■ **Original Research** ■

Safety and Efficacy of Embolization Using N-Butyl Cyanoacrylate via a Percutaneous Direct Approach for Endoleaks after Abdominal/Thoracic Endovascular Aortic Repair

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──────── **Abstract** ────────

Purpose: To elucidate the safety and efficacy of embolization using N-butyl cyanoacrylate (NBCA) for endoleaks after abdominal/thoracic endovascular aortic repair (EVAR/TEVAR) via a direct percutaneous approach versus a transarterial approach.

Materials and Methods: The retrospective design of the study was approved by the institutional ethics committee, and the requirement for informed written consent was waived. Sixteen patients underwent embolization for endoleaks after EVAR/TEVAR, which was diagnosed as type II, from March 2010 to December 2013 at our institution. The number of embolization sessions was 21. A direct percutaneous approach was used in 10 sessions, and a transarterial approach was used in 11 sessions. There were 11 and 15 embolic sites for the two approaches, respectively. The procedure time, amount of contrast media used, therapeutic effect, and complications were evaluated.

Results: The mean procedure time (per embolic site) was 100 min (53-170) in the direct percutaneous approach, which was significantly shorter than the 191 min (76-275) in the transarterial approach. The mean amount of contrast media used during the procedure (per embolic site) was 12.8 ml (3-25) by the direct percutaneous approach, which was significantly lesser than the 71.8 ml (30-180) in the transarterial approach. Local control of the embolic site and interval increase in the size of aneurysm after embolization were not significantly different between the two approaches. In one case each, mesenteric hematoma and migration of the embolic agent occurred with a direct percutaneous approach, and a small arterial injury occurred with the transarterial approach; aneurysmal rupture/perianeurysmal hematoma and neurological dysfunction were not observed.

Conclusion: A direct percutaneous approach is a feasible procedure for embolization of endoleaks after EVAR/TEVAR.

Key words: EVAR, TEVAR, endoleak, embolization, NBCA, percutaneous direct approach

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Introduction

Endovascular abdominal/thoracic aortic aneurysm repair (EVAR/TEVAR) is a less invasive technique than open aneurysm repair and has lower operative morbidity and mortality; several studies have confirmed that this approach is a suitable alternative [1-3]. An endoleak, defined as a persis-

Table 1. Patient characteristics

Number	16
Age	64 – 93 years old (median: 78)
Gender	12 males / 4 females
eGFR*	22-67 ml/min/1.73 mm^2 (median: 42)
Prior procedure	EVAR**: 10 / TEVAR***: 6

*eGFR: estimated glomerular filtration rate, **EVAR: endovascular aortic repair,

***TEVAR: thoracic endovascular aortic repair

tent blood flow outside the endograft, but within the aneurysmal sac, is the most common complication of EVAR/ TEVAR. Endoleaks are classified as types I-V [4, 5]: type I is leak at the attachment site, type II is a retrograde flow from the aortic or iliac branch into the aneurysmal sac, type III is graft failure or leak at the junction, type IV is porosity of the graft wall, and type V is endotension. A type II endoleak is the most common, accounting for 40% of all endoleaks [6]. The causes of type II endoleak are retrograde flow of the inferior mesenteric artery, lumbar artery, intercostal artery, or subclavian artery to the aneurysmal sac outside the endograft, in conjunction with peripheral anastomosis with the superior mesenteric artery, iliac branches such as the iliolumbar artery, or branches of the subclavian artery. Indications of treatment for type II endoleaks are persistent flow into the aneurysmal sac and interval increase in the size of the aneurysmal sac. A less-invasive embolization is first selected to treat a type II endoleak. There are two methods to access the aneurysmal sac for the embolic procedure as follows: a direct percutaneous approach and a transarterial approach. Numerous studies on the use of embolization for a type II endoleak by a direct percutaneous or transarterial approach have previously been published [7-15], but only three studies have offered a detailed comparison of the efficacy and safety of the embolic procedure between a direct percutaneous approach and a transarterial approach [14-16]. To our knowledge, there has been no report regarding the procedure time or the volume of contrast material in type II endoleak treatment. Thus, the purpose of this retrospective study was to elucidate the safety and efficacy of embolization for endoleaks after EVAR/TEVAR by a direct percutaneous approach, compared with a transarterial approach, with a particular focus on the procedure time and the volume of contrast material.

