction from the MRA and on the angiography. The angle between the graft body and the left graft limb was measured to evaluate possible angulation of the stent-graft.
- *The aortic neck diameter* was measured on T1-weighted transverse MR images and on CT, directly beneath the most distal renal artery, just above the aneurysm and at the mid-point between these two sites.
- *The widest aneurysmal diameter* was measured on T1-weighted transverse MR images and on CT.
- *The stent-graft blood flow* was evaluated on the contrast medium-enhanced MRA, CT and on angiography.
- *Stent-graft leakage* was evaluated on MRA (MIP and MPR), correlated with T1-weighted transverse MR images. Leakage was defined as a region with high signal intensity within the aneurysmal thrombus on MRA without high signal intensity in the corresponding location on the unenhanced T1-weighted images. It was also evaluated on CT and angiography.
- *Blood flow in lumbar arteries* was evaluated on MRA (MIP and MPR), CT, and angiography.
- *The intra-aneurysmal thrombus* was characterised with regard to signal intensity on MRI. Unorganised thrombus has high signal intensity on T1- and T2-weighted images, partially organised thrombus has inhomogeneous signal intensity with hyper-intense areas on T1- and T2-weighted images, and organised thrombus has low signal intensity on T1- and T2-weighted images.[22]
- *Periaortic inflammation* was evaluated on T1- and T2-weighted transverse MR images and on CT.
- *Vertebral body infarction* was evaluated on T1-weighted sagittal MR images on the lumbar spine.

The study protocol was approved by the local committee. All patients gave their informed consent.

Results

Stent-graft morphology

In the interval 1–12 months, eight out of 11 patients with bifurcated stent-grafts displayed an increasing angulation (5–40°) of the graft limbs on MRA and angiography. This was also seen on the transverse CT-images but it was not possible to measure the angulation. Three patients have only been followed-up at 1 month and one has a straight stent-graft.

Changes of the aortic neck diameter

The aortic neck diameter at the stent-graft insertion site was unchanged in eight patients, increased by 3mm in one patient, and decreased by 4mm in one patient. Size changes of the aortic neck diameter were equally well determined with MRI and CT. Three patients have only been followed up at 1 month and in two patients it was not possible to evaluate the aortic neck diameter.

Changes of the aneurysmal diameter

The aneurysmal diameter was unchanged in three patients, increased by 4–9mm in two, and decreased by 2–22mm in seven patients. The most significant shrinkage of the aneurysmal diameter occurred during the interval 1–6 months. This was equally well seen on MRI and CT, but could not be evaluated on angiography. Three patients have only been followed up at 1 month.

Stent-graft blood flow (Fig. 1)

MRA, CT and angiography were all able to demonstrate blood flow in the stent-graft. MRA however, showed decreased signal intensity at the junction of the graft limbs in 12 patients. Angiography showed a minor stenosis at the junction of the graft limbs in three of these 12 patients. CT could not be evaluated with regard to stenosis at the junction due to pronounced metal artefacts.

Fig. 1. Coronal 3D breath-hold contrast enhanced MRA (MIP) at 1 month showing blood flow in stent-graft and decreased signal intensity at the left graft limb junction (arrow) corresponding to the slightly tapered configuration at the junctiion.

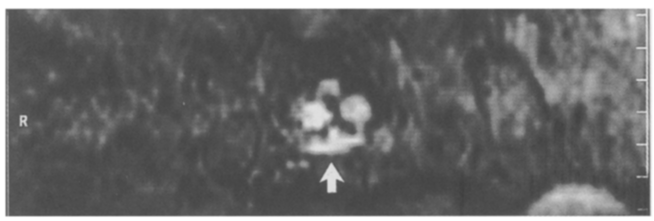

Fig. 2. Transverse MPR of 3D breath-hold contrast enhanced MRA showing minor-contrast accumulation (arrow) in the thrombus around the stent-graft bifurcation.

Stent-graft leakage

Major leakage. In four out of 15 patients a significant leakage was seen on MRA, CT and angiography. It was detected after 1 month in one patient, 8 months in two patients and after 12 months in one patient.

