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The Role of Infrarenal Aortic Side Branches in the Pathogenesis of Endoleaks after Endovascular Aneurysm Repair

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Aim: *to investigate the relation between the number of preoperative patent side branches and the presence or absence of postoperative endoleaks, and to study the fate of patent branches after operation.*
Patients and Methods: *thirty consecutive patients were included Cine mode viewing of axial CT angiography images was applied to detect infrarenal aortic side branches The position of side branches relative to the renal arteries, branch patency and run-off pathways were studied.*
Results: *a total of 160 patent side branches were found. All patients had two or more patent side branches. A patent inferior mesenteric artery was found in 22/30 patients (73%) Postoperative CT scans revealed major endoleaks in five patients (16%) and minor endoleaks in eight (27%). There was no significant difference in the number of preoperative patent side branches in patients with a completely thrombosed aneurysm sac (five; range 2–8) compared to patients with postoperative endoleaks (six; range 3–9,* $p=0.12$*) Backbleeding from patent side branches as the sole cause of endoleak was seen in one patient only (3 3%)*
Conclusion: *postoperative endoleaks are not related to the number of preoperative patent side branches. In patients without endoleaks, contrast enhancement of side branches was repeatedly seen in the vicinity of the aneurysm wall. Although close follow-up of these branches is warranted, they did not affect the outcome of endovascular aneurysm repair.*

Key words: Endovascular aneurysm repair, Patent branches; Endoleaks; Houncefield index.

Introduction

Incomplete exclusion of an aneurysm of the infrarenal aorta after endovascular aneurysm repair may result in continuing expansion of the aneurysm sac.[1–4] If blood flow outside the endovascular graft but inside the excluded aortic segment can be demonstrated, this situation is described as an endoleak.[5]

Patent side branches of the diseased infrarenal aorta have been identified as part of endoleak circuits [5,6] These may serve as run-off channels for leaks originating from areas of incomplete seal of the stents of the endograft to the aortic wall On the other hand, persistent backflow from patent lumbar and inferior mesenteric arteries into the aneurysm sac has been reported despite a well positioned graft.[7,8] The exact role of patent side branches in the pathogenesis of endoleaks is currently unknown.

If patent infrarenal aortic side branches could be identified as important determinants of endoleak outcome, there might be a role for pre-emptive coil embolisation of these arteries. We therefore studied the role of patent side branches in the pathogenesis of endoleaks. The aim of the study was to correlate the number of preoperative patent infrarenal aortic side branches with the presence or absence of postoperative endoleaks, and to study the fate of patent branches after operation.

Patients and Methods

Thirty patients with pre- and postoperative CT scans available for measurements were included. All patients were treated by a first or second generation endovascular technologies endograft, as part of an FDA supervised international trial. A tube endograft was inserted in 13 patients, a bifurcated endograft in 17.

Twenty-six patients were male. The median age was 68 (51–86), the median preoperative aneurysm size was 58.4 mm (36.5–74.5).

Spiral CT angiography was used for the detection of infrarenal aortic side branches. Patients were scanned

