

## Role of Aggressive Aneurysm Sac Embolization Before Endovascular Abdominal Aneurysm Repair in Preventing Type II Endoleak and Sac Expansion

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### ABSTRACT

**Background** This study aimed to evaluate the effect of aggressive embolization of side branches arising from the aneurysmal sac before endovascular aneurysm repair.

**Methods** This retrospective study included 95 patients who underwent endovascular infrarenal abdominal aortic aneurysm repair at Tottori University Hospital between October 2016 and January 2021. Of these, 54 underwent standard endovascular aneurysm repair (conventional group), and 41 underwent coiling of the inferior mesenteric and lumbar arteries before undergoing endovascular aneurysm repair (embolization group). The occurrence of type II endoleak, change in aneurysmal sac diameter, and reintervention rate due to type II endoleak during follow-up were evaluated.

**Results** Compared to the conventional group, the embolization group had a significantly lower incidence of type II endoleak, more frequent aneurysmal sac shrinkage, and lower aneurysmal sac growth related to type II endoleak.

**Conclusion** Our results demonstrated the effectiveness of aggressive aneurysmal sac embolization before endovascular aneurysm repair to prevent type II endoleak and the consequent long-term aneurysmal sac enlargement.

**Key words** abdominal aortic aneurysm; endovascular aneurysm repair; type II endoleak

Endovascular repair of abdominal aortic aneurysms (AAAs) has shown lower perioperative mortality and complication rate than open repair.<sup>1, 2</sup> However, the

long-term reintervention rate after endovascular aneurysm repair (EVAR) is significantly higher than that after open repair.<sup>3</sup> Endoleak, defined as an incomplete exclusion of the aneurysmal sac from circulation, is the most common complication after EVAR and the primary cause of reintervention. Type II endoleak (T2EL) is a retrograde perfusion into the aneurysmal sac from aneurysmal side branches such as the inferior mesenteric arteries (IMAs) and lumbar arteries (LAs).<sup>4</sup> Persistent T2EL leads to significantly higher long-term rates of reintervention, conversion to open repair, and rupture after sac enlargement during follow-up.<sup>5</sup>

T2EL occurs in approximately 10–30% of patients treated by EVAR.<sup>6, 7</sup> Adequate management of T2EL has been widely discussed in the literature, but no definitive solutions have been reported.<sup>8, 9</sup> Treating aneurysmal sac enlargement due to T2EL is challenging.<sup>10</sup> Secondary interventions such as transarterial embolization and endoscopic ligation of the feeding branches, direct sac puncture, aneurysm sac plication, and surgical reconstruction with endograft explantation have been reported; however, no definitive treatment has emerged.<sup>8, 9</sup> These additional procedures might lead to additional medical expenses and increased patient exposure to radiation and contrast agents during follow-up. Therefore, prevention of T2EL may be preferable to treatment.

Several studies have reported on the effect of IMA embolization alone or IMA and LA embolization before or during EVAR on the treatment outcomes<sup>11–13</sup>; however, the success rate of LA embolization in these studies did not exceed 60%.<sup>14</sup> The reason for this low success rate is mainly because LAs are small and twisted, and it's difficult to embolize them completely. In our hospital, since October 2018, experienced interventional radiologists started performing aggressive sac embolization 2 or 3 days before the EVAR procedure to increase the LA embolization success rate.

This study aimed to compare our AAA treatment strategy of EVAR with aggressive aneurysm sac embolization with coils and the traditional EVAR in terms of the T2EL rate and aneurysm sac shrinkage.

