

## REVIEW ARTICLE

# DIAGNOSIS AND TREATMENT OF ENDOLEAKS AFTER ENDOVASCULAR REPAIR OF THORACIC AND ABDOMINAL AORTIC ANEURYSMS

S. Heye<sup>1</sup>

A common complication of endovascular repair of a thoracic or abdominal aortic aneurysm (TEVAR – EVAR) is an endoleak occurring in up to 30% of cases. Endoleak is defined as the persistence of blood flow outside the lumen of the endoprosthesis, but within the aneurysm sac and can be classified into 5 categories, depending on the blood flow into the aneurysm sac. Typical features of the different types of endoleaks are discussed as well as the imaging modalities to detect and classify an endoleak and the diverse (endovascular) treatment options.

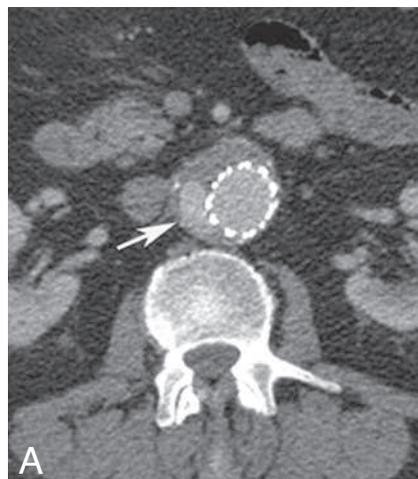
**Key-words:** Aneurysm, aortic – Aneurysm, therapy.

The goal of endovascular repair of a thoracic or abdominal aortic aneurysm (TEVAR – EVAR) is – as with open surgical repair – to prevent enlargement and rupture of the aneurysm (1). A common complication of TEVAR and EVAR is an endoleak and this is seen in up to 30% of cases (2). Endoleak is defined as the persistence of blood flow outside the lumen of the endoprosthesis, but within the aneurysm sac (3). A classification system for endoleaks has been developed, organizing endoleaks into 5 categories, depending on the blood flow into the aneurysm sac (4).

### Endoleak categories

#### Type I endoleak

In type I endoleak the blood flow passes alongside the proximal (IA) or distal (IB) attachment sites of the endoprosthesis, as a result of poor or insufficient apposition between the attachment site and the arterial wall (4, 5) (Fig. 1A-C, Fig. 2A,B). An endoleak through a non-occluded iliac artery in a patient with an aorto-uni-iliac endoprosthesis and a femoral-femoral bypass is a type IC endoleak (2). In type I endoleaks there is a direct communication between the aneurysm sac and the systemic arterial circulation and therefore the aneurysm sac is at high risk for rupture (5). Type I endoleak is the most common type of endoleak in TEVAR (1).



**Fig. 1.** – Contrast-enhanced CT-scan. Multiplanar reconstruction (MPR) images in (A) axial and (B) coronal plane showing a type IA endoleak in a patient with EVAR. There is contrast alongside the endoprosthesis, within the aneurysm sac (arrow). C. DSA confirms the CT-findings of a type IA endoleak, with contrast in between the vessel wall and the endoprosthesis (arrows).

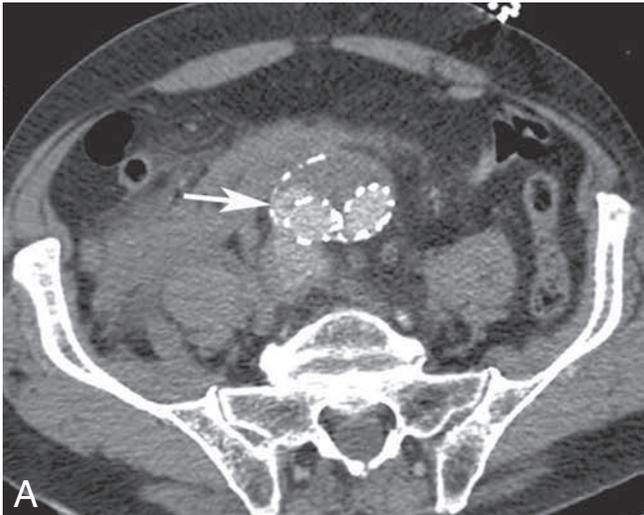
#### Type II endoleak

Retrograde filling of the aneurysm sac through side branches, mainly from intercostal/lumbar arteries and/or inferior mesenterica artery causes a type II endoleak (1, 2). A distinction is made between a type II endoleak involving a single side branch (IIA) (Fig. 3A-C) and a type II endoleak with more complex blood flow through 2 or more arteries (IIB). Type



\* Paper presented at the Annual Symposium of the SRBR-KBVR, Tervuren, 26.01.2013. From: 1. Department of Imaging and Pathology, Radiology Division, University Hospitals Leuven, Leuven, Belgium. Address for correspondence: S. Heye, Department of Imaging and Pathology, Radiology Division, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium. E-mail: sam.hey@uz.kuleuven.ac.be

II endoleak is the most common type of endoleak after EVAR (1). An association with aneurysmal expansion and rupture is possible, but the risk is lower in comparison to type I and type III endoleaks (0.5 vs 3.4%) (2).



