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ORIGINAL ARTICLE

Risk factors of secondary intervention for type II endoleaks in endovascular aneurysm repair: An 8-year single institution study

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Summary *Background/Objectives:* The natural history of type II endoleaks (T2ELs) is still not completely understood; however, it is widely accepted that those associated with aneurysmal sac growth are harmful. We aimed to review our experience with T2ELs in endovascular aneurysm repair (EVAR).
Methods: We retrospectively reviewed electronic medical records of all patients who underwent EVAR for infrarenal-type abdominal aortic aneurysms (AAAs) at a single institution from August 2007 to November 2015. Demographic and clinical data were collected. Preoperative contrast computed tomography scans were reviewed to determine aneurysm morphology (the maximum AAA diameter, number of lumbar arteries that enter the AAA sac, size of the inferior mesenteric artery (IMA), proximal neck diameter, proximal neck angle, existence of thrombosis, presence of atheroma, and existence of rupture).
Results: Sixty-two patients underwent EVAR; the follow-up duration was 35.82 ± 31.89 months. There were statistically significant differences in female sex ($P = .040$), number of lumbar arteries on preoperative computed tomography scans ($P = .010$), and non-smoking status ($P = .031$) between patients with and without T2ELs. There were statistically significant differences in the maximum AAA diameter ($P = .034$) and size of the IMA ($P = .043$) between patients with and without secondary intervention in T2EL. There was one mortality after EVAR but no mortality associated with T2ELs.

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Conclusions: A more judicious approach that considers risk factors of T2ELs is needed before EVAR. The risk of secondary intervention in patients developing a T2EL after EVAR could increase with the maximum AAA diameter ≥7 cm or IMA ≥3 mm.

1. Introduction

Endovascular aneurysm repair (EVAR) is a minimally invasive alternative to open repair for patients with abdominal aortic aneurysms (AAAs) (maximum diameter >4.5 cm in women and 5.5 cm in men).[1] An endoleak is the most common complication that requires secondary intervention after EVAR, and type II endoleaks (T2ELs) are the most common type of endoleak; up to 20% of patients undergoing EVAR develop a T2EL.[2–4] T2ELs are caused by collateral retrograde flow into the aneurysm sac from the aortic branches, such as the inferior mesenteric artery (IMA), lumbar arteries, sciatic arteries, and accessory renal arteries. T2ELs have a mostly benign prognosis, if there is no sac expansion of the AAA.[5] The natural history of T2ELs is still not completely understood; however, it is widely accepted that those associated with aneurysmal sac growth are harmful.[4]

We review our 8-year experience with T2ELs at a single institution, and we report the risk factors of T2EL occurrence in EVAR and factors affecting secondary intervention for T2ELs.

2. Methods

We retrospectively reviewed the electronic medical records of all patients who underwent EVAR for infrarenal type AAA at our institution from August 2007 to November 2015. Preoperative planning and device selection were discussed by the vascular surgeon and radiologist, and these were based on a contrast computed tomography (CT) scan with 2-mm cuts and 3-dimensional reconstruction that enabled accurate, centerline measurements of the infrarenal aorta. We used three stent grafts: the Excluder (W.L. Gore and Associates, Flagstaff, AZ, USA), Endurant (Medtronic, Minneapolis, MN, USA), and Zenith (Cook Inc., Bloomington, IN, USA). Cannulations through both common femoral arteries were performed using a percutaneous technique guided by ultrasonography under local anesthesia in all patients.

Demographic and clinical data were collected for each patient, and preoperative contrast CT scans were reviewed to determine the aneurysm morphology (the maximum AAA diameter, number of lumbar arteries that enter the AAA sac, size of the IMA, proximal neck diameter, proximal neck angle, existence of thrombosis, existence of atheroma, and existence of rupture) and sacrifice of the internal iliac artery. Renal insufficiency was determined as a creatinine level ≥2.0 mg/dL.