Minor leakage (Fig. 2). In 10 out of 15 patients, MRA revealed a minor contrast accumulation in the thrombus around the stent-graft bifurcation. This was interpreted as a minor leakage. This minor leakage was not possible to see on CT due to rather pronounced metal artefacts from the stent-graft. MRA showed only minimal metal artefacts. Angiography did not demonstrate any minor leakage. The minor contrast accumulation was detected after 1 month in six patients, after 6 months in three patients and after 12 months in one patient. The minor leakage remained unchanged or increased slightly on later examinations.

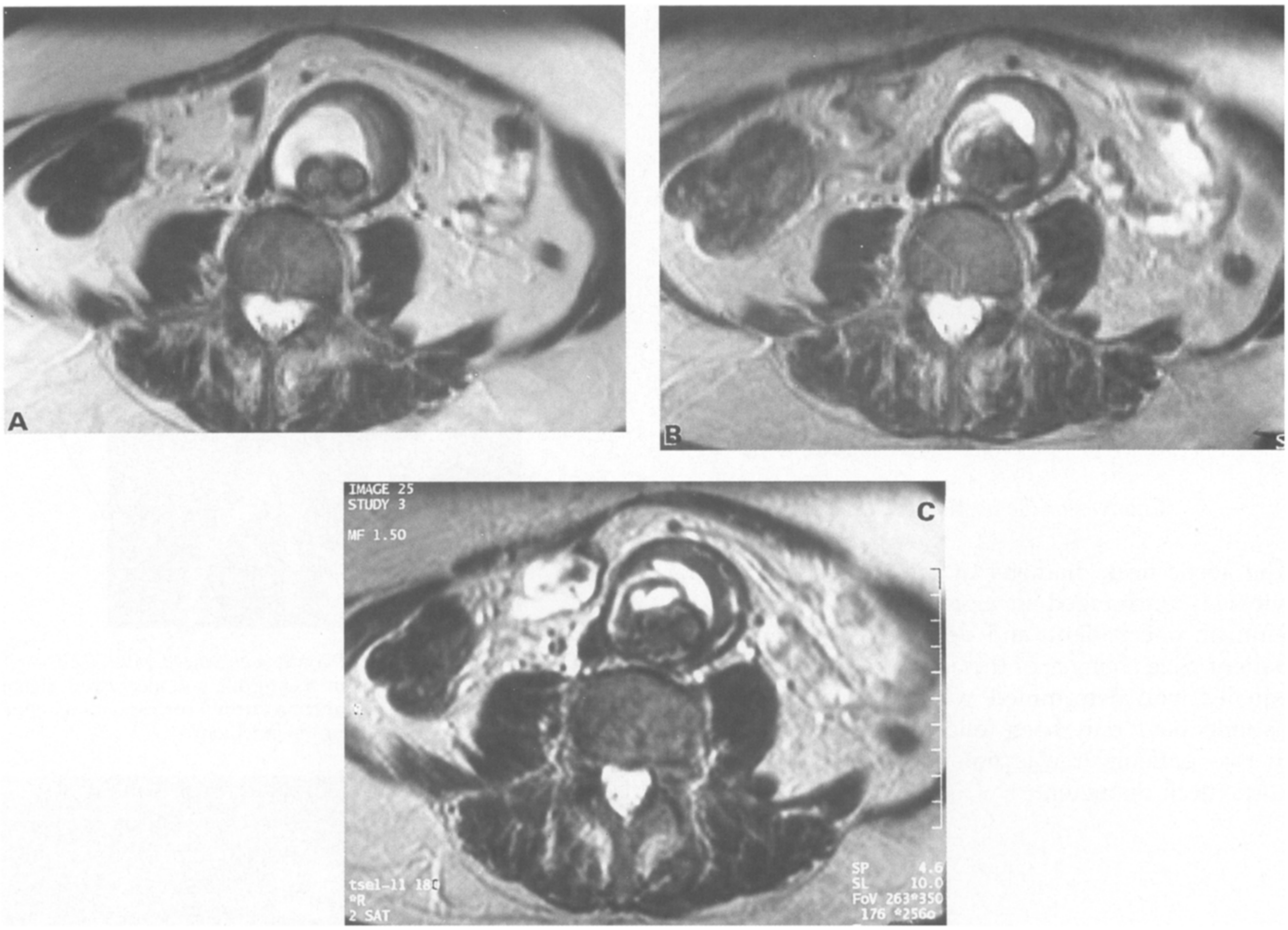

Fig. 3(a–c). Transverse T2-W MRI at (a) 1 month, (b) 6 months and (c) 12 months after stent-graft insertion showing increasing thrombus organisation.