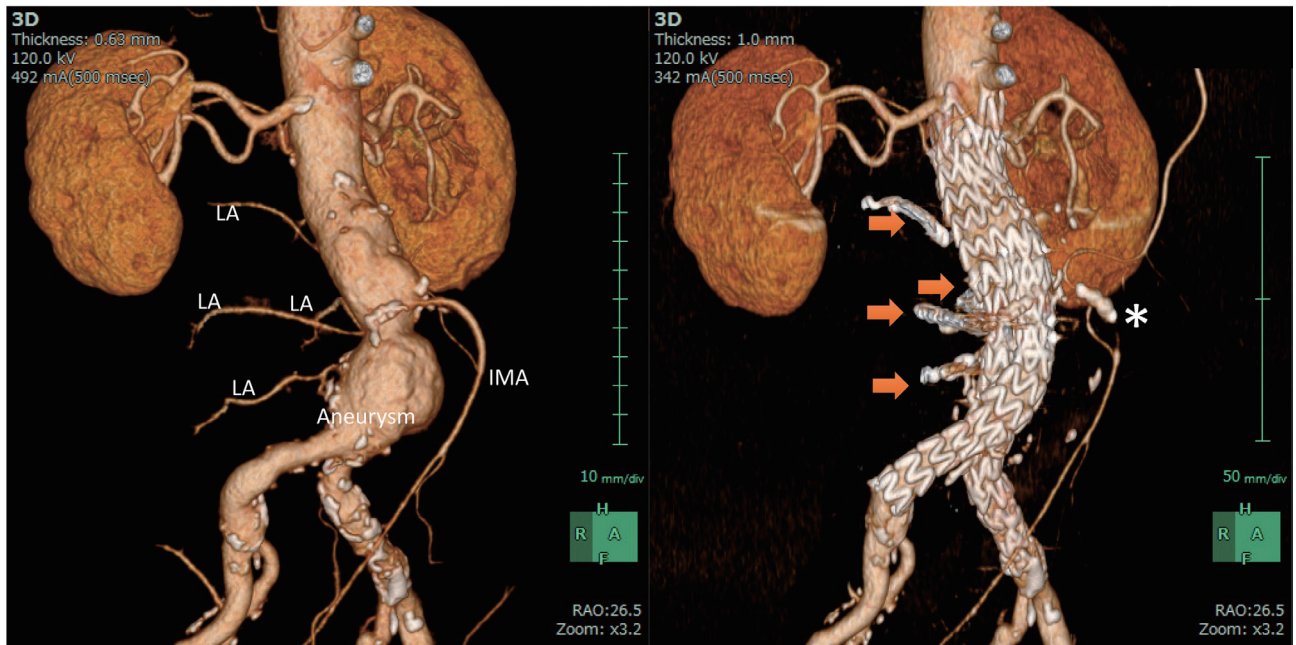
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Abbreviations: AAAs, abdominal aortic aneurysms; BMI, body mass index; CTA, computed tomography angiograms; DOAC, direct oral anticoagulant; EVAR, endovascular aneurysm repair; Gy, gray; IMAs, inferior mesenteric arteries; LAs, lumbar arteries; T2EL, Type II endoleak; VKA, vitamin K agonist



**Fig. 1.** Representative CT angiogram prior and after EVAR with aggressive embolization. Left panel: representative preoperative CT angiogram. IMA and 4 LAs were arising from aneurysm. Right panel: postoperative CT angiogram of the same patient. Both IMA (shown with asterisk) and all LAs (shown with red arrows) were embolized with coils and endograft was placed in the aneurysm. IMA, inferior mesenteric artery; LA, lumbar artery.

## SUBJECTS AND METHODS

### Patients

We retrospectively reviewed the records of 95 consecutive patients who underwent EVAR for infrarenal AAA at our hospital between October 2016 and January 2021. Fifty-four patients underwent standard EVAR between October 2016 and September 2018 (conventional group), and 41 underwent IMA and LA coiling 2 or 3 days before the EVAR procedure between October 2018 and January 2021 (embolization group). The Institutional Review Board of the Faculty of Medicine, Tottori University, approved this study (Registration No. 22A146) and waived the requirement for informed consent due to its retrospective nature. The study has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Patient demographic and preoperative characteristics, outcomes, and follow-up data were retrieved from the medical records, and pre and postoperative computed tomography angiograms (CTA) were reviewed.

### Inclusion and exclusion criteria

We included anatomically suitable patients who underwent EVAR for infrarenal AAA. All commercially available aortobifurcated endografts were included. We excluded patients who underwent EVAR with associated

complex procedures such as chimney, branched, or fenestrated grafts, those who required an urgent or emergent EVAR procedure, and those who could not undergo CTA 6 or 12 months after the procedure for any reason. Patients with aortoiliac and tubular grafts and those who underwent the double-barrel technique procedure were also excluded.

### Aggressive embolization

IMA and LA embolizations were performed in the embolization group by specialized interventional radiologists under local anesthesia 2 or 3 days before the EVAR procedure. We used fiber interlock mechanically detachable coil (Boston Scientific, Natick, MA), C-stopper Coil (Piolax Medical Device, Kanagawa, Japan), Target XL (Stryker Neurovascular, Fremont, CA), AZUR CX18 (Terumo, Tokyo, Japan), DELTAFILL (Cerenovus, Tokyo, Japan), and ED Coil (Kaneka Medics, Kanagawa, Japan). The coils were selected based on operator preferences. Unlike previous studies, we aimed complete embolization of all the side branches of the aneurysmal sac. We tried to embolize all the aneurysm side branches identified by CTA unless they were too small for microcatheter cannulation or the branch ostium was occluded on the aortogram during the procedure. The representative CTA of the embolization group is shown in Fig. 1.