**Fig. 2.** – A. Contrast-enhanced CT-scan demonstrating a type IB endoleak, with contrast in the aneurysm sac, close to the right leg of the endoprosthesis (arrow). B. DSA in the same patient showing that there is poor apposition of the right leg of the endoprosthesis to the vessel wall, allowing leakage of contrast into the aneurysm sac alongside the right leg of the endoprosthesis (arrows).

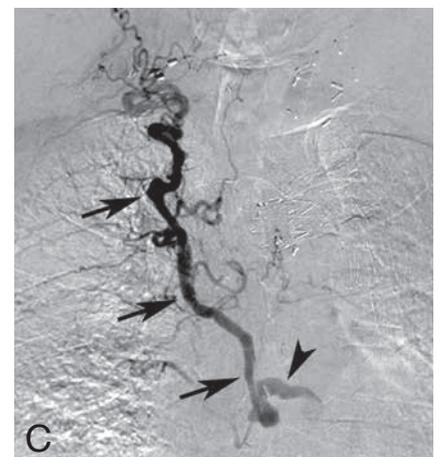
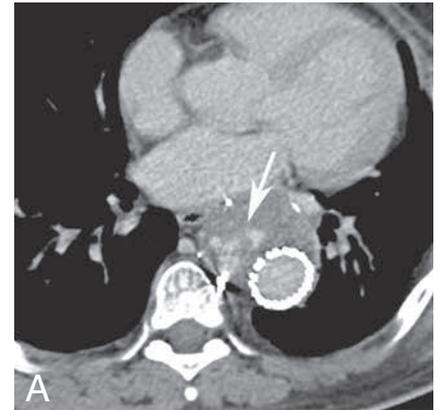
**Type III endoleak**

A type III endoleak occurs when there is a structural failure of the endoprosthesis, such as a hole in the fabric of the stent-graft (type IIIA) or a poor apposition or disconnection of different components of a modular endoprosthesis device (type IIIB) (Fig. 4A-C). These endoleaks are – as type I endoleaks – considered at high

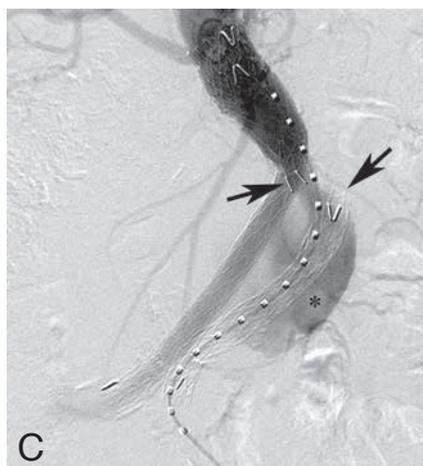
risk for rupture because of the aneurysm sac is subject to the arterial pressure (2, 5).

**Type IV endoleak**

Type IV endoleaks are caused by porosity of the endoprosthesis fabric and identified during implantation of the device, when the patient is fully anticoagulated. These endoleaks are



**Fig. 3.** – Contrast-enhanced CT-scan. A. MPR images in axial plane showing contrast in the aneurysm sac after TEVAR (arrow). B. Maximum-intensity projection (MIP) images in right anterior oblique plane and (C,D) corresponding DSA images demonstrating the right superior intercostal artery as the inflow/outflow vessel to the endoleak (type IIA endoleak) (arrows). The connection between inflow/outflow vessel (arrows) and the endoleak (arrowhead) can be seen on DSA.



**Fig. 4.** — Contrast-enhanced CT-scan. A,B. MPR images in axial plane revealing contrast in the aneurysm sac (asterisk) and an abrupt displacement of the anteriorly located leg of the endoprosthesis (medially located on (A) and at the lateral border of the aneurysm on B)). C. DSA in the same patient confirming the type IIIB endoleak (asterisk), caused by a disconnection of the left leg of the endoprosthesis from the short leg of the body of the endoprosthesis (arrows).

rarely seen in the devices that are used nowadays and will seal spontaneously when the coagulation profile is normalized (1).