Outcomes included perioperative and long-term mortality, cause of death, hospitalization period, intensive care unit period, and follow-up duration. All deaths within 30 days of EVAR were classified as aneurysm-related. A T2EL was defined as secondary to patency of the aortic branches (IMA and lumbar arteries), and the vascular specialist of radiology interpreted the angiogram at EVAR and the CT scan post-EVAR.

The secondary intervention for T2EL was usually performed if there was aneurysm sac growth on serial CT scans or T2EL in the past 1 year or more. At our institution, post-EVAR CT surveillance is performed at 1, 6, and 12 months

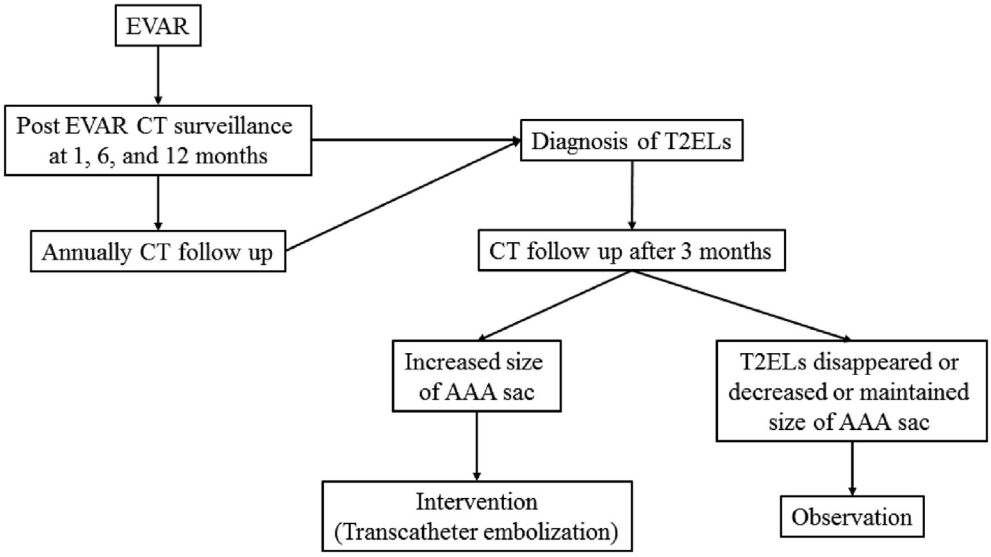

Figure 1 The strategy for treating type II endoleaks at our institution. EVAR: endovascular aneurysm repair; CT: computed tomography; T2ELs: type II endoleaks; AAA: abdominal aortic aneurysms.

and then annually. When T2ELs were diagnosed, we performed CT 3 months later if there was no interval change in the size of the aneurysm (Fig. 1).

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional review board of Pusan National University Hospital and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards (review number: 1706-015-056).

2.1. Statistical analysis

Means of continuous variables were compared between two groups using the two t-test or Wilcoxon rank-sum test. We compared categorical variables between outcome subgroups using the Fisher exact tests. All statistical analyses were performed using SAS statistical software, version 9.4 (SAS Institute, Cary, NC, USA). Statistical significance was defined as $P < .05$.

3. Results

Sixty-two patients underwent EVAR during this period, and the follow-up duration was 35.82 ± 31.89 months. At our institution, T2ELs were diagnosed in 26 patients (42%), and secondary interventions were needed in 4 patients (6.5%) who underwent expansion of the AAA sac. Patient demographic characteristics and medical comorbidities are described in Table 1, and this cohort was divided into two groups: those with and without T2ELs. There were statistically significant differences in female sex ($P = .040$), number of lumbar arteries that enter the AAA sac on a preoperative computed tomography scan ($P = .010$), and non-smoking status ($P = .031$) between patients with and without T2ELs.