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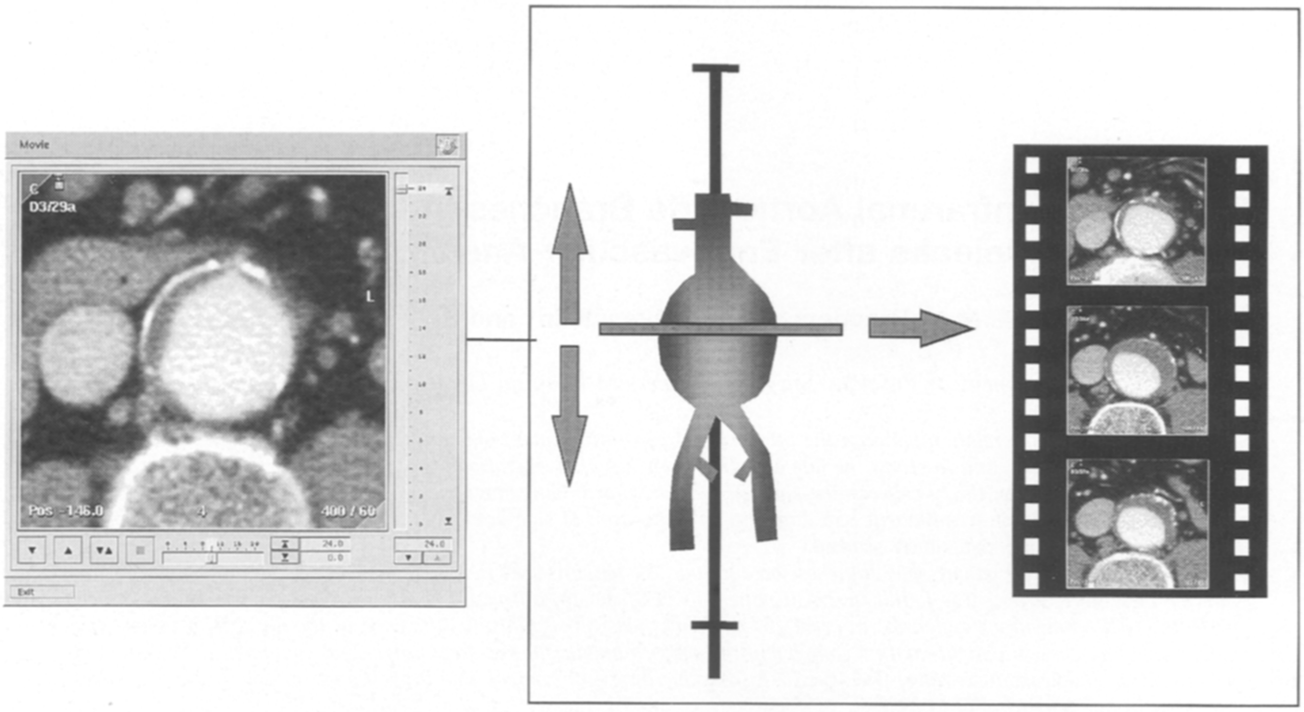


Fig. 1. Tracing of small calibre aortic side branches using cine-mode viewing of axial CTA images.

preoperatively, on the third postoperative day, at 6 months and every 12 months after the procedure. In case of postoperative endoleaks, an additional scan was made at 3 months follow-up. All CT investigations were performed according to a protocol designed for abdominal aortic aneurysm, using a Philips EV-AP CT scan (Philips Medical Systems; Best, The Netherlands). According to this protocol, scanning started at the upper limit of the twelfth thoracic vertebra, which was the presumed level of the coeliac trunk. At least 50 continuous rotations of 1 s each were made. The collimation was set at 5 mm and the table speed at 5 mm per second, resulting in a pitch of 1. The length of the scanned volume was 25 cm at the minimal number of 50 rotations, stretching from the level of the coeliac trunk to the level of the external iliac arteries. Intravenous contrast was given at a rate of 1–2 ml per s, starting injection 30 s ahead of scanning. Out of the acquired volume of CT data, axial images with an imaginary thickness of 5 mm were reconstructed every 2 mm. This resulted in a dataset of at least 123 overlapping axial reconstructions. The images were transferred to an EasyVision Workstation (Philips Medical Systems; Best, The Netherlands).

Cine mode viewing was applied to study aortic side branches. This application of the workstation allows visualization of axial CT images in a movie-like fashion (Fig. 1).[9] The number of side branches for each patient was documented on the preoperative and the postoperative scans. Side branches were classified as lumbar, sacral, inferior mesenteric (IMA), accessory renal or other. Only those side branches with an ostium covered by the endograft were evaluated. In patients with a tube endograft, this meant that sacral arteries originating at the level of the aortic bifurcation were excluded.

The analysis of side branches was based on three parameters. First, the level of the ostium of the side branches was registered relative to the level of the left renal artery, using the vertical body axis as a scale. The levels of patent branches on preoperative scans were used as a tool to trace both patent and thrombosed branches on postoperative and follow-up scans. Second, the anatomy of side-branches was documented. The ostium and path of the arteries, and the level of the first branch bifurcation were registered using the aorta and the vertebrae as anatomic landmarks. This documentation was used to investigate the extent of side branch thrombosis at postoperative and follow-up investigations. Third, side branches were classified into four groups: patent, partially thrombosed, completely thrombosed and undetectable. Patency was defined by detection of contrast enhancement extending from the aortic or endoleak lumen into the side branches. In case a side branch was classified as partially thrombosed, contact between the branch and the aortic lumen or endoleak was no longer present, but contrast enhancement was seen in the vicinity of side branch bifurcations.