Materials and Methods

Subjects

Sixteen patients who underwent embolization for an endoleak after EVAR/TEVAR between March 2010 and December 2013 at our institution were enrolled. They were all diagnosed with a type II endoleak by contrast-enhanced CT or angiography, and the aneurysmal sac was increased in size more than 5 mm in the 6 months after EVAR/EVAR. There were 12 males and 4 females, with a median age of 78 years (range: 64 to 93 years) and median estimated glomerular filtration rate (eGFR) of 42 ml/min/1.73 mm2 (range: 22-67 ml/min/1.73 mm2). The prior procedures were EVAR in 10 cases and TEVAR in 6 cases. The embolic procedure, i.e., a direct percutaneous or transarterial approach, was selected in reference to contrast-enhanced CT and prior angiographic findings, such as tortuosity of the feeding/ drainage vessels and the availability of a percutaneous puncture route to the aneurysmal sac. In cases where access to the aneurysmal sac seemed to be possible by a transarterial approach, we selected a transarterial approach; where such access was not possible, we selected a direct percutaneous approach. A summary of the patient characteristics is shown in **Table 1**. A total of 21 embolic sessions were used for the 16 patients. A direct percutaneous approach was adopted in 10 sessions, and a transarterial approach was adopted in 11 sessions. The total number of embolic sites was 11 for the direct percutaneous approach and 15 for the transarterial approach. The feeding/drainage vessels were the inferior mesenteric artery for 8 embolic sites, the lumbar artery for 9 embolic sites, the internal iliac arterial branch for 3 embolic sites, the subclavian artery for 3 embolic sites, the intercostal artery for 2 embolic sites, and bronchial artery for 1 embolic site. There was only one case that required an embolic procedure by a direct percutaneous approach after failure by

Table 2. Summary of the embolization

	Direct	Transarterial
Session	**10**	**11**
	EVAR*: 7	**EVAR: 8**
	TEVAR**: 3	**TEVAR: 3**
Embolic site	**11**	**15**
Feeding/drainage vessel	**IMA***: 2, lumbar: 5, Internal iliac: 1, intercostal: 2, bronchial: 1**	**IMA: 6, lumbar: 4, internal iliac: 2, subclavian: 3,**
Embolic agent	**NBCA****: 10, NBCA + coil : 1**	**NBCA: 7, Coil : 5, NBCA + coil : 2, Not used: 1**

*EVAR: endovascular aortic repair, **TEVAR: thoracic endovascular aortic repair,

***IMA: inferior mesenteric artery, ****NBCA: N-butyl cyanoacrylate

the transarterial approach. A summary of the embolic procedures is shown in **Table 2**.