**Table 1 . Patient baseline characteristics**

Variable	Embolization group ( <i>n</i> = 41)	Conventional group ( <i>n</i> = 54)	<i>P</i>
Age, years	77.4 ± 7.7	78.8 ± 7.5	0.388
Sex, male (%)	32 (78.0)	35 (64.8)	0.161
Hypertension, <i>n</i> (%)	34 (82.9)	41 (75.9)	0.407
Hyperlipidemia, <i>n</i> (%)	20 (48.8)	32 (59.3)	0.309
Diabetes, <i>n</i> (%)	2 (4.9)	6 (11.1)	0.279
Coronary artery disease, <i>n</i> (%)	8 (19.5)	10 (18.5)	0.903
Stroke, <i>n</i> (%)	9 (22.0)	12 (22.2)	0.975
Hemodialysis, <i>n</i> (%)	0 (0.0)	3 (5.6)	0.125
COPD, <i>n</i> (%)	11 (26.8)	18 (33.3)	0.495
BMI, kg/m <sup>2</sup>	22.8 ± 2.6	22.1 ± 3.3	0.244
Current smoker, <i>n</i> (%)	4 (9.8)	5 (9.3)	0.935
VKA, <i>n</i> (%)	1 (2.4)	5 (9.3)	0.176
DOAC, <i>n</i> (%)	1 (2.4)	0 (0.0)	0.249
Antiplatelet agents, <i>n</i> (%)	14 (34.1)	23 (42.6)	0.403
Aneurysmal diameter, mm	48.5 ± 9.3	46.9 ± 11.4	0.482
Saccular type, <i>n</i> (%)	7 (17)	7 (13.0)	0.576
Aorto-iliac type, <i>n</i> (%)	9 (22.0)	22 (40.7)	0.053
Patent IMA, <i>n</i> (%)	30 (73.2)	39 (72.2)	0.918
Patent LA, branches/patient	4.9 ± 1.4	4.4 ± 1.9	0.152

BMI, body mass index; DOAC, direct oral anticoagulant; IMA, inferior mesenteric artery; LA, lumbar artery; VKA, vitamin K agonist.

### Endpoints and definitions

The primary endpoint was the occurrence of T2EL during follow-up. The secondary endpoints included maximum aneurysmal diameter change (mm), aneurysmal sac growth, and complications due to side branch embolization.

Follow-up CTA was performed essentially 6 and 12 months postoperatively in all patients and once a year thereafter. Some patients could not get CTA because of poor renal function and/or allergy due to the contrast medium. Thus, follow-up CTA was performed on 39 patients at 6 months and 32 patients at 12 months in the embolization group, and 49 patients at 6 months and 46 patients in the conventional group. The CTA images used to analyze the anatomical data, including endoleak and maximal aneurysmal diameter (mm), were reconstructed at a slice thickness of 2 mm. Aneurysmal sac growth was defined as an increase in the maximum diameter by ≥ 2 mm per year during follow-up.

### Statistical analysis

Numerical data are presented as mean ± standard deviation. The data were analyzed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY).

The unpaired *t*-test and chi-square test were used to compare continuous and categorical variables, respectively. Kaplan–Meier curves and the log-rank test were used to compare the survival rate and rate of freedom from aorta-related and -unrelated events and death. Statistical significance was set at *P* < 0.05.

## RESULTS

### Baseline characteristics

Patient characteristics and anatomical details are shown in Table 1. Follow-up was completed for all included patients. The duration of follow-up in the conventional group was significantly longer than that in the embolization group because these patients underwent EVAR earlier in the study. The baseline parameters were similar in both groups. The mean preoperative aneurysm diameter in the conventional and embolization groups was similar (48.5 ± 9.3 vs. 46.9 ± 11.4 mm; *P* = 0.482). Of the preoperative anatomical characteristics identified by CTA, aortoiliac aneurysms occurred more frequently in the conventional group than in the embolization group, although the difference was statistically insignificant. The groups were also similar in terms of IMA patency and the number of patent LAs.

