

Selective Inferior Mesenteric Artery Embolization during Endovascular Abdominal Aortic Aneurysm Repair to Prevent Type II Endoleak

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Purpose: The purpose of this study was to evaluate the efficacy of simultaneous IMA (s-IMA) embolization during the endovascular abdominal aortic aneurysm repair (EVAR). **Materials and Method:** From July 2007 to January 2011, 189 patients in the no embolization (NE) group underwent EVAR without the indication for s-IMA embolization. Since February 2011 to April 2014, 143 patients have undergone EVAR. Among these patients, 26 patients underwent s-IMA embolism under a predefined indication and constituted the simultaneous embolization (SE) group. The indications for s-IMA embolization were defined by preoperative computed tomography (CT) findings, as follows: (1) the diameter was greater than 2.5 mm and (2) no stenosis due to thrombus or calcification at its orifice. **Results:** The incidence of a type II endoleak from the IMA was 3.4% (5/143) in the SE group patients and 13.2% (25/189) in the NE group patients ($p=0.013$), and the incidence of a type II endoleak from all branches (i.e., IMA, lumbar, medial sacral arteries) was 15.4% (22/143) in the SE group patients and 32.3% (61/189) in the NE group patients ($p = 0.0003$). During the follow-up period (range, 6–72 months; mean: 28 months), the reintervention rate for a type II endoleak from the IMA and/or other branches was 9.5% (18/189) in the NE group and 0.6% (1/143) in the SE group ($p = 0.0001$). **Conclusion:** In selected patients, performing an s-IMA embolization, based on CT findings, decreased the incidence of a type II endoleak and reintervention from the IMA and from all branches.

INTRODUCTION

Endovascular abdominal aortic aneurysm repair (EVAR) has become the mainstream therapy for abdominal aortic aneurysms (AAAs) with suitable anatomy.^{1,2} This less invasive technique has been established as a safe and effective method of short-term aneurysm exclusion. Endovascular abdominal aortic aneurysm repair requires continued surveillance because up to 11% of patients require a reintervention for major adverse events, in particular an endoleak.³ An endoleak is defined as continued perfusion of the aneurysmal sac, despite endograft deployment. The most commonly involved branches are the inferior mesenteric artery (IMA) and the lumbar arteries (LAs). A persistent type II endoleak, which is defined as a leak lasting longer than 6 months, has been associated with an increased incidence of adverse outcomes such as aneurysmal sac growth, reintervention, the need to convert to open repair, and rupture. Various strategies exist for managing a persistent type II endoleak. To preclude a type II endoleak, some investigators advocate intervention for preemptive adjunctive procedures such as IMA coil embolization.⁴⁻⁷ However, there are controversial studies on the effectiveness of preoperative embolization of aortic side branches to prevent a type II endoleak. Selective preoperative endovascular intervention should be based on a substantial risk of a persistent type II endoleak.⁸

We have previously reported that an IMA with a diameter greater than 2.5 mm but without stenosis or calcification at the orifice may cause a persistent type II endoleak and may increase the risk of reintervention. In our previous study, we proposed that the indication for preoperative embolization of the IMA is that it has a diameter greater than 2.5 mm, and it has no stenosis due to calcification or mural thrombus at the IMA origin.^{9,10} The purpose of this study was to investigate the efficacy of preoperative IMA embolization under our policy.

MATERIALS AND METHODS

Characteristics of the patients

We performed a retrospective review of the charts of 383 patients who underwent EVAR for the primary repair of an infrarenal AAA from July 2007 to April 2014 at the National Cerebral and Cardiovascular Center in Suita,

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Japan. Among these patients, 51 patients were excluded from this study because the IMA was occluded on the preoperative CT scan (40 patients) or because of the lack of enhanced preoperative CT (11 patients). Three hundred thirty-two patients were enrolled in this study and divided into two cohorts. From July 2007 to January 2011, 189 patients underwent EVAR before selective pre-EVAR IMA embolization was utilized and constituted the no embolization (NE) group. In this group, six male patients (78–80 years old) underwent reintervention because of a type II endoleak from the IMA for an aneurysm sac growth greater than 5 mm during follow-up period. Between February 2011 and April 2014, 143 patients underwent EVAR of which 26 patients (59–89 years old), which included one woman underwent IMA embolization according to the predefined criteria based on CT scan, and constituted the simultaneous embolization (SE) group (Table I). Procedural time, cost, and the volume of contrast agent used for embolization as the reintervention and the embolization simultaneous with the EVAR were analyzed between the two groups.