A comparison of baseline demographic characteristics and medical comorbidities between patients with and without secondary intervention for T2ELs is presented in Table 2. There were statistically significant differences in the maximum AAA diameter ($P = .034$) and size of the IMA

Table 1 Comparison of baseline demographic characteristics and medical comorbidities between patients with and without type II endoleaks.

	Overall N = 62 (100%)	No type II endoleaks N = 36 (58.1%)	Type II endoleaks N = 26 (41.9%)	*p*-value
Female sex	**11 (17.7%)**	**3 (8.3%)**	**8 (30.8%)**	**0.040**
Male sex	51 (82.3%)	33 (91.7%)	18 (69.2%)	
Age (years, mean ± standard deviation)	71.34 ± 6.77	72.25 ± 6.03	70.08 ± 7.63	0.215
Maximum AAA diameter (mm, mean ± standard deviation)	60.56 ± 11.08	62.31 ± 10.71	58.15 ± 11.33	0.147
Number of lumbar arteries* (mean ± standard deviation)	**5.37 ± 1.46**	**4.97 ± 1.44**	**5.92 ± 1.32**	**0.010**
IMA size (mm, mean ± standard deviation)	1.85 ± 1.24	1.76 ± 1.31	1.99 ± 1.15	0.463
Proximal neck diameter (mm, mean ± standard deviation)	19.69 ± 3.33	20.32 ± 3.56	18.83 ± 2.81	0.081
Proximal neck angle (°, mean ± standard deviation)	45.57 ± 17.13	45.07 ± 20.19	46.27 ± 12.04	0.789
Existence of thrombosis	37 (59.7%)	23	14	0.445
Existence of atheroma	25 (40.3%)	12	13	0.203
Existence of rupture	2 (3.2%)	2	0	0.505
Sacrifice of the internal iliac artery	15 (24.2%)	11	4	0.233
BMI (kg/m^2)	23.20	23.01	23.45	0.543
Non-smoking status	**41 (66.1%)**	**28**	**13**	**0.031**
COPD	5 (8.1%)	2	3	0.641
Hypertension	41 (66.1%)	24	17	1.000
Diabetes mellitus	7 (11.3%)	4	3	1.000
Dyslipidemia	10 (16.1%)	6	4	1.000
CAOD	15 (24.2%)	6	9	0.137
PAOD	1 (1.6%)	1	0	1.000
CVA	9 (14.5%)	7	2	0.282
DVT	0	0	0	
Renal insufficiency	6 (9.7%)	5	1	0.387
Follow-up duration (months, median [interquartile range])	28.00 [0.00, 167.00]	26.50 [0.00, 167.00]	29.00 [4.00, 82.00]	0.716
Hospital stay (days, median [interquartile range])	8.00 [4.00, 36.00]	8.00 [4.00, 32.00]	8.00 [4.00, 36.00]	0.846
ICU stay (days, mean ± standard deviation)	1.37 ± 1.00	1.33 ± 1.01	1.42 ± 0.99	0.729
In-hospital mortality	0	0	0	
30-day mortality	0	0	0	
Death	8 (12.9%)	5	3	1.000

AAA = abdominal aortic aneurysm; IMA = inferior mesenteric artery; BMI = body mass index; COPD = chronic obstructive pulmonary disease; CAOD = coronary arterial occlusive disease; PAOD = peripheral arterial occlusive disease; CVA = cerebrovascular accident; DVT = deep vein thrombosis; ICU = intensive care unit.

* = the number of lumbar arteries that enter the AAA sac on a preoperative computed tomography scan.

($P = .043$) between patients with and without secondary intervention in T2EL. The probability of a secondary intervention for T2ELs is shown in Fig. 2.