Blood flow in lumbar arteries

In all patients blood flow in lumbar arteries was seen on both MRA and angiography. On CT it was generally not possible to determine if the lumbar arteries were patent. In one patient, MRA performed at 1 month demonstrated retrograde flow through lumbar arteries resulting in a minor contrast accumulation in the aneurysmal thrombus with an unchanged aneurysmal diameter. This retrograde flow was confirmed by angiography.

Table 2. Increasing organisation of thrombus shown by MRI.

	1 month	6 months	12 months
Unorganised	3 →		
	1 →	→	↘
	1 →	→ ↘	
Partially organised	2 →	→	
	5 →	→	→
	1 ↘	↘	↘
Organised			→
	2 →	→	→
No. of patients	15	12	10

Changes of the intra-aneurysmal thrombus (Fig. 3a–c)

The aortic aneurysm thrombus surrounding the stent-graft was possible to characterise only by MRI, showing signal changes consistent with gradually increasing organisation (Table 2). All patients with unorganised and partially organised thrombus had high signal

Fig. 4. Sagittal T1-W MRI of the lumbar spine with vertebral body infarction of L3.

intensity in the innermost layer on T2-weighted transverse images.

Periaortic inflammation

In two patients signs of periaortic inflammation were seen on MRI at 1 month with complete regression at 6 months. CT also revealed signs of inflammation in one of these patients.

Vertebral body infarction (Fig. 4)

In two patients, lesions consistent with vertebral body ischemia/infarction were seen on MRI at 1 month, remaining unchanged at 6 months. At 12 months, one was unchanged while one had decreased slightly in size. CT did not reveal these changes. Both patients had clinical signs of microembolisation to the lumbosacral plexus.

Discussion

In this study, MRI/MRA provided detailed and relevant information regarding stent-graft morphology, changes of the aortic neck- and aneurysmal diameter, stent-graft blood flow, stent-graft leakage, blood flow in lumbar arteries, changes of the intra-aneurysmal thrombus, periaortic inflammation and vertebral body infarction. We have not compared MRI/MRA with good quality CT-angiography 3D reconstructions, since these were not available at our centre until recently. There is, however, no reason to believe that this technique would yield relevantly different information than the combination of spiral-CT with transverse images and angiography as a reference for comparison.

The bifurcation device always requires one, and frequently several, extensions. Consequently, one or more junctions are needed. These junctions and the rigid nature of the stent-graft, entirely supported by the metal stent, make the device liable to graft–limb angulation. The angulation is probably caused by organisation and fibrosis of the thrombus surrounding the stent-graft. One patient with bilateral graft limb leakage, due to distal detachment on one side and detachment between two extension on the other side, had a considerable bilateral graft–limb angulation of 35°. The other patients with graft–limb angulation showed no signs of stent-graft leakage. The increasing angulation of the graft limbs was equally well seen on MRA and angiography.

An important issue is what happens to the aneurysm in the long term. The aim should be to exclude the aneurysm and to prevent progression of the aneurysmal disease. In this series only one patient had an increase of the aortic neck diameter, although it should be noted that our patients have only been followed for 1 year. It is not known whether this is of importance.[10] Retrograde flow in lumbar arteries was seen in all patients and did not correlate with changes of the aneurysm diameter. In only one patient was the retrograde flow found to enter the aneurysm thrombus, and the leak was embolised unilaterally with microcoils. The four patients with major endoleaks had no increase of the aneurysm diameter. Two of the patients underwent a complementary endovascular procedure due to stent-graft separation, one was treated with conventional emergency surgery due to suture rupture and a subsequent aneurysm rupture, and in the remaining patient the leakage thrombosed spontaneously. In other reports there has been a correlation between stent-graft leakage and increase of the aneurysmal diameter.[10,12]