The incidence of type II endoleaks after the EVAR procedure was also analyzed. The reintervention-free rate between two groups was also accessed. All clinical data, which include the radiographic data, were obtained retrospectively from the chart of each patient.

All patients provided written, informed consent. In addition, the institutional review board of the National Cerebral and Cardiovascular Center (Suita, Japan) approved this study.

Table I. Baseline Characteristics

<i>Predictor</i>	<i>NE group (n=189)</i> July/2007-January/2013	<i>SE group (n=143)</i> February/2013- April 2014	<i>all (n=332)</i>	<i>p value</i>
Preoperative comorbidities				
Age	77.5±6.9	79.3±7.2	78.3±7.0	0.0032*
Sex (male)	146 (77.2%)	111 (77.6%)	260 (78.3%)	0.79
Hypertension	161 (85.1%)	107 (74.8%)	268 (80.7%)	0.0183*
Diabetes mellitus	31 (16.4%)	16 (11.2%)	47 (14.2%)	0.173
Hyperlipidemia	97 (51.3%)	52 (36.4%)	149 (44.9%)	0.0065*
Previous history				
cardiac disease	87 (46.0%)	40 (30.0%)	127 (38.3%)	0.0007*
cerebral disease	42 (22.2%)	30 (21.0%)	72 (21.7%)	0.78
Respiratory disease	24 (12.7%)	2 (1.4%)	26 (7.8%)	< 0.0001
Kidney disease	24 (12.7%)	37 (25.9%)	61 (18.4%)	0.0022*
Smoking				
Current smoker	31 (16.4%)	21 (14.7%)	52 (15.7%)	
Past smoker	87 (46.0%)	35 (24.5%)	122 (36.7%)	< 0.0001
Antiplatelet drug use	92 (48.7%)	68 (47.6%)	160 (48.2%)	0.83

Image protocol

All patients received a contrast-enhanced CT scan within 1 month before the initial EVAR procedure. All CT scans were performed with intravenous contrast material and thin collimation. After the unenhanced scan, a bolus injection of contrast was administered at 1.5–2.0 mL/s with a 20- to 25-second preparation delay. The images were reconstructed with 2-mm cuts. Three minutes after the early phase scan, delayed phase image were also obtained for all patients. The CT examination was usually acquired using 0.5- to 0.6-mm collimation. The data were reconstructed to 2-mm slice thickness to analyze the anatomical factors of the IMA. Image analysis of preoperative contrast-enhanced CT included the axial datasets, multiplanar reconstructions (usually in the oblique plane), manually and automatically created curved planar reconstructions, slab maximum intensity projections, and three-dimensional volume-rendered (3D-VR) images.¹¹ They were then clinically evaluated. At 6 months and 12 months after the EVAR, the patients underwent follow-up CT scans, and at least yearly thereafter. The presence of a type II endoleak was determined through CT scan in all patients, except for a few patients who voluntarily stopped attending our hospital for their follow-up visits. In accordance with previous reports, a type II endoleak was considered persistent if it did not resolve spontaneously within 6 months.^{8,12}

Indication of simultaneous IMA embolization and secondary intervention for a type II endoleak

The CT findings of the IMA such as diameter, thrombus, stenosis, and calcification in the orifice were analyzed. For IMA stenosis, we opted for the quantitative assessment of arteriography such as quantitative coronary angiography.¹¹ Two independent radiological specialists quantified the degree of stenosis from the IMA orifice to the anastomosis of the left colic artery by using area-based measurements.¹¹ Stenosis of the IMA orifice was

significant if it was associated with more than a 75% diameter reduction because of mural thrombus and/or calcification on cross-sectional image analysis. Calcification was defined as a protrusion of calcified plaque around the IMA orifice. The indications of simultaneous IMA embolization were the following: (1) a diameter greater than 2.5 mm, and (2) no stenosis due to thrombus or calcification at its orifice.¹⁰

As for general technical detail of the IMA embolization, IMA orifice was selected using a 5-Fr Michaelson-shaped catheter (Terumo Clinical Supply, Tokyo, Japan). After selective angiography, the IMA proximal of the anastomosis of the left colic artery was occluded using detachable coils. Two to three coils were necessary to occlude the proximal IMA.