#### Type V endoleak

A continued expansion of the aneurysm sac after TEVAR – EVAR, without a radiological evidence of an endoleak or endotension (5, 6). The exact cause is unknown, but may be an undiagnosed or occult endoleak (because of very slow flow or suboptimal imaging) or ultrafiltration through the device fabric (4-6). Others suggested that in some patients the thrombus in the aneurysm sac provides an ineffective barrier to transmission of arterial pressure and that these significant forces continue to affect the sac (4).

#### Surveillance

Because of the potential complications after TEVAR – EVAR, such as an endoleak, a life-long imaging surveillance is necessary (1). The ideal frequency and imaging technique has

however not yet been determined (1). In the EUROSTAR registry imaging surveillance at 1, 6, 12, 18 and 24 month after TEVAR - EVAR and then yearly is suggested (7, 8). Other centers perform surveillance at 1 month, 6 months and 12 months and then annually (1).

For endoleaks imaging surveillance is used for the detection and (if possible) the classification of endoleaks and for demonstration of any problems or deformities of the endoprosthesis.

Several imaging techniques have been used for surveillance, but (multi-detector) CT angiography remains the most widely used.

#### MR angiography

Gadolinium-enhanced MR angiography can be used to detect endoleaks, but only if the stents of the endoprosthesis are suitable for MR imaging. Stainless steel stents cause large susceptibility artifacts resulting in a nondiagnostic study. Elgiloy stents may obscure the vessel lumen. An endoprosthesis with nitinol stents will cause little or no artifacts and are therefore suitable for MR imaging (1). Time-resolved MR imaging can be used for characterization of the endoleak (1) and showed a 97% concordance with the findings of digital subtraction angiography (DSA) in one study (9).

#### Ultrasound

Ultrasound (US) has well known advantages over (MD)CTA (safe, inexpensive, no radiation, no use of iodine), but remains operator and patient dependent. Measurement of the aneurysm size with US correlates well with (MD)CT (1). Sensitivity for detecting an endoleak ranges between 67% and 86% in comparison to (MD)CT. Specificity varies between 67% and 100%. Positive predictive value (PPV) and negative predictive value (NPV) was between 29-100% and 90-100% respectively (10, 11). In 6 to 25% of cases US resulted in an inconclusive exam (10, 11). In the study of Uthoff and colleagues, the use of US as imaging surveillance technique increased during follow-up (26.6% at 6 months, 35.5% at 3 years), especially in experienced centers (12).

Since US is not able to give sufficient information on the conformation of the stent-grafts, US is usually combined with plain radiographs of the endoprosthesis. US has also limited use in the surveillance after TEVAR (4).

### MDCT angiography

MDCTA remains the most commonly used imaging modality for surveillance of TEVAR – EVAR. Sensitivity in depicting endoleaks is higher in comparison to DSA (92% versus 63%). Multiphase MDCTA is recommended to increase sensitivity since endoleaks have variable flow rates and therefore they can be detected at variable time points after injection of contrast material (1). Images without contrast are used to differentiate between contrast in the aneurysm sac and calcifications, while delayed venous phase images are used to depict endoleaks that are not visible during arterial phase (such as some slow flow type II endoleaks). Multiphase MDCTA can therefore also help to classify an endoleak, although classification – together with radiation dose – remains a problem.

In order to reduce patient radiation dose from MDCTA exams, several possibilities have been suggested. One way to reduce radiation dose is to replace the triple-phase MDCTA by a dual-phase MDCTA, by removing either the pre-contrast phase (except for the first examination at 1 month), or the arterial or venous phase. Removing the arterial phase was suggested in case of a stable or regressing aneurysm. Moreover since sensitivity for depicting endoleaks is higher with a delayed venous phase than with an arterial phase in some studies, it has been suggested to eliminate the arterial phase (1, 13). Others found that the decrease of sensitivity to detect endoleaks in the arterial phase was not significant, while specificity and PPV improved with the arterial phase. Therefore they proposed to eliminate the venous phase (13, 14).

Dual-energy dual-source CT has been examined, comparing standard triple-phase examinations to either virtual non-enhanced + arterial + delayed phase or virtual non-enhanced images + delayed phase in 2 studies (15, 16). Examinations with virtual non-enhanced images + delayed phase resulted in a 61% reduction of radiation dose compared with triple-phase imaging and a 41% reduction in radiation compared with dual phase imaging with a sensitivity, specificity, NPV and PPV of 100%, 97%, 100%, and 96% respectively (15, 16).

To improve the classification of endoleaks with CT, Sommer and colleagues examined time-resolved CTA in 54 patients and compared the

findings to contrast-enhanced US (17). They found a sensitivity, specificity, PPV and NPV of 94%, 93%, 89% and 96% respectively, with a mean effective radiation dose of 14.6 mSv (17).