Leakage into the aneurysmal thrombus is seen as a hyperintense region within the otherwise hypointense thrombus on the contrast-enhanced MRA. However, methaemoglobin formation in the thrombus may also be hyperintense on MRA. It is therefore important to correlate with the T1-weighted MR images, where no hyperintensity was found corresponding to the leakage in our patients. Major endoleaks were equally well demonstrated by all three techniques. Minor contrast accumulation at the stent-graft bifurcation was detected only on MRA. We believe that this accumulation was caused by a minor leakage through the stent-graft bifurcation seam. The two patients with the seamless Vanguard™ stent-graft have so far not shown any signs of leakage. Only one of the 12 patients treated with bifurcated Miahle Stentor™ stent-graft has not shown any signs of minor leakage.

The decreased signal intensity seen on MRA at the graft limb junction could be due to the slightly tapered configuration at the junction, with secondary complex flow resulting in flow void (decreased signal) on MRA. In addition, the overlapping metal frame could cause minor metal artefacts with decreased signal. Angiography demonstrated the tapering at the graft limb junction in three out of the twelve patients. Transverse CT scans did not reveal any of these changes because of pronounced metal artefacts.

Endoluminal stent-graft placement leaves the aortic thrombus in place, and further thrombus is expected to form around the stent-graft inside the aneurysmal sac. Not surprisingly, complex biological reactions occur.[9,21] Briefly, endovascular treatment may cause a rapid inflammatory response whilst open surgery causes a response depending on the ischaemia-reperfusion and the surgical trauma. In the present study, MRI was the only method that could demonstrate a gradually increasing thrombus organisation. The high signal intensity in the innermost layer on T2-weighted images is interpreted as a formation of a fresh clot. To what extent reorganisation of the mural thrombus and formation of fresh thrombus influence changes of the aneurysm diameter is not known. We believe that further work is needed to investigate whether these features correlate with each other. MRI displays relevant organisation indicating inflammatory changes after aortic endovascular stent-graft placement. This is in support of earlier reported work suggesting that MRI is superior to other methods in identifying the presence of inflammation associated with aneurysms preoperatively[23] and postoperatively after conventional surgical placement of aortic graft prosthesis.[24] In two of our patients, MRI revealed inflammatory changes and CT demonstrated this in one of them. The periaortic inflammation was a transient finding and the reason for its occurrence is not explained.

MRI was the only method that revealed body infarction in two patients, both with clinical signs of microembolisation to the lumbosacral plexus.

We conclude that MRI, with gadolinium-based contrast medium-enhanced MRA, provides the relevant information needed for follow-up of endoluminally treated abdominal aortic aneurysms. MRI was the sole method demonstrating intra-aneurysmal thrombus organisation and vertebral body infarction. MRI with MRA may be the method of choice for this follow-up because of its use of contrast media with very low nephrotoxicity, lack of ionising radiation and non-invasiveness.

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References

1 Volodos NL, Karpovich IP, Troyan VI *et al.* Clinical experience of the use of self-fixing synthetic prostheses for remote endoprosthetics of the thoracic and abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction. *Vasa Suppl* 1991; **33**: 93–95.
2 Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vasc Surg* 1991; **5**: 491–499.
3 Parodi JC, Criado FJ, Barone HD, Schoenholtz C, Queral LA. Endoluminal aortic aneurysm repair using a balloon-expandable stent-graft device; A progress report. *Ann Vasc Surg* 1994; **8**: 523–529.
4 Parodi JC. Endovascular repair of abdominal aortic aneurysms and other arterial lesions. *J Vasc Surg* 1995; **21**: 549–557.
5 Moore WS, Rutherford RB. Transfermoral endovascular repair of abdominal aortic aneurysm: Results of the North American EVT phase I trial. *J Vasc Surg* 1996; **23**: 543–553.
6 Balm R, Eikelboom BC, May J, Bell PRF, Swedenborg J, Collin J. Early experience with Transfermoral Endovascular Aneurysm Management (TEAM) in the treatment of aortic aneurysms. *Eur J Vasc Endovasc Surg* 1996; **11**: 214–220.
7 Blum U, Langer M, Spillner G *et al.* Abdominal Aortic Aneurysms: Preliminary technical and clinical results with transfemoral placement of endovascular self-expanding stent-grafts. *Radiology* 1996; **198**: 25–31.
8 Blum U, Voshage G, Lammer J *et al.* Endoluminal stent-grafts for infrarenal abdominal aortic aneurysms. *N Engl J Med* 1997; **336**: 13–20.
9 Swartbol P, Norgren L, Albrechtsson U *et al.* Biological

responses differ considerably between endovascular and conventional aortic aneurysm surgery. *Eur J Vasc Endovasc Surg* 1996; **12**: 18–25.