During the follow-up period, significant aneurysmal sac growth was defined as an aneurysmal sac growth greater than 5 mm from the preoperative maximal sac diameter. A secondary intervention procedure was initiated if the patient had a type II endoleak persisting more than 6 months with enlargement of the aneurysmal diameter greater than 5 mm after the EVAR on the follow-up CT scan. The final decision of whether to treat and the method of treatment were determined by the vascular surgeon and interventional radiologist. If the CT scan showed a patent IMA to the nidus of the aneurysmal sac, IMA embolization was performed as the secondary procedure using a 5-Fr. angiographic catheter and 2.3-Fr microcatheter as the coaxial system *via* superior mesenteric artery. The orifice of the IMA was approached from the superior mesenteric artery *via* the meandering artery. The IMA orifice and/or the aneurysmal sac was occluded with conventional spring coils or detachable coils or with *n*-butyl-cyanoacrylate-lipiodol emulsion.

Statistical analysis

Statistical analysis was performed using JMP software (SAS Inc., Cary, NC, USA). Univariate comparisons of patient demographic and preoperative risk factors were performed using the Cox–Mantel test. The reintervention-free rate was calculated by using the Kaplan–Meier curve with the log-rank test.

RESULTS

The incidence of type II endoleaks from the IMA and other aortic side branches

In the NE group, the CT scan showed a type II endoleak in 61 (42.7%) patients. Among the 61 patients, the source of type II endoleak was the IMA in 25 patients. Spontaneous resolution of the type II endoleak from the IMA within 6 months occurred in three patients of the 25 patients. In the SE group, the incidence of a type II endoleak from the IMA was 3.4% (5/143 patients), which was statistically significant from the incidence of 13.2% (25/189 patients) in the NE group ($p = 0.0013$). In addition, the incidence of a type II endoleak from other aortic side branches such as the LAs and/or median sacral artery was 24.3% (46/189 patients) in the NE group and 13.2% (19/143 patients) in the SE group, which was statistically significantly different ($p = 0.0107$). The incidence of type II endoleak from all branches in the NE group and SE group was 32.3% (61/189) and 15.4% (22/143), respectively, ($p = 0.0003$). The incidence of a type II endoleak was significantly decreased in the SE group (Table II).

Table II. Incidence of type II endoleak of patients in two phases

<i>Variable</i>	NE group July/2007-January/2013	SE group February/2013- April 2014	p value
Patients	189	143	
Type II endoleak from IMA	25 (13.2%)	5 (3.4%)	0.0013*
Lumbar / median sacral artery	46 (24.3%)	19 (13.3%)	0.0107*
All branches	61 (32.3%)	22 (15.4%)	0.0003*
Re-intervention to type II endoleak	18 (9.5%)	1 (0.7%)	0.0001*

The IMA embolization procedure

During the follow up, CT showed a significant sac growth in 18 NE group patients. In six patients of the 18 patients (age range, 78–80 years), significant aneurysmal sac growth may have been caused by a type II endoleak from the IMA. Therefore, IMA embolization was performed as the secondary procedure. However, only one patient of the six patients had a complete disappearance of the type II endoleak because of persistent flow from

the LAs. An additional embolization procedure for the LAs was performed three times in one patient, twice in two patients, and once in two patients.

The IMA embolization was performed simultaneously with the EVAR procedure in 26 SE group patients per the indication defined by the CT scan. No major complications such as ischemic colitis and distal embolization to the lower extremities occurred in this study in either group.

Procedure time, volume of contrast material, and cost of embolization

The procedure time for reintervention and for simultaneous IMA embolization was 192 ± 48 min and 29 ± 22 min, respectively. The procedure time for the management of a type II endoleak was significantly shorter in patients treated by simultaneous IMA embolization ($p = 0.0002$). The volume of contrast material used for reintervention and for simultaneous IMA embolization was 160 ± 68 mL and 20 ± 14 mL, respectively ($p = 0.0002$). This difference was also significant. However, the cost for reintervention and for simultaneous IMA embolization was $\$465 \pm 232$ and $\$425 \pm 159$, respectively ($p = 0.716$). The cost was not statistically different, even though expensive detachable coils were used for the simultaneous IMA embolization.