In order to support the differentiation between patency or thrombosis of side branches in a quantitative manner, the maximal houncefield (HF) index of side branches was measured and compared to the mean HF index of the aortic thrombus. HF indices were measured using the computer calibrated HF definition tool of the Easy Vision CT/MRI program. This tool provides a graphic display of HF indices along a hand drawn straight line of variable length. The mean HF index along this line is displayed, together with the minimal and maximal value. The maximal HF index of side branches was found by drawing the line of measurement in a 90 degree angle over the most clearly enhanced part of the side branch (Fig. 2). The mean thrombus HF index was defined by drawing a line of 2–3 cm in the thrombus at the level displaying the most extensive amount of aortic thrombus mass. The HF ratio was defined by dividing the HF index of the side branch by the HF index of the thrombus.

Reference data on these type of measurements are not available. Therefore, the HF ratios of all branches on pre- and postoperative scans that were defined as completely patent or fully thrombosed by visual analysis were listed (Table 1). The mean HF ratio of patent branches was 3.7 (range 1.1–9 2), compared to a mean HF ratio of 0.9 of thrombosed branches (range −0.6–1.6). After evaluating the data listed in Table 1, a HF ratio of 1.5 was chosen as cut-off level; a ratio up to 1.5 was considered to be supportive for side branch thrombosis, a ratio higher than 1.5 for side branch patency. This HF ratio classification was correlated to visual analysis in all branches studied. Reinvestigation was performed in case of discrepancy, resulting in a change of classification in three cases.

Endoleak was defined as the presence of contrast enhancement outside the endograft but inside the wall of the aortic aneurysm.[5] Patients were divided in two groups, one with and one without postoperative endoleaks. Endoleaks were categorised in two groups.

Major endoleaks were those due to an incomplete seal of one of the endograft stents to the aortic wall. These endoleaks presented as large areas of contrast enhancement in the partially thrombosed aneurysm.

Minor endoleaks were solely encountered in patients with a correctly positioned endograft. These endoleaks presented as streaks of contrast enhancement in the thrombosed aneurysm sac or as small contrast enhanced areas in the vicinity of the ostium of aortic side branches.

The Mann–Whitney U-Test was used for statistical analysis of the relation between the median number of preoperative patent side branches and the presence of postoperative endoleak. A Chi-squared test was applied to investigate the relation between a patent inferior mesenteric artery (IMA) and postoperative endoleaks.

Results

Patent aortic side branches on preoperative CT images

A total of 160 patent side branches were found on the preoperative CT images (Table 2). At least two patent branches could be identified in each patient. The median number of patent branches per patient was six (range 2–9). The second left and right lumbar arteries appeared to be patent most frequently, being identified in 24 patients each (80%). The fourth left lumbar artery was thrombosed most often. This branch was patent in 13 out of 30 patients (43%). The IMA was patent in 22 patients (73%), the sacral artery in 19 (63%). However, in five patients the ostium of the sacral artery was outside the aortic segment covered by a tube endograft and therefore in these particular cases not included in the figures of the study. In four patients, one accessory renal artery was found and in one patient two accessory renal arteries.

Endoleaks

Major endoleaks were encountered in five patients (16%) and minor endoleaks in eight (27%) on the immediate postoperative CT scans (Fig. 3). Patent aortic side branches circuits could be identified in all cases of endoleak. In cases of major endoleak, the area of incomplete seal of the stent to the aortic wall could be identified at the level of the proximal neck in three patients, at the distal neck in one and in the right common iliac artery in one. All five endoleaks were due to technical failures; a mismatch in limb size of the endograft and common iliac artery ($n=1$), proximal deployment to distal from the renal arteries ($n=3$), and entanglement of two hooks of a distal aortic stent ($n=1$). The endoleak circuit of minor endoleaks was found to be in contact with the attachment area of the proximal stent in three patients and to the attachment area of the left or right common iliac arteries in four. In one case of a minor endoleak involving the left fourth lumbar and the sacral artery, there was no indication of contact with the aortic or iliac lumen.