Four patients (3 men, 1 woman; mean age 76 years) underwent a secondary intervention caused by a T2EL at 20.67 ± 18.24 months after EVAR. Both the IMA and lumbar artery accounted for a T2EL, and transcatheter embolization of both the IMA and lumbar arteries was performed in 4 patients (Fig. 3). In the other patients (n = 22, 35.5%) who did not undergo a secondary intervention for a T2EL, the T2EL disappeared on follow-up CT scan or the size of the AAA sac was decreased or maintained. Causes of a T2EL were the IMA (n = 3, 12%), lumbar arteries (n = 17, 65%), and both (n = 6, 23%).

Overall mortality for the 8-year study period was 8 deaths (12.9%). There was one instance of mortality associated with EVAR; however, no mortality was associated with a T2EL. There was no instance of 30-day and in-hospital mortality after EVAR. There was one instance of late mortality after EVAR. The patient was diagnosed as having AAA rupture caused by a type III endoleak upon arrival to our hospital and died of multi-organ failure on postoperative day 17. The other 7 deaths were not related to EVAR: prostatic cancer (2 patients), bladder cancer (1 patient), cholangiocarcinoma (1 patient), lung cancer (2 patients), and pneumonia (1 patient).

4. Discussion

EVAR has been widely accepted as the standard of care for repairing AAAs with proper anatomy, especially in older patients and in those with a high risk of morbidity, and it is preferentially considered because of the lower risk of

Table 2 Comparison of baseline demographic characteristics and medical comorbidities between patients with and without secondary intervention in the type II endoleaks group.

	Overall N = 26 (100%)	No secondary intervention N = 22 (84.6%)	Secondary intervention N = 4 (15.4%)	*p*-Value
Female sex	8 (30.8%)	7 (31.8%)	1 (25.0%)	1.000
Male sex	18 (69.2%)	15 (68.2%)	3 (75.0%)	
Age (age, mean ± standard deviation)	70.08 ± 7.63	69.00 ± 7.76	76.00 ± 2.94	0.092
Maximum AAA diameter (mm, mean ± standard deviation)	**58.15 ± 11.33**	**56.18 ± 10.58**	**69.00 ± 10.03**	**0.034**
Number of lumbar arteries* (mean ± standard deviation)	5.92 ± 1.32	5.73 ± 1.32	7.00 ± 0.82	0.076
IMA size (mm, mean ± standard deviation)	**1.99 ± 1.15**	**1.80 ± 1.13**	**3.05 ± 0.54**	**0.043**
Proximal neck diameter (mm, mean ± standard deviation)	18.83 ± 2.81	18.66 ± 2.88	19.75 ± 2.50	0.486
Proximal neck angle (°, mean ± standard deviation)	46.27 ± 12.04	46.55 ± 12.93	44.75 ± 5.74	0.790
Existence of thrombosis	14 (53.8%)	12	2	1.000
Existence of atheroma	13 (50.0%)	11	2	1.000
Existence of rupture	0	0	0	
Sacrifice of the internal iliac artery	4 (15.4%)	2	2	0.099
BMI (kg/m^2)	23.45 ± 2.70	23.64 ± 2.86	22.43 ± 1.36	0.418
Non-smoking status	13 (50%)	10	3	0.593
COPD	3 (11.5%)	3	0	1.000
Hypertension	17 (65.4%)	14	3	1.000
Diabetes mellitus	3 (11.5%)	3	0	1.000
Dyslipidemia	4 (15.4%)	4	0	
CAOD	9 (34.6%)	8	1	1.000
PAOD	0	0	0	
CVA	2 (7.7%)	2	0	1.000
DVT	0	0	0	
Renal insufficiency	4	2	2	0.099
Follow-up duration (months, median [interquartile range])	29.00 [4.00, 82.00]	23.50 [4.00, 82.00]	34.00 [27.00, 57.00]	0.499
Hospital stay (days, median [interquartile range])	8.00 [4.00, 36.00]	8.50 [4.00, 36.00]	8.00 [6.00, 15.00]	0.692
ICU stay (days, mean ± standard deviation)	1.42 ± 0.99	1.41 ± 1.01	1.50 ± 1.00	0.869
In-hospital mortality	0	0	0	
30-day mortality	0	0	0	
Death	3 (11.5%)	2	1	0.408

AAA = abdominal aortic aneurysm; IMA = inferior mesenteric artery; BMI = body mass index; COPD = chronic obstructive pulmonary disease; CAOD = coronary arterial occlusive disease; PAOD = peripheral arterial occlusive disease; CVA = cerebrovascular accident; DVT = deep vein thrombosis; ICU = intensive care unit.