### Procedural data

Operative variables are presented in Table 2. The mean duration of the embolization procedure was  $141 \pm 45$  minutes. Operation time in the embolization group was significantly shorter than that in the conventional group, mainly because many patients underwent puncture with a vessel closure device rather than a cut-down procedure in recent years. The rate of successful IMA embolization was 90% (27/30). The successful LA embolization was  $3.1 \pm 1.5$  branches per patient and the total successful embolization of the aneurysmal sac was obtained 34 out of 41 patients (82.9%). No differences were found in the endograft types used between the two groups. No complications related either to the embolization procedure or to the EVAR, such as bleeding, bowel ischemia, and access site injury, were noted.

### Incidence of T2EL during follow-up

The incidence of T2EL during follow-up is shown in Table 3. T2EL incidence in the embolization group was significantly lower than that in the conventional group. The sources of T2EL were mostly related to LAs in the conventional (17/18, 95%) and embolization (2/2, 100%) groups.

### Changes in the sac diameter 6 and 12 months after the procedure

The sac shrinkage 6 and 12 months after the EVAR procedure in the embolization group ( $-2.6$  and  $-4.5$  mm, respectively, Table 3) was significantly greater than that in the conventional group ( $-0.6$  and  $-1.1$  mm, respectively;  $P < 0.05$ ). On the other hand, the cases with sac enlargement of over 2 mm were seen in both embolization and conventional groups during follow up. That was 1/39, 2.6% and 8/49, 16.3% at 6 months and 3/32, 9.4% and 11/46, 23.9% at 12 months postoperatively in the embolization and conventional group, respectively (Table 4).

### DISCUSSION

This study investigated the occurrence of T2EL after EVAR with or without aggressive aneurysm sac embolization. We showed that aggressive aneurysm sac embolization before the EVAR procedure was associated with a significant reduction in the rate of T2EL and increased aneurysmal sac diameter shrinkage.

T2EL management remains controversial. Short-term outcome analyses suggested that T2EL could spontaneously resolve; therefore, treatment was unnecessary in such cases.<sup>15, 16</sup> Conversely, T2EL was reported to correlate with an increased long-term risk of

**Table 2 . Operative Variables**

Variables	Embolization group ( <i>n</i> = 41)	Conventional group ( <i>n</i> = 54)	<i>P</i>
<b>Embolization before EVAR</b>			
Procedure time, min	$141 \pm 45$	--	
Fluoroscopy time, min	$65 \pm 24$	--	
Contrast medium (Iopamidol 370 mg /mL), mL	$77.6 \pm 26$	--	
Radiation exposure dose, Gy	$1.41 \pm 0.8$	--	
Successful IMA embolization/patent IMA	27 / 30	9 / 39	
Successful LA embolization, branches/patient	$3.1 \pm 1.5$	--	
Total successful embolization, <i>n</i> (%)	34 (82.9)	--	
Complications related to procedure, <i>n</i> (%)	0 (0.0)		
<b>EVAR</b>			
Operation time, min	$96 \pm 25$	$127 \pm 59$	0.003
Type of endograft			0.674
Gore, <i>n</i> (%)	17 (41.5)	24 (44.4)	
Medtronic, Endurant, <i>n</i> (%)	19 (46.3)	26 (48.1)	
Endurant, AFX, <i>n</i> (%)	4 (9.8)	4 (7.4)	
Cook, Zenith, <i>n</i> (%)	0 (0.0)	0 (0.0)	
Lombard Medical, Aorfix, <i>n</i> (%)	1 (2.4)	0 (0.0)	
Complications related to procedure, <i>n</i> (%)	0 (0.0)	0 (0.0)	

EVAR, endovascular aneurysm repair; Gy, gray; IMA, inferior mesenteric artery; LA, lumbar artery.



**Table 3 . Incidence of type 2 endoleak by discharge and changes of the aneurysmal sac diameter during follow up**

	Embolization group	Conventional group	<i>P</i>
T2EL incidence, <i>n</i> (%)	2 (4.9%)	18 (33.3%)	0.001
Endoleak source			
LA, <i>n</i>	2	16	
IMA, <i>n</i>	0	1	
LA and IMA, <i>n</i>	0	1	
Changes of the aneurysmal sac diameter			
At 6 month, mm	-2.6 ± 4.1	-0.6 ± 3.8	0.031
At 12 month, mm	-4.5 ± 5.9	-1.1 ± 4.5	0.014

Plus-minus values are mean ± SD; IMA, inferior mesenteric artery; LA, lubar artery; T2EL, type 2 endoleak.