Overall type II endoleak reintervention-free rate

During the follow-up period (6–72 months; mean period, 28 months), reintervention for a type II endoleak from the IMA and/or other branches such as the LAs or median sacral arteries was performed in 18 NE group patients and in only one SE group patient. For the one patients of SE group patients, IMA embolization was not indicated. The reintervention-free rate at 1, 3, and 5 years in the NE group patients was 99.4%, 94.8%, and 77.2% respectively, whereas the intervention-free rate at 1 and 3 years in the SE group patients was 100% and 97.8%, respectively. However, this difference was not statistically different ($p = 0.52$) because the follow-up period was shorter in the SE group patients (1–37 months; mean period, 15.4 months) than in the NE group patients (1–72 months; mean period, 37.5 months). In addition, intervention-free survival rate for type II endoleak at 1 and 3 years in SE group without IMA embolization ($n=117$) was 100% and 97.9%, respectively.

DISCUSSION

A type II endoleak commonly occurs after the EVAR procedure and reportedly occurs in 9–30% of patients.^{12,13} The clinical significance of a type II endoleak after the EVAR has not been established and controversies persist regarding the safety and risk of a type II endoleak.

However, multivariate analysis demonstrated that the type II endoleak is an independent predictor of aneurysm sac enlargement. A persistent type II endoleak, recurrent type II endoleak, and an association with a type I or III endoleak were highly predictive factors of sac growth.^{4,12} In addition, several investigators report a significant increase in aneurysm rupture associated with the conversion to an open repair.

Patients with a type II endoleak paired with sac enlargement may be treated by embolization or by variety of surgical techniques. Embolization involves occluding the feeding arteries and/or the endoleak nidus by the transarterial route or by direct puncture of the aneurysm sac.¹⁴ Despite encouraging early and midterm results in endoleak resolution and aneurysm sac diameter stabilization, some long-term results in the available limited data have not been favorable.^{12,15} In addition, it is important that the few long-term results that are available in the literature on embolization indicate an appreciable rate of recurrence that require repeat intervention and patients may experience delayed aneurysm sac growth, despite initial treatment success.^{16,17}

This study demonstrates the effectiveness of simultaneous IMA embolization in selected patients by using a predefined indication identified by CT scan. At the start of the EVAR era, many clinicians believed that preoperative embolization of potential causes of a type II endoleak could prevent it and thereby prevent the need for reintervention during the follow-up period. However, the results have been various and mixed. Gould et al.¹⁸ reported a similar incidence of type II endoleak in patients who underwent SE and in patients did not undergo SE. Muthu et al.¹⁹ reported their findings of routine preoperative embolization of the IMA and thrombin injection into the aneurysm sac. This technique reduced the occurrence of type II endoleak, but the difference failed to attain statistical significance. These preoperative embolization techniques appear attractive, although most patients with patent side branches will not develop type II endoleak; therefore, routine embolization before the EVAR exposes many patients to an unnecessary longer procedure time, comorbidities, and cost.¹²

We previously reported that if all patent IMAs were to undergo preoperative embolization, more than 95% of embolization procedures would have been unnecessary.¹⁰ This constitutes a strong argument for selective preoperative endovascular intervention in view of the substantial risk of persistent type II endoleak.^{8,9}

In this study, we selected to perform simultaneous IMA embolization, based on the indication defined by CT scan. The patency of the IMA and one or more LAs before the EVAR are risk factors for the development of a type II endoleak.²⁰ The EUROSTAR collaborators reported IMA patency in 47% (150/320) of patients with an endoleak, compared to 36% (1179/3275) of patients with no endoleak.²⁰ Their finding led us to speculate that the

embolization of a patent large IMA may reduce a type II endoleak from the LAs and the embolization of a large IMA without stenosis of the orifice is technically feasible with an appropriately shaped 5-Fr catheter.

We have not indicated the embolization of the LAs or other side branches because of the relation between patency, number of LAs, and incidence of endoleaks has not been determined. Technical difficulties such as catheterization, complications such as distal embolism, and the necessity of using more contrast material and coils are expected.