10 May J, White G, Yu W, Waugh R, Stephen M, Harris J. A prospective study of anatomico-pathological changes in abdominal aortic aneurysms following endoluminal repair: Is the aneurysmal process reversed? *Eur J Vasc Endovasc Surg* 1996; **12**: 11–17.

11 Rozenblit A, Marin ML, Veith FJ, Cynamon J, Wahl SI, Bakal CW. Endovascular repair of abdominal aortic aneurysm: Value of postoperative follow-up with helical CT. *AJR* 1995; **165**: 1473–1479.

12 Balm R, Kaatee R, Blankensteijn JD, Mali WPTM, Eikelboom BC. CT-angiography of abdominal aortic aneurysms after transfemoral endovascular aneurysm management. *Eur J Vasc Endovasc Surg* 1996; **12**: 182–188.

13 Guinet C, Buy J-N, Ghossain MA *et al.* Aortic anastomotic pseudoaneurysms: US, CT, MR, and angiography. *J Comput Assist Tomogr* 1992; **16**: 182–188.

14 Prince MR, Narasimham DL, Stanley JC *et al.* Breath-hold gadolinium-enhanced MR angiography of the abdominal aorta and its major branches. *Radiology* 1995; **197**: 785–792.

15 Prince MR. Gadolinium enhanced MR aortography. *Radiology* 1994; **191**: 155–164.

16 Prince MR, Narasimham DL, Stanley JC *et al.* Gadolinium-enhanced magnetic resonance angiography of abdominal aortic aneurysms. *J Vasc Surg* 1995; **21**: 656–669.

17 Prince MR, Arnoldus C, Frisoli JK. Nephrotoxicity of high-dose gadolinium compared with iodinated contrast. *JMRI* 1996; **1**: 162–166.

18 Niendorf HP, Alhassan A, Haustein J, Clauss W, Cornelius I. Safety and risk of gadolinium-DTPA: Extended clinical experience after more than 5,000,000 applications. *Advances in MRI Contrast* 1993; **2**: 12–19.

19 Schuhmann-Giampieri G, Clauss W, Krestin GP. Pharmacokinetics and safety of Gd-DTPA in patients with impaired renal function. In: Bydder G, Felix R, Buecheler E, Drayer BP, Niendorf HP, Takahashi M, Wolf KJ, eds. Contrast media in MRI *Bussum*, Netherlands: Medicom Europe, 1990: 313–319.

20 Harris PL, Buth J, Mialhe C *et al.* The need for clinical trials of endoluminal stent-graft techniques for abdominal aortic aneurysm repair. The EUROSTAR project. *Endovasc Surg* 1997; **4**: 72–79.

21 Norgren L, Albrechtsson U, Swartbol P. Side-effect of endovascular grafting to treat aortic aneurysm. *Brit J Surg* 1996; **83**: 520–521.

22 Castrucci M, Mellone R, Vanzulli A *et al.* Mural thrombi in abdominal aortic aneurysms: MR imaging characterization – Useful before endovascular treatment? *Radiology* 1995; **197**: 135–139.

23 Tennant WG, Hartnell GG, Baird RN, Horrocks M. Radiologic investigation of abdominal aortic aneurysm disease: Comparison of three modalities in staging and the detection of inflammatory change. *J Vasc Surg* 1993; **17**: 703–709.

24 Spartera C, Morettini G, Petrassi C, Di Cesare E, La Barbera G, Ventura M. Healing of aortic prosthetic grafts: A study by Magnetic Resonance Imaging. *Ann Vasc Surg* 1994; **8**: 536–542.

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