Embolic procedures

Direct percutaneous approach: Unenhanced CT was obtained with the patient in a suitable position, and a puncture route was planned in order to reach the aneurysmal sac near the orifice of the feeding/drainage vessel while avoiding major organs. Under local anesthesia, an 18G PTCD needle (Hanako Medical, Saitama, Japan) was advanced to the aneurysmal sac by CT-guidance. Digital subtraction angiography (DSA; maximum 10 ml of iopamidol (Iopamiron 300; Bayer, Osaka) at a ratio of 1-2 ml/sec) and CT angiography (CTA; maximum 10 ml of iopamidol (Iopamiron 150; Bayer, Osaka) at a ratio of 1-2 ml/sec) were performed to assess the distribution of contrast media and confirm that any vessels that should not be embolized, such as the anterior spinal artery, were not visualized. We embolized the aneurysmal sac and proximal side of the feeding/drainage vessel under fluoroscopy using a mixture of N-butyl cyanoacrylate (NBCA; Histoacryl; B. Braun, Aesculap, Germany)-lipiodol (Guerbet Japan, Tokyo) at a ratio of 1:1-4. The endpoint of the embolization was distribution of the embolic mixtures to the feeding/drainage vessel or use of the maximum allowable volume of mixture (10 ml). Tract embolization was added while removing the PTCD needle. Immediately after embolization, an unenhanced CT was obtained to assess the distribution of NBCA-lipiodol. *Transarterial approach:* Under local anesthesia, the femoral or brachial artery was punctured, and a 4-5 F sheath (Medikit, Tokyo) was inserted. DSA from the inferior mesenteric artery, internal iliac artery, or subclavian artery was obtained to assess the hemodynamics of the endoleak. For selective catheterization to the aneurysmal sac via thin and tortuous vessels, we used a double or triple co-axial system. DSA and CTA were obtained as described above, and embolization of the aneurysmal sac and proximal side of the feeding/drainage vessels was performed with an NBCA-lipiodol mixture and/or metallic coil (VortX and IDC; Boston Scientific, Boston, MA). Immediately after embolization, DSA was obtained to confirm the disappearance of the aneurysmal flow, and unenhanced CT was obtained to assess the distribution of the NBCA-lipiodol.

Evaluation

The procedure time of embolization for endoleaks was defined as the time from the patient entering to the patient exiting the operation room. The procedure time of embolization by the direct percutaneous approach was compared with that by the transarterial approach. The amount of contrast media (300 mgI/l iopamidol solution) used during the embolic procedure by the direct percutaneous approach was also compared with that by the transarterial approach. Technical success was defined as reaching the endoleak cavity and achieving local control of the embolic site after embolization. To evaluate technical success, we assessed the distribution of the NBCA-lipiodol mixture to the aneurysmal sac and feeding/drainage vessel by unenhanced CT immediately after embolization, and adequate deposition of NBCA-lipiodol mixture to the aneurysmal sac was regarded as a technically successful embolization. The size of the aneurysmal sac after embolization could be followed by contrast-enhanced or unenhanced CT using 64-row multidetector CT (Aquilion; Canon Medical Systems, Otawara, Japan) with 2-mm reconstruction for more than two months in seven direct percutaneous and seven transarterial embolic procedures. More than 5-mm enlargement of the aneurysmal sac along the short axis was defined as the interval of increase in the size of the aneurysmal sac. Student's t-tests and Chi-square tests were used for the statistical analysis. A P value of <

Table 3. Procedure time of embolization for endoleaks by the direct and transarterial approaches

		Direct	Transarterial	t-test
Procedure time (min) (per embolic site)	EVAR*	85±23 (53-120)	177±83 (76-275)	p<0.05
	TEVAR**	136±33 (105-170)	225±52 (167-268)	p<0.05
	Total	100±35 (53-170)	191±77 (76-275)	p<0.05

*EVAR: endovascular aortic repair, **TEVAR: thoracic endovascular aortic repair

Table 4. Amount of contrast media used for embolization of endoleaks by the direct and transarterial approaches

		Direct	Transarterial	t-test
Amount of contrast media (ml) (per embolic site)	EVAR*	12.7±6.8 (5-25)	74.8±39.8 (30-130)	p<0.05
	TEVAR**	13.0±9.2 (3-21)	63.7±29.2 (30-82)	p<0.05
	Total	12.8±7.1 (3-25)	71.8±36.1 (30-130)	p<0.05

*EVAR: endovascular aortic repair, **TEVAR: thoracic endovascular aortic repair

Table 5. Technical success of embolization for endoleaks by the direct and transarterial approaches

	Direct (n=11)