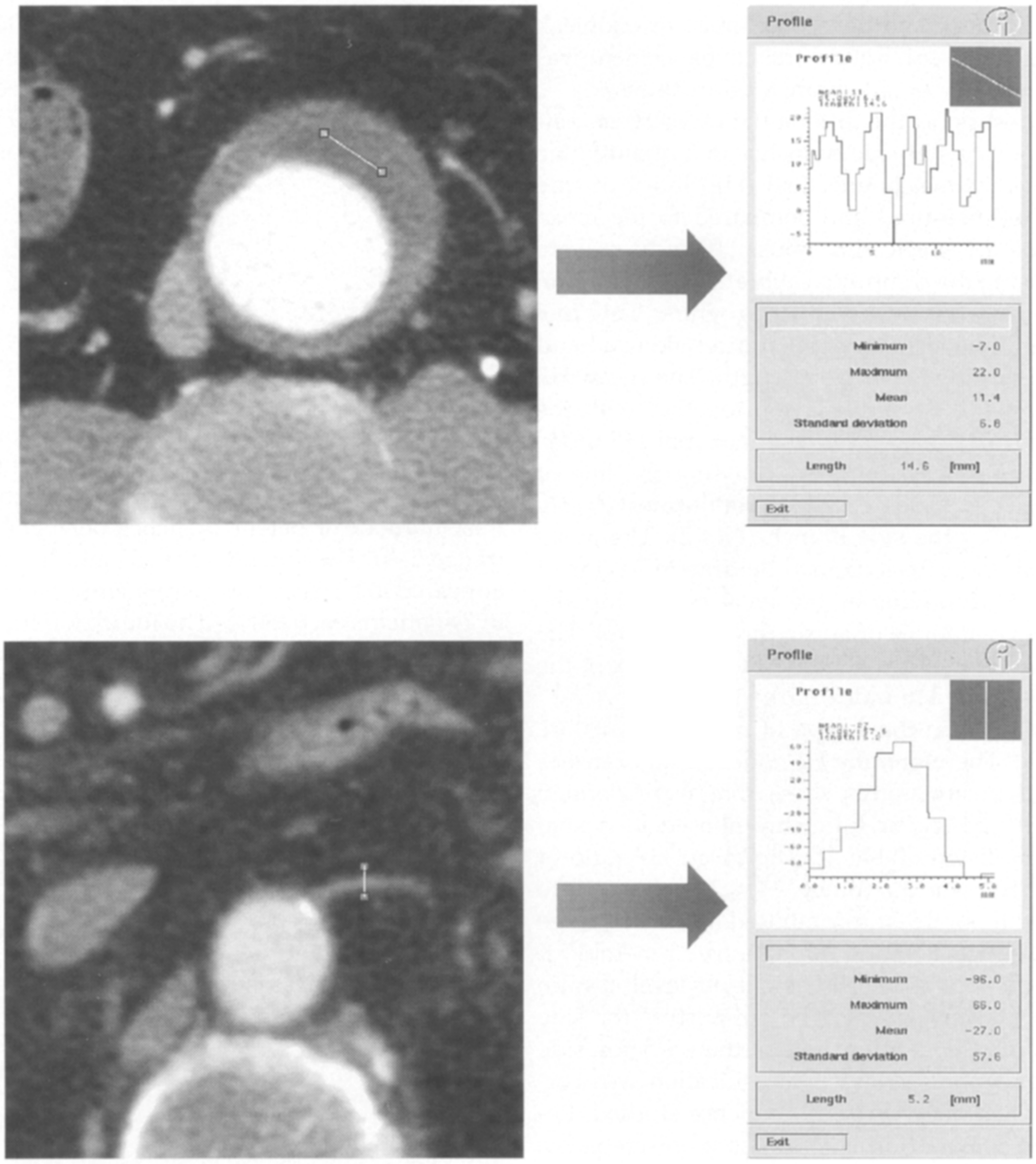


Fig. 2. Measurement technique of the mean houncefield ratio of the aortic thrombus mass and the maximum houncefield ratio of aortic side branches