* = the number of lumbar arteries that enter the AAA sac on a preoperative computed tomography scan.

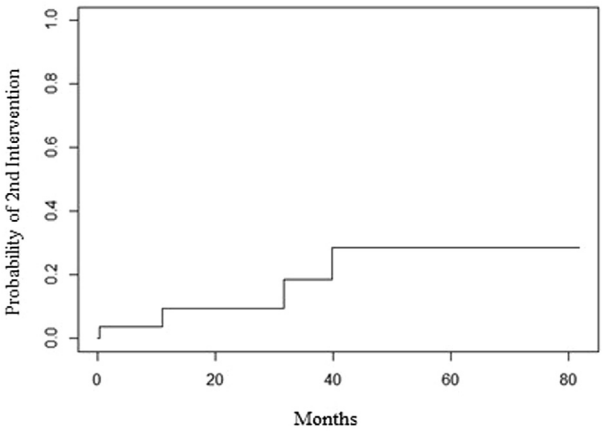

Figure 2 Probability of secondary intervention for the type II endoleaks group according to Kaplan–Meier analysis.

perioperative death compared to open repair.[6] However, endoleak management has been a main issue of EVAR since more than two decades ago. Types I and III endoleaks should be repaired immediately with definitive secondary intervention, but the treatment of types II, IV, and V endoleaks depends on the increased size of the AAA sac or patient's symptoms such as abdominal pain.[7]

In this study, 42% of patients had a T2EL during the follow-up duration; however, not all of them had a persistent T2EL. Previous studies have reported the prevalence of a T2EL after EVAR ranging from 7.8% to 44%.[8–10] The incidence of secondary intervention owing to a T2EL was reported from 23.4% to 25.9% of patients diagnosed as having a T2EL after EVAR.[11,12] In this study, 15.4% of patients with a T2EL required a secondary intervention because of the increasing size of the aneurysm sac, and there were no aneurysm rupture or aneurysm-related mortality in those with a T2EL. According to a systematic review of treatment for a T2EL after EVAR,[11] AAA rupture after EVAR secondary to an isolated T2EL is rare (0.9%); however, more than one-third of AAA ruptures occur in the absence of sac expansion. Therefore, closed monitoring for sac expansion and consideration of the risk factors of a T2EL are needed, although the progression of a T2EL is benign.

Between patients with and without a T2EL, female sex ($P = .040$) and non-smoking status ($P = .031$) among the demographic characteristics, and the number of lumbar arteries that enter the AAA sac on a preoperative computed tomography scan ($P = .010$, 4.97 versus 5.92) were statistically significantly different. A previous study reported that the risk factors of a persistent T2EL were a large, patent IMA or more than two lumbar arteries identified on a preoperative CT angiogram.[13] Compared with the previous study, the number of lumbar arteries was very different, and this factor may have an adverse effect on a T2EL. According to our results, physicians should take a more cautious approach to EVAR in patients with $\geq$6 lumbar arteries that enter the AAA sac on a preoperative computed tomography scan, female patients, and non-smokers to prevent the occurrence of a T2EL. There were more occurrences of a T2EL in the non-smoking group than in the smoking group. In a study on the effect of smoking on EVAR,[14] non-smokers had more late T2ELs than former smokers and current smokers (58.5%, 55.9%, and 35.5%, respectively; $P < .001$) in the European