### Digital subtraction angiography

Although time-resolved imaging techniques may be promising, DSA remains the most specific modality for endoleak classification. Stavropoulos reported only an 86% agreement between CTA and DSA for the classification of endoleaks and DSA did change the choice of treatment in 11% of cases (18). In nearly all endoleaks contrast was seen in the inferior mesenteric artery and/or the lumbar arteries, but these findings reflect either inflow/outflow in a type II endoleak or – and probably more importantly – outflow from a type I or type III endoleak (1).

Moreover in 2 studies on percutaneous interventions for suspected type II endoleaks (based on CTA findings), respectively 21% and 36% of the presumed type II endoleaks appeared to be occult type I or type III endoleaks (19, 20).

### Endoleak treatment

#### Type I and type III endoleaks

Because of the high risk for rupture in type I and type III endoleaks (arterial systemic pressure on the aneurysm sac), immediate treatment is needed. This can be done by endovascular means such as angioplasty balloons and bare stent to improve the apposition of the stent-graft to the vessel wall (in type I endoleaks) or additional stent-graft to extend the covering of the aneurysm (type I) (Fig. 5 A,B) or to cover the hole in the fabric/the zone of the junctional disconnection (type III) (Fig. 6). In selective cases with a type I endoleak, embolization has been described (1).

Surgical conversion is another option.

#### Type II endoleak

A lack of consensus exists concerning the treatment of type II endoleaks. Some groups believe that a type II endoleak that persists beyond 6 months should be treated (unless shrinkage of the aneurysm sac is documented) because the endoleak prevents thrombosis of the aneurysm sac and therefore a potential risk of aneurysm expansions and rupture exists (1). Others advocate a more conservative approach with close follow-up of the endoleak as

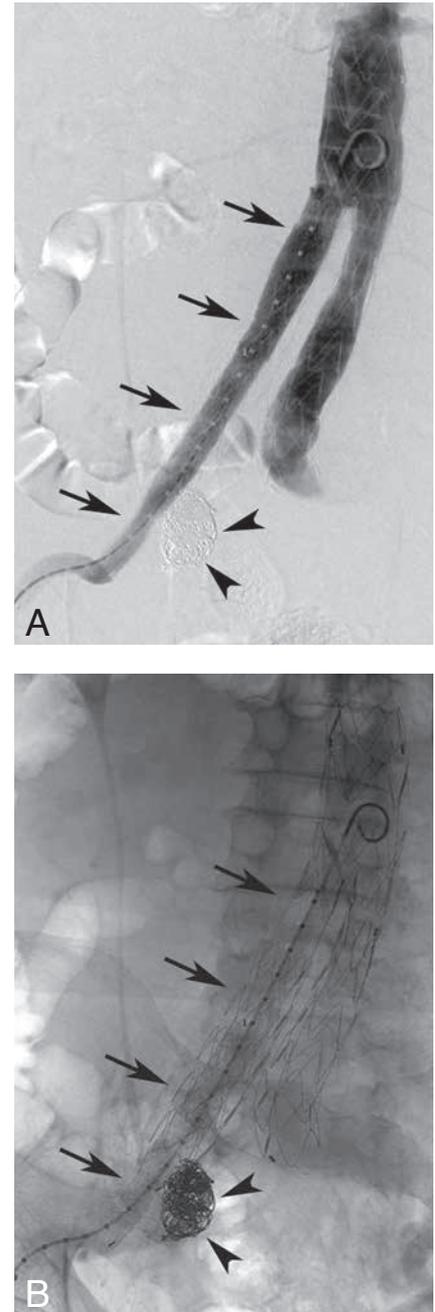


Fig. 5. — A. DSA and (b) digital angiography (DA) image of the same patient as in fig. 2 with a type IB endoleak showing extension of the right leg of the endoprosthesis with a long stent-graft ending in the right external iliac artery (arrows) successfully treating this type IB endoleak. In order to prevent potential type II endoleak via retrograde flow in the right internal iliac artery, the internal iliac artery was embolized with coils (arrowheads) prior to the stent-graft placement.

long as the aneurysm does not show an increase in size. This is based upon the fact that 40% of the type II endoleaks will seal spontaneously. For this reason they believe that a



Fig. 6. — DSA of the same patient as in Fig. 4 after placement of an additional stentgraft covering the location of the junctional disconnection at the left iliac axis. No residual type III endoleak is seen.

type II endoleak should only be treated if there is a combination with an expansion of the aneurysm sac greater than 5 mm, which is a rare phenomenon (1%-2.2%) (19, 21). Even though the debate is still going on, review of the evidence is in favor for the latter approach (22).