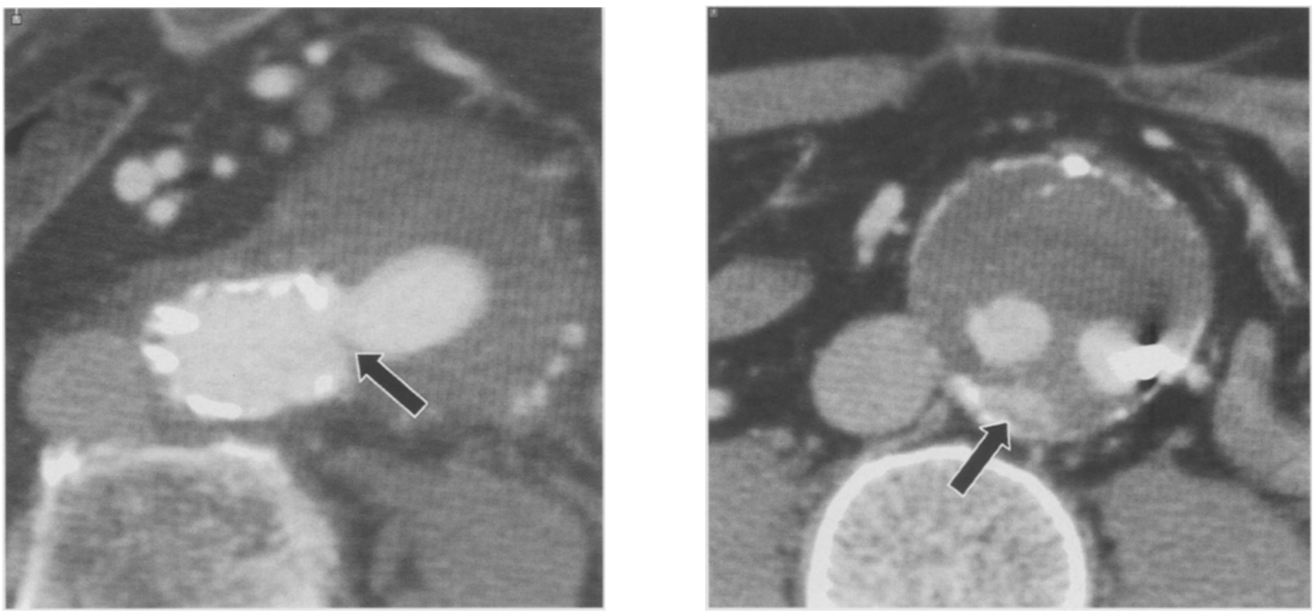
Table 1. Overview of houncefield ratios; patent versus thrombosed infrarenal aortic side branches.

	Houncefield ratio						
	−1–0	0–1	1–1 5	1 5–2	2–3	3–5	5–10
Number of patent branches	0	0	1	12	64	84	40
Number of thrombosed branches	1	18	24	1	0	0	0

In order to depict the relation between preoperative patent side branches and postoperative endoleaks, side branch patency was listed separately for the endoleak group and the no endoleak group (Table 2). A median of six (three to nine) patent branches was found on the preoperative scan in patients that developed an endoleak compared to five (two to eight) in those that had a completely excluded aneurysm sac after the procedure ($p=0.12$). When considering minor endoleaks only, a median number of 6.5 (four to eight) patent branches was found ($p=0.10$). A patent IMA was found in 11/13 cases in the endoleak group (85%) and in 11/17 cases in the no endoleak group (65%). The positive predictive value for the presence of post-

Table 2. Number and percentage of preoperative patent side branches on pre- and postoperative CT images in the endoleak and no endoleak group.

	Preoperative CT		Postoperative CT
	Endoleak group ($n=13$)	No endoleak group ($n=17$)	Endoleak group ($n=13$)
Total	76	84	41
Second left lumbar	9 (70%)	15 (88%)	3 (23%)
Second right lumbar	11 (85%)	13 (76%)	4 (31%)
Third left lumbar	8 (62%)	11 (65%)	4 (31%)
Third right lumbar	8 (62%)	12 (71%)	3 (23%)
Fourth left lumbar	7 (54%)	6 (35%)	4 (31%)
Fourth right lumbar	8 (62%)	6 (35%)	6 (46%)
Sacral	10 (77%)	4 (24%)	8 (62%)
IMA	11 (85%)	11 (65%)	7 (54%)
Accessory renal	2 (15%)	4 (24%)	1 (8%)
Other	2 (8%)	1 (6%)	1 (8%)



A B

Fig. 3. Examples of endoleak (A) Major endoleak due to incomplete sealing of the distal stent to the inferior aneurysm neck (B) Minor endoleak involving the fourth lumbar arteries.

operative endoleak in case of a patent IMA was 50%; the positive predictive value for the absence of post-operative endoleak in case of a thrombosed IMA was 75%. A median number of four lumbar arteries was found in the endoleak group, compared to three in the no endoleak group ($p=0.10$).