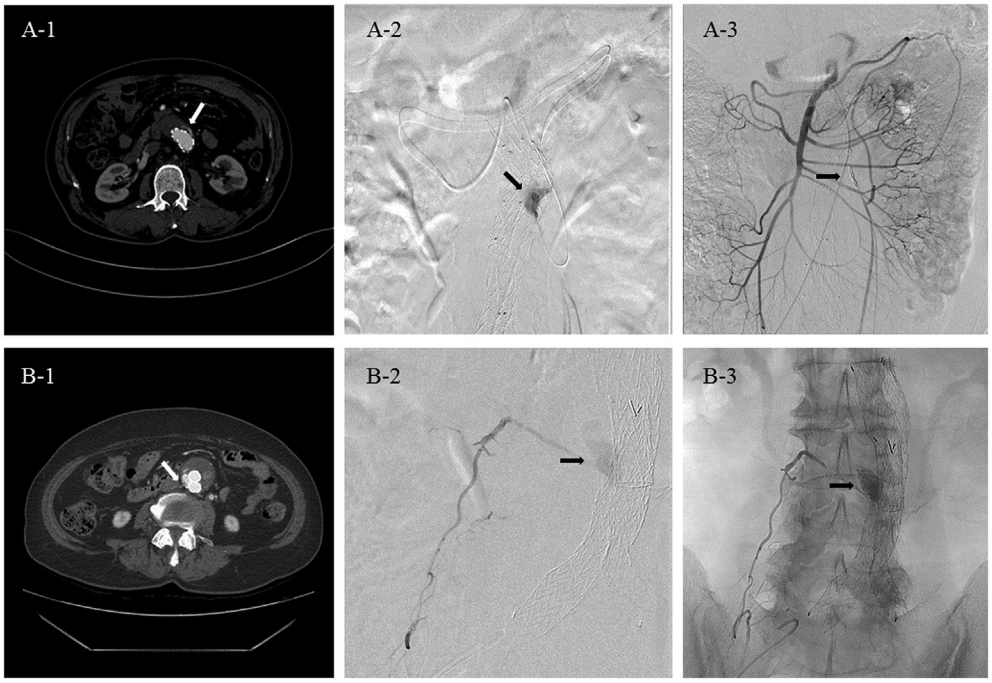

Figure 3 The cases of secondary intervention for the type II endoleaks. **A-1:** The type II endoleak by inferior mesenteric artery was observed in the contrast computed tomography. (arrow). **A-2:** The type II endoleak by inferior mesenteric artery was observed in the angiogram. (arrow). **A-3:** The coil embolization was performed. (arrow). **B-1:** The type II endoleak by iliolumbar artery (L3 level) was observed in the contrast computed tomography. (arrow). **B-2:** The type II endoleak by iliolumbar artery (L3 level) was observed in the angiogram. (arrow). B**-3:** The embolization was performed by histoacryl – lipiodol mixture. (arrow).

Collaborators on Stent-Graft Techniques for Aortic Aneurysm Repair database.

Between patients with and without secondary intervention for a T2EL, there were statistically significant differences in the maximum AAA diameter ($P = .034$, 56.18 mm versus 69.00 mm) and size of the IMA ($P = .043$, 1.80 mm versus 3.05 mm). Couchet et al.[15] reported that the IMA diameter (3.49 mm versus 2.71 mm, $P < .001$) was a morphologic predictive factor of a T2EL. Our results may be associated with the etiology of a T2EL with retrograde arterial flow into the aneurysm sac most commonly due to the lumbar artery or IMA.[16] The risk of secondary intervention in patients developing a T2EL after EVAR could increase with a maximum AAA diameter $\geq$7 cm or IMA $\geq$3 mm.

The present study has a couple limitations. The total number of secondary interventions for treating a T2EL was modest, and the study design was a non-randomized, retrospective, observational study. Additionally, it is necessary to collect data for the diameter of the lumbar arteries and sac diameter post-EVAR.