To determine the indication of selective intervention of the IMA before the EVAR, preoperative CT constitutes the most reliable and easily available image source. We previously reported that stenosis and thrombosis of the IMA orifice is associated with transient type II endoleak and permanent type II endoleak. In addition, setting the indication of IMA embolization at 2.5 mm diameter at its orifice has a reported sensitivity of 100%, specificity of 93%, and negative predictive value of 100%.¹⁰

In the present study, 18.2% (26/143) of candidate patients were selected for simultaneous IMA embolization, which was a little higher than the incidence of type II endoleak from IMA without the indication of IMA embolization (13.2%; 25/189 patients). However, we recognize that this ratio is acceptable.

This study demonstrated a high technical success rate, lower dose of contrast material, and shorter procedure time of simultaneous IMA embolization, compared to reintervention of a type II endoleak from the IMA. Moreover, the incidence of type II endoleak from the IMA and from all branches (i.e., IMA, LAs, and medial sacral arteries) decreased significantly. This finding led us to speculate that patency of the IMA and one or more LAs before the EVAR are risk factors for the development of a type II endoleak.^{20,21}

At least two branch arteries are required for the formation of a type II endoleak, although there may be several. The IMA may usually be a dominant inflow artery with one or more outflow arteries; therefore, IMA embolization performed simultaneously with an EVAR may decrease the incidence of a type II endoleak from other branches such as the LAs and the median sacral arteries.

A limitation of this study was that the indication for embolization of the IMA was based on our previous retrospective study. However, this simple indication, which is based on the diameter and the status of the orifice of IMA diagnosed on CT, could be easily applied and showed utility in this study.

In conclusion, simultaneous IMA embolization performed according to CT findings in selected patients decreased the incidence of a type II endoleak and reintervention from the IMA and from all branches. Long-term follow up is necessary to confirm the effectiveness of this study, although the appropriate indication for simultaneous IMA embolization were (1) a diameter greater than 2.5 mm and (2) no stenosis due to thrombus or calcification at its orifice

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REFERENCES

1. **Parodi, J. C., Palmaz, J. C., and Barone, H. D.** 1991. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vasc Surg* **5**: 491-499.
2. **Greenhalgh, R. M., and Powell, J. T.** 2008. Endovascular repair of abdominal aortic aneurysm. *N Engl J Med* **358**: 494-501. doi: 10.1056/NEJMct0707524.
3. **Conrad, M. F. Adams, A. B., Guest, J. M., Paruchuri, V., Brewster, D. C. et al.** 2009. Secondary intervention after endovascular abdominal aortic aneurysm repair. *Ann Surg* **250**, 383-389, doi: 10.1097/SLA.0b013e3181b365bd.
4. **Baum, R. A., Carpenter, J. P., Stavropoulos, S. W., and Fairman, R. M.** 2001. Diagnosis and management of type 2 endoleaks after endovascular aneurysm repair. *Techniques in vascular and interventional radiology* **4**: 222-226.
5. **Chikazawa, G., Yoshitaka, H., Hiraoka, A., Tanaka, K. Mouri, N., Tamura, K. et al.** 2013. Preoperative Coil Embolization to Aortic Branched Vessels for Prevention of Aneurysmal Sac Enlargement Following EVAR: Early Clinical Result. *Ann Vasc Dis* **6**: 175-179. doi: 10.3400/avd.0a.12.00079.
6. **Nevala, T., Biancari, F., Manninen, H., Matsi, P., Mäkinen, K. et al.** 2010. Inferior mesenteric artery embolization before endovascular repair of an abdominal aortic aneurysm: effect on type II endoleak and aneurysm shrinkage. *J Vasc Interv Radiol* **21**: 181-185. doi: 10.1016/j.jvir.2009.10.014.
7. **Nevala, T., Biancari, F., Manninen, H., Aho, P. S., Matsi, P. Mäkinen, K. et al.** 2010. Type II endoleak after endovascular repair of abdominal aortic aneurysm: effectiveness of embolization. *Cardiovasc Intervent Radiol* **33**: 278-284. doi:10.1007/s00270-009-9685-5.
8. **Jones, J. E., Atkins, M. D., Brewster, D. C., Chung, T. K., Kwolek, C. J., LaMuraglia, G. M. et al.** 2007. Persistent type 2 endoleak after endovascular repair of abdominal aortic aneurysm is associated with adverse