Involvement of side branches in endoleak circuits

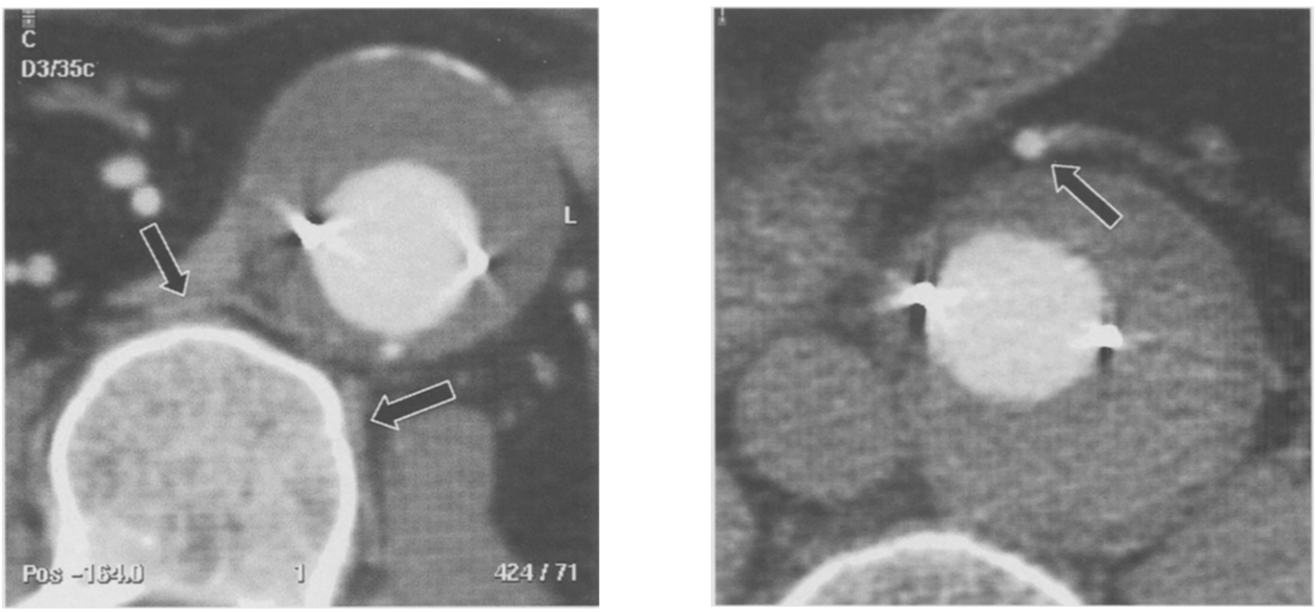
Seventy-six of the 160 patent side branches were found in the group of 13 patients that developed an endoleak after endovascular aneurysm repair. Forty-one of these 76 branches could be identified as part of endoleak circuits on post-operative CT images (54%; Table 2), the remaining 35 branches occluded. An IMA, a sacral or a lumbar artery as a single run-off channel for the endoleak was seen in three cases (23%).

The fate of preoperative patent side branches in patients without endoleak

All patent side branches in the group of 17 patients with a fully thrombosed aneurysm sac occluded to some extent by losing their contact with the aortic lumen. The postoperative fate of these branches varied from complete occlusion to partial patency due to

Table 3. Fate of preoperative patent aortic side branches in the no endoleak group.