**Table 4 . Cases with sac enlargement > 2.0 mm during follow-up**

	Embolization group	Conventional group	<i>P</i>
At 6 months, <i>n</i> (%)	1/39 (2.6)	8/49 (16.3)	0.092
At 12 months, <i>n</i> (%)	3/32 (9.4)	11/46 (23.9)	0.169

adverse events, including sac growth and rupture.<sup>5, 7, 17</sup> Several endovascular attempts have been made to avoid aneurysmal sac growth due to T2EL after EVAR, including embolization of the branch vessels causing the T2EL. However, the therapeutic outcomes of these attempts were limited.<sup>18, 19</sup> Thus, aneurysmal sac growth due to T2EL appears to be a treatment failure difficult to resolve by an endovascular approach.

In recent years, the concept of preventing T2EL rather than treating it has been developed.<sup>20</sup> Selective embolization of vessels branching from the aneurysmal sac before EVAR was thought to be a possible T2EL preventive method. Several studies have examined whether embolization of the IMA, the main patent vessel to cause T2EL, before EVAR could prevent T2EL.<sup>12, 20–23</sup> In these studies, the T2EL and secondary intervention rates following IMA embolization were significantly lower, and the aneurysmal sac shrinkage was significantly greater than in the non-embolization group. Furthermore, IMA embolization was performed with a high technical success rate and extremely low complication rate in these reports.<sup>12</sup>

Conversely, embolization of the LAs, other patent vessels arising from the aneurysmal sac, was thought to be a more powerful method for preventing T2EL. Several studies reported that embolization of both IMAs and LAs could achieve a lower T2EL rate than IMA embolization alone.<sup>14, 24, 25</sup> However, embolization of LAs is technically difficult, cannot always be performed, and has a success rate of approximately 60%.<sup>14, 24</sup> LAs

are small, tortuous, and perpendicular to the aneurysm. Therefore, catheter cannulation and targeted LA embolization is more challenging and complicated, and takes longer to perform than IMA embolization.

This study attempted to clarify the effect of aggressive aneurysm embolization that included, as much as possible, embolization of IMA and LAs. Because the duration of the aggressive aneurysm embolization procedure was quite long (mean, 141 min), it was performed under local anesthesia in the catheterization laboratory before EVAR. By performing the embolization procedure on a separate day, the interventional radiologists can spend as much procedure time as necessary. This strategy was not reported previously and that is why we call it “aggressive embolization”. This could help reduce the time spent in the operating room and the duration of general anesthesia for EVAR procedure. The total successful embolization rate was improved to 82.9% by this strategy, compared with around 60% of previous reports. Also, the strategy reduced the T2EL rate from 33.3% in the conventional group to 4.9%. A randomized controlled trial of EVAR with IMA embolization found that T2EL occurred in 24.5% of the cases treated using IMA embolization.<sup>12</sup> Compared to such previous reports, the aggressive embolization that included LAs showed a marked reduction in T2EL occurrence. Furthermore, the aneurysmal sac shrinkage in the embolization group was significantly greater than that in the conventional group. However, the degree of sac shrinkage and the percentage of cases with sac

enlargement were similar to those reported in a previous study of IMA embolization alone.<sup>12</sup> This discrepancy can be attributed to the relatively short observation period. A long follow-up could clarify the effect T2EL reduction has on aneurysmal sac shrinkage.

The downside of aggressive embolization is longer hospital stay, higher cost, and increased irradiation for the patients. In this study, 9 patients in the conventional group underwent IMA embolization at the time of EVAR. But, the operative times for these 9 patients were similar to the other patients in the conventional group. Because complete aneurysmal sac embolization including LAs takes considerable time, this procedure would be most suitable for younger patients, that is in their 60's or early 70's, who can look forward to a longer life expectancy.

An aneurysm sac enlargement by over 2 mm was observed in approximately 10% of patients in the embolization group despite having no apparent endoleaks. This result suggests that some patients showed aneurysm sac enlargement despite having no type 2 endoleaks. A long-term follow-up is necessary to clarify the fate of the aneurysm sac in such cases.

In conclusion, our findings revealed that aggressive aneurysm sac embolization including IMAs and LAs before EVAR was associated with a marked reduction in the 1-year rate of T2EL. Although the procedure takes substantial time and increases medical expenses, it could benefit patients with AAA, especially those in whom future laparotomy should be avoided and relatively young patients with hostile abdomen or serious comorbidities.

## LIMITATIONS

This single-center, retrospective, non-randomized study involved a small cohort of patients. The study was limited by the follow-up period when evaluating changes in aneurysmal sac diameter. Moreover, the follow-up was limited to T2EL evaluation, which may resolve spontaneously or appear late during follow-up.

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*The authors declare no conflict of interest.*

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