- late outcomes. *J Vasc Surg* **46**: 1-8. doi: 10.1016/j.jvs.2007.02.073.
9. **Otsu, M., Ishizaka, T., Watanabe, M., Hori, T., Kohno, H., Ishida, K. et al.** 2016. Analysis of anatomical risk factors for persistent type II endoleaks following endovascular abdominal aortic aneurysm repair using CT angiography. *Surg Today* **46**: 48-55. doi:10.1007/s00595-015-1115-5.
 10. **Fukuda, T., Matsuda, H., Sanda, Y., Morita, Y., Minatoya, K. et al.** 2014. CT Findings of Risk Factors for Persistent Type II Endoleak from Inferior Mesenteric Artery to Determine Indicators of Preoperative IMA Embolization. *Ann Vasc Dis* **7**: 274-279. doi:10.3400/avd.oa.14-00008.
 11. **Hoe, J. W., and Toh, K. H.** 2007. A practical guide to reading CT coronary angiograms--how to avoid mistakes when assessing for coronary stenoses. *Int J Cardiovasc Imaging* **23**: 617-633. doi:10.1007/s10554-006-9173-9.
 12. **Chung, R., and Morgan, R. A.** 2014. Type 2 Endoleaks Post-EVAR: Current Evidence for Rupture Risk, Intervention and Outcomes of Treatment. *Cardiovasc Intervent Radiol* **38**: 507-522. doi:10.1007/s00270-014-0987-x.
 13. **Gelfand, D. V., White, G. H., and Wilson, S. E.** 2006. Clinical significance of type II endoleak after endovascular repair of abdominal aortic aneurysm. *Ann Vasc Surg* **20**: 69-74. doi:10.1007/s10016-005-9382-z.
 14. **Ohki, T., Veith, F. J., Shaw, P., Lipsitz, E., Suggs, W. D., Wain, R. A. et al.** 2001. Increasing incidence of midterm and long-term complications after endovascular graft repair of abdominal aortic aneurysms: a note of caution based on a 9-year experience. *Ann Surg* **234**: 323-335.
 15. **El Batti, S., Cochenec, F., Roudot-Thoraval, F., and Becquemin, J. P.** 2013. Type II endoleaks after endovascular repair of abdominal aortic aneurysm are not always a benign condition. *J Vasc Surg* **57**: 1291-1297. doi:10.1016/j.jvs.2012.10.118.
 16. **Gallagher, K. A., Ravin, R. A., Meltzer, A. J., Khan, M. A., Coleman, D. M., Graham, A. R. et al.** 2012. Midterm outcomes after treatment of type II endoleaks associated with aneurysm sac expansion. *J Endovasc Ther* **19**: 182-192. doi:10.1583/11-3653.1.
 17. **Sarac, T. P., Gibbons, C., Vargas, L., Liu, J., Srivastava, S., Bena, J. et al.** 2012. Long-term follow-up of type II endoleak embolization reveals the need for close surveillance. *J Vasc Surg* **55**: 33-40. doi:10.1016/j.jvs.2011.07.092.
 18. **Gould, D. A., McWilliams, R., Edwards, R. D., Martin, J., White, D., Joeke, E. et al.** 2001. Aortic side branch embolization before endovascular aneurysm repair: incidence of type II endoleak. *J Vasc Interv Radiol* **12**: 337-341.
 19. **Muthu, C., Maani, J., Plank, L. D., Holden, A., and Hill, A.** 2007. Strategies to reduce the rate of type II endoleaks: routine intraoperative embolization of the inferior mesenteric artery and thrombin injection into the aneurysm sac. *J Endovasc Ther* **14**: 661-668. doi: 10.1177/152660280701400509.
 20. **van Marrewijk, C. J., Fransen, G., Laheij, R. J., Harris, P. L., and Buth, J.; EUROSTAR Collaborators.** 2004. Is a type II endoleak after EVAR a harbinger of risk? Causes and outcome of open conversion and aneurysm rupture during follow-up. *Eur J Vasc Endovasc Surg* **27**: 128-137. doi: 10.1016/j.ejvs.2003.10.016.
 21. **Arko, F. R., Rubin, G. D., Johnson, B. L., Hill, B. B., Fogarty, T. J., and Zarins, C. K.** 2001. Type-II endoleaks following endovascular AAA repair: preoperative predictors and long-term effects. *J Endovasc Ther* **8**: 503-510. doi: 10.1177/152660280100800513.