	Inferior mesenteric arteries ($n=1$)	Lumbar and sacral arteries ($n=68$)	Accessory renal arteries ($n=5$)
Complete thrombosis or no longer detectable	1	22	4
Patent up to outer aneurysm wall	7	—	—
Partial thrombosis between aneurysm and first side branch bifurcation	—	10	1
Patient at level of first side branch bifurcation	3	10	—
Left to right collateral pathways at backside aneurysm	—	26	—



A B

Fig. 4. The fate of side branches after successful endovascular aneurysm repair (A) Lumbar collateral circuits at the backside of the aneurysm (B) Patency of the IMA up to the aneurysm wall

retrograde filling (Table 3). In seven out of 10 patients with a patent IMA, retrograde filling was in this artery observed up to outer limit of the aneurysm sac (Fig. 4). Lumbar patency due to collateral pathways from left to right lumbar arteries at the dorsal side of the aneurysm was seen in 9/17 patients without endoleaks (53%) A total of 26 lumbar arteries were involved in those collateral circuits (Fig. 4)

Discussion

One of the differences between transabdominal and endovascular aneurysm repair is the lack of control on backbleeding from aortic side branches during the latter procedure. In contrast to open aneurysm repair, backflow from aortic side branches cannot be seen before insertion of the vascular prosthesis. However, patent side branches are supposed to close spontaneously due to cut-off of inflow, and obstruction of outflow in case of backbleeding. This hypothesis is supported by research on the fate of the excluded aneurysm sac after aortic ligation and bypass surgery for aneurysms of the infrarenal aorta. Resnikof *et al.* reported on 831 patients operated on a 10-year period.[10] In 17 patients, aortic side branches were ligated during the procedure because of incomplete exclusion of the aneurysm sac, assessed by pressure measurement. Persistent flow in the aneurysm sac was diagnosed in another 17 patients during follow-up. Fourteen patients were reoperated, demonstrating the IMA or lumbar arteries as the cause of endoleaks in six. Incomplete exclusion of the aneurysm sac due to patent aortic side branches was therefore demonstrated in 23/813 (2.8%) of all patients in this group, including endoleaks that might have disappeared in the early postoperative phase. Blumenberg *et al.* performed a prospective study on 100 consecutive patients treated by exclusion of the aneurysm, using a stapling device, combined with an aortobi-iliac bypass graft.[11] Persistent flow in the aneurysm sac was encountered in 5% of the patients, probably from lumbar arteries in all cases.

Various authors have reported on persistent endoleaks due to retrograde perfusion by aortic side branches following successful placement of an aortic endograft. Persistent endoleaks due to lumbar or IMA backbleeding only were reported in 0–9.3% of the cases in seven studies that included more than 30 patients (median 2%).[1,8,12–16] In all cases of lumbar backbleeding, collateral pathways involving ileolumbar branches between the hypogastric and the lumbar arteries could be demonstrated. Coil embolisation of these pathways was successful in 90% of all attempts.

A relation between the number of patent side branches on preoperative CT images and the presence of postoperative endoleaks could not be demonstrated in our study; contrast enhancement indicating flow was found in a relatively high percentage of all side branches in both the endoleak and the no endoleak group. These results do not support the hypothesis that infrarenal aortic side branches are the direct cause of failure of endovascular aneurysm repair. Although the number of patent side branches is not predictive for postoperative endoleak, they are probably an essential part of the endoleak circuits in patients with an incomplete inclusion of the aneurysm by the endograft. Golzarian *et al.* demonstrated that the aneurysms of these patients may be excluded completely after coil embolisation of the involved side branches.[13] The impact of these procedures on the size of the aneurysm sac will have to be followed with care, as the thrombus may still be subjected to arterial pressure. Preferably, this type of endoleak should be treated by secondary sealing of the area of incomplete stent to wall contact, for example by inserting a second endograft or an extension cuff.

In patients with a completely excluded aneurysm sac, contrast enhancement of lumbar and inferior mesenteric arteries was frequently seen in close vicinity of the aneurysm wall. Although the outcome of endovascular aneurysm repair in patients without endoleaks was not affected by partially thrombosed side branches or collateral lumbar circuits, close follow-up is warranted. This was demonstrated by one case of a persistent endoleak, in which an initially partly thrombosed IMA became part of the endoleak circuit during follow-up.

In conclusion, patent infrarenal aortic side branches play an important role as run-off channels in patients with persistent endoleaks due to incomplete sealing of the endograft. Persistent backbleeding from side branches in patients with an adequately positioned endograft is encountered infrequently. Arguments for pre-emptive coil embolisation could not be found based on the results of this study.

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