The first treatment of choice for type II endoleaks is embolization. From a treatment point of view, type II endoleaks have been compared with an arteriovenous malformation, with the sac as the nidus and the side branches of the aorta as inflow and outflow vessels communicating with each other through a channel (that can be different from the endoleak). (6). Goal of the treatment is to disrupt the communications between the inflow and outflow vessels, thus occluding the vessels and the communicating channels (6).

The approach for embolization can be either transarterial or direct via translumbar or transabdominal puncture (Fig. 7A-C, Fig. 8A-H). Both routes are equally effective if the endoleak cavity and the communicating vessels are embolized (23). The embolic agent used varies between the studies: most commonly used are coils and liquid embolic agents such as n-butyl cyanoacrylate (NBCA) and Ethylene-Vinyl-Alcohol-Copolymer (EVOH, Onyx®), and often a combination of these materials is needed. Gelfoam slurry or throm-

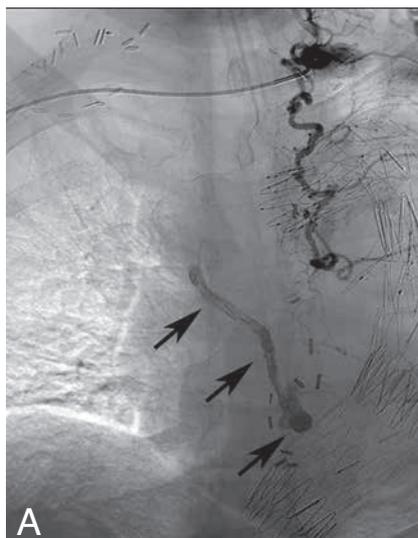
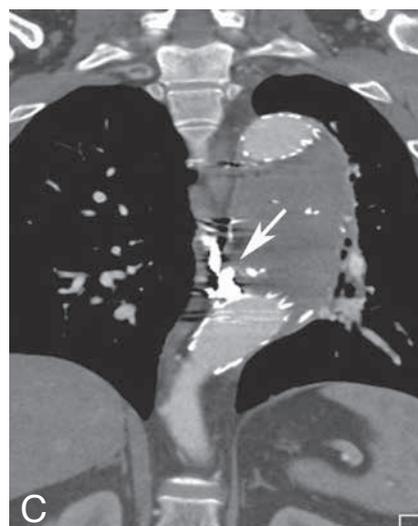
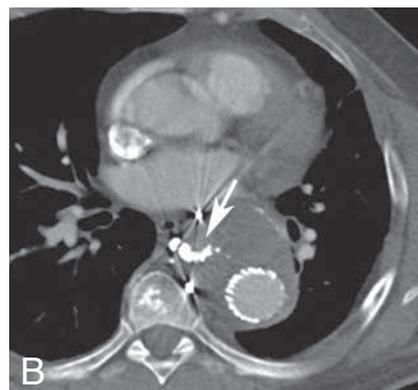


Fig. 7. — A. DA of the same patient as in Fig. 3 showing the cast of Onyx® in the right superior intercostal artery (arrows). Contrast-enhanced CT-scan. MPR images in B axial and C coronal plane demonstrating the cast of Onyx® extending in the type II endoleak (arrow).

bin are less frequently used in addition to coils (6).

The outcome of type II endoleak embolization is variable for several reasons. First of all different inclusion criteria are used in the studies (all type II endoleaks versus all persistent endoleaks versus only type II endoleaks with enlarging aneurysms) and second different types of definitions and outcome parameters are used (19-21, 23-29). Some authors consider absence of a type II endoleak as successful, while others describe success as a stable or regressing aneurysm with or without a (residual) endoleak (19-21, 23-29). Some take aneurysm rupture or aneurysm-related death as clinical endpoint. Funaki and colleagues made a clear difference between technical success (absence of an endoleak on follow-up CT) and clinical success, defined as stabilization of the aneurysm sac (20), but in other studies this difference is not clearly made. In most studies different approaches and different embolic agents are used in the studied population, making it impossible to determine if the material used is a predictive factor for success or failure (19-21, 23-29). Moreover patient selection was sometimes done based only on CT, while others did perform a pre-intervention DSA study (19-21, 23-29). This may influence outcome as well, since some studies demonstrated an