A more judicious approach that considers the risk factors of T2EL in EVAR (female sex, $\geq$6 lumbar arteries that enter the AAA sac on a preoperative computed tomography scan, and non-smoker status) is necessary. It is also necessary to consider the probability of secondary intervention for T2EL in patients who have a maximum AAA diameter $\geq$7 cm and IMA $\geq$3 mm.

Conflicts of interest

The authors declare that they have no conflict of interest.

Acknowledgments

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References

1. Hammond CJ, Shah AH, Snoddon A, Patel JV, Scott DA. Mortality and rates of secondary intervention after EVAR in an unselected population: influence of simple clinical categories and implications for surveillance. *Cardiovasc Intervent Radiol*. 2016;39:815—823.
2. Sampram ES, Karafa MT, Mascha EJ, et al. Nature, frequency, and predictors of secondary procedures after endovascular repair of abdominal aortic aneurysm. *J Vasc Surg*. 2003;37:930—937.
3. United Kingdom EVAR Trial Investigators, Greenhalgh RM, Brown LC, et al. Endovascular versus open repair of abdominal aortic aneurysm. *N Engl J Med*. 2010;362:1863—1871.
4. Saqib NU, Charlton-Ouw KM, Azizzadeh A. Managing type II endoleaks. *Endovascular Today*; 2013:45—50. http://evtoday.com/2013/02/managing-type-ii-endoleaks/. Accessed July 16, 2017.
5. Silverberg D, Baril DT, Ellozy SH, et al. An 8-year experience with type II endoleaks: natural history suggests selective intervention is a safe approach. *J Vasc Surg*. 2006;44:453—459.
6. Sajid MS, Desai M, Haider Z, Baker DM, Hamilton G. Endovascular aortic aneurysm repair (EVAR) has significantly lower perioperative mortality in comparison to open repair: a systematic review. *Asian J Surg*. 2008;31:119—123.
7. Sarac TP, 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.
8. Marrewijk C, Buth J, Harris PL, Norgren L, Nevelsteen A, Wyatt MG. Significance of endoleaks after endovascular repair of abdominal aortic aneurysms: the EUROSTAR experience. *J Vasc Surg*. 2002;35:461—473.
9. Choke E, Thompson M. Endoleak after endovascular aneurysm repair: current concepts. *J Cardiovasc Surg (Torino)*. 2004;45:349—366.
10. Aburahma AF, Mousa AY, Campbell JE, et al. The relationship of preoperative thrombus load and location to the development of type II endoleak and sac regression. *J Vasc Surg*. 2011;53:1534—1541.
11. Sidloff DA, Stather PW, Choke E, Bown EM, Sayers RD. Type II endoleak after endovascular aneurysm repair. *Br J Surg*. 2013;100:1262—1270.
12. Walker J, Tucker LY, Goodney P, Candell L, Hua H, Okuhn S. Type II endoleak with or without intervention after endovascular aortic aneurysm repair does not change aneurysm-related outcomes despite sac growth. *J Vasc Surg*. 2015;62:551—561.
13. Arko FR, Rubin GD, Johnson BL, Hill BB, Fogarty TJ, Zarins CK. Type-II endoleaks following endovascular AAA repair: preoperative predictors and long-term effects. *J Endovasc Ther*. 2001;8:503—510.
14. Koole D, Moll FL, Buth J, et al. The influence of smoking on endovascular abdominal aortic aneurysm repair. *J Vasc Surg*. 2012;55:1581—1586.
15. Couchet G, Pereira B, Carrieres C, et al. Predictive factors for type II endoleaks after treatment of abdominal aortic aneurysm by conventional endovascular aneurysm repair. *Ann Vasc Surg*. 2015;29:1673—1679.
16. Toya N, Kanaoka Y, Ohki T. Secondary interventions following endovascular repair of abdominal aortic aneurysm. *Gen Thorac Cardiovasc Surg*. 2014;62:87—94.