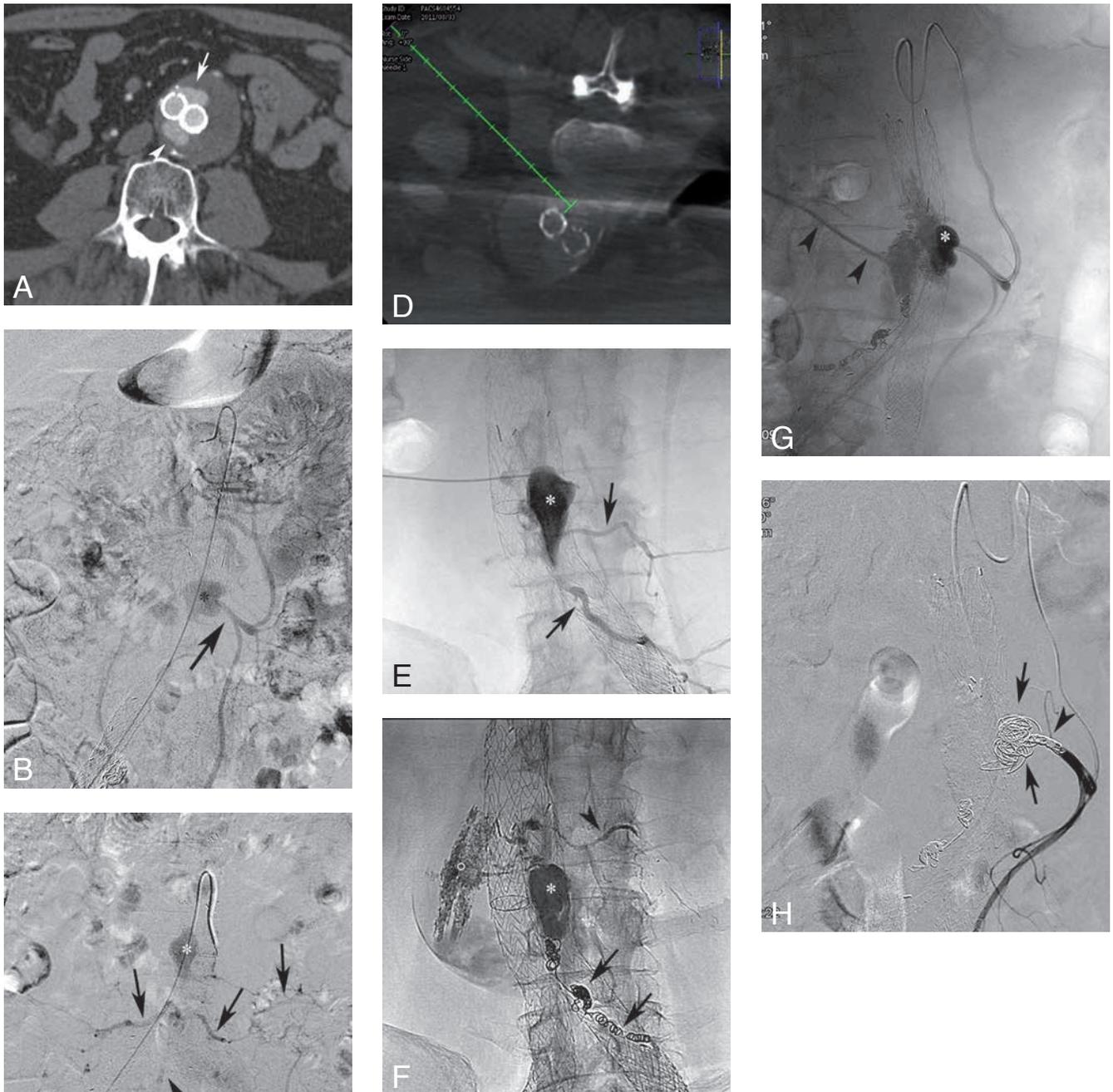


occult type I/III endoleak in about one third of patients. If this could be extrapolated to other studies, this may affect directly the outcome, because stabilization of the aneurysm is not to be expected (or at least to a lesser degree) in type I/III endoleaks.

In general one could conclude from the available studies that a second percutaneous intervention is often needed and that technical success varies between 28% and 100%. There was also a wide range of clinical success between 44% and 100% if it was defined as stable or decreasing aneurysm diameter. No aneurysm rupture or aneurysm-related death was seen. Complication rate varied between 0% and 9.6%.

#### Type IV endoleak

As this is rare with the current devices and only seen during placement while the patient is fully anticoagulated, there is no specific treatment for this type of endoleak. Type IV endoleaks are self-limited and resolve spontaneously when the coagulation status of the patient is normalized (1). An endoleak demonstrated during follow-up is per definition not a type IV endoleak.



**Fig. 8.** — A. Contrast-enhanced CT-scan showing an endoleak anterior (arrow) and posterior (arrowhead) to the two legs of the endoprosthesis. (B,C). DSA shows that these are two independent type II endoleaks. The anteriorly located endoleak (asterisk) is opacified through retrograde flow in the inferior mesenteric artery (arrow) via the superior mesenteric artery. The inflow/outflow arteries of the posterior endoleak (white asterisk) are a common origin of the fourth lumbar artery on both sides and middle sacral artery and lumbar artery L3 at the left side (arrows). D. Percutaneous direct puncture of the posterior endoleak was done guided by a pre-planned trajectory on a cone-beam CT-scan performed with a flat-panel detector system. E. DSA through the percutaneous needle showing the endoleak (white asterisk) and the inflow/outflow vessels (arrows). F. DA after embolization of lumbar artery L4 on the left side with microcoils (arrows) and after embolization of the endoleak with glue (white asterisk). There is some spilling of glue in left lumbar artery L2 (arrowhead) and in the psoas muscle (white circle).

#### *Type V endoleak*

Treatment options are limited in type V endoleaks. It is important however to confirm the diagnosis of endotension (and to exclude an underlying endoleak as cause of the aneurysm expansion). Endotension can be treated by relining (placing a new endoprosthesis within the old

G. DA showing superselective transarterial catheterization of the anterior endoleak (white asterisk) with a microcatheter. The outflow vessel of this endoleak is a right inferior polar artery (arrowheads). H. DSA after embolization of the endoleak (arrows) and the proximal segment of the inferior mesenteric artery (arrowhead) with microcoils. No more filling of the anterior endoleak through the inferior mesenteric artery is seen.

one) or by conversion to surgery. The risk of rupture in patients treated conservatively is however very low (< 1%) in the first 4 years if patients were not treated with Vanguard stent-grafts and had aneurysm diameters < 70 mm (8).

## Conclusions

Endoleak is a common complication of TEVAR and EVAR and therefore lifelong imaging surveillance is important. The ideal frequency and imaging technique have not yet been determined and the pros and cons of the different imaging modalities should be kept in mind. For the moment MDCTA is the most widely used technique for detection of endoleaks and classification is done by DSA. Type I and III endoleaks require immediate treatment because these endoleaks are prone to rupture. Available evidence support the conservative management of type II endoleaks, with treatment restricted to type II endoleaks with enlargement of the aneurysm sac >5 mm over a 6-month period or >10 mm in comparison with the diameter before TEVAR – EVAR. Before treating type II endoleaks one must exclude underlying occult type I/III endoleaks and the goal of the intervention should be to embolize the inflow and outflow vessels and the communicating channels in between.

Treatment of type V endoleaks remains unclear and may be conservative, endovascular or surgical.

## References

- Stavropoulos S.W., Charagundla S.R.: Imaging techniques for detection and management of endoleaks after endovascular aortic aneurysm repair. *Radiology*, 2007, 243: 641-655.
- Golzarian J., Maes E.B., Sun S.: Endoleak: treatment options. *Tech Vasc Interv Radiol*, 2005, 8: 41-49.
- Grande W., Stavropoulos S.W.: Treatment of complications following endovascular repair of abdominal aortic aneurysms. *Semin Interv Radiol*, 2006, 23: 156-164.
- Stavropoulos S.W., Carpenter J.P.: Postoperative imaging surveillance and endoleak management after endovascular repair of thoracic aortic aneurysms. *J Vasc Surg*, 2006, 43 Suppl A: 89A-93A.
- Bashir M.R., Ferral H., Jacobs C., McCarthy W., Goldin M.: Endoleaks after endovascular abdominal aortic aneurysm repair: management strategies according to CT findings. *AJR Am J Roentgenol*, 2009, 192: W178-W186.
- Golzarian J., Valenti D.: Endoleakage after endovascular treatment of abdominal aortic aneurysms: diagnosis, significance and treatment. *Eur Radiol*, 2006, 16: 2849-2857.
- Buth J., Harris P.L., van Marrewijk C., Fransen G.: The significance and management of different types of endoleak. *Semin Vasc Surg*, 2003, 16: 95-102.
- Koole D., Moll F.L., Buth J., et al.: Annual rupture risk of abdominal aortic aneurysm enlargement without detectable endoleak after endovascular abdominal aortic repair. *J Vasc Surg*, 2011, 54: 1614-1622.
- Cohen E.I., Weinreb D., Siegelbaum R., et al.: Time-resolved MR angiography for the classification of endoleaks after endovascular aneurysm repair. *J Magn Reson Imaging*, 2008, 27: 500-503.
- Gray C., Goodman P., Herron C.C., et al.: Use of color duplex ultrasound as a first line surveillance tool following EVAR is associated with a reduction in cost without compromising accuracy. *Eur J Vasc Endovasc Surg*, 2012, 44: 145-150.
- Karthikesalingam A., Al-Junbi W., Jackson D., et al.: Systematic review and meta-analysis of duplex ultrasonography, contrast-enhanced ultrasonography or computed tomography for surveillance after endovascular aneurysm repair. *Br J Surg*, 2012, 99: 1514-1523.
- Uthoff H., Peña C., Katzen B.T., et al.: Current clinical practice in postoperative endovascular aneurysm repair imaging surveillance. *J Vasc Interv Radiol*, 2012, 23: 1152-1159.e6.
- Laks S., Macari M., Chandarana H.: Dual-energy computed tomography imaging of the aorta after endovascular repair of abdominal aortic aneurysm. *Semin Ultrasound CT MR*, 2010, 31: 292-300.
- Iezzi R., Cotroneo A.R., Filippone A., et al.: Multidetector CT in abdominal aortic aneurysm treated with endovascular repair: are unenhanced and delayed phase enhanced images effective for endoleak detection? *Radiology*, 2006, 241: 915-921.
- Chandarana H., Godoy M.C.B., Vlahos I., et al.: Abdominal aorta: evaluation with dual-source dual-energy multidetector CT after endovascular repair of aneurysms – initial observations. *Radiology*, 2008, 249: 692-700.
- Stolzmann P., Frauenfelder T., Pfammatter T., et al.: Endoleaks after endovascular abdominal aortic aneurysm repair: detection with dual-energy dual-source CT. *Radiology*, 2008, 249: 682-691.
- Sommer W., Becker C.R., Haack M., et al.: Time-resolved CT angiography for the detection and classification of endoleaks. *Radiology*, 2012, 263: 917-926.
- Stavropoulos S.W., Clark T.W., Carpenter J.P., et al.: Use of CT angiography to classify endoleaks after endovascular repair of abdominal aortic aneurysms. *J Vasc Interv Radiol*, 2005, 16: 663-667.
- Aziz A., Menias C.O., Sanchez L.A., et al.: Outcomes of percutaneous endovascular intervention for type II endoleak with aneurysm expansion. *J Vasc Surg*, 2012, 55: 1263-1267.
- Funaki B., Birouti N., Zangan S.E., et al.: Evaluation and treatment of suspected type II endoleaks in patients with enlarging abdominal aortic aneurysms. *J Vasc Interv Radiol*, 2012, 23: 866-872.
- Steinmetz E., Rubin B.G., Sanchez L.A., et al.: Type II endoleak after endovascular abdominal aortic repair: a conservative approach with selective intervention is safe and cost-effective. *J Vasc Surg*, 2004, 39: 306-313.
- Patatas K., Ling L., Dunning J., Shrivastava V.: Stasis sac size with a type II endoleak post-endovascular abdominal aortic aneurysm repair: surveillance or embolization? *Interact Cardiovasc Thorac Surg*, 2012, 15: 462-466.
- Stavropoulos S.W., Park J., Fairman R., Carpenter J.: Type 2 endoleak embolization comparison: translumbar embolization versus modified transarterial embolization. *J Vasc Interv Radiol*, 2009, 20: 1299-1302.
- Rosen R.J., Green R.M.: Endoleak management following endovascular aneurysm repair. *J Vasc Interv Radiol*, 2008, 19: S37-S43.
- Nevala T., Biancari F., Manninen H., et al.: Type II endoleak after endovascular repair of abdominal aortic aneurysm: effectiveness of embolization. *Cardiovasc Interv Radiol*, 2010, 33: 278-284.
- Abdularrage C.J., Patel V.I., Conrad M.F., Schneider E.B., Cambria R.P., Kwolek C.J.: Improved results using Onyx glue for the treatment of persistent type 2 endoleak after endovascular aneurysm repair. *J Vasc Surg*, 2012, 56: 630-636.
- Uthoff H., Katzen B.T., Gandhi R., Peña C.S., Benenati J.F., Geisbüch P.: Direct percutaneous sac injection for postoperative endoleak treatment after endovascular aortic aneurysm repair. *J Vasc Surg*, 2012, 56: 965-972.
- Massis K., Carson W.G. III, Rozas A., Patel V., Zwiebel B.: Treatment of type II endoleaks with Ethylene-Vinyl-Alcohol-Copolymer (Onyx). *Vasc Endovasc Surg*, 2012, 46: 251-257.
- Sarac T.P., Gibbons C., Vargas L., et al.: Long-term follow-up of type II endoleak embolization reveals the need for close surveillance. *J Vasc Surg*, 2012, 55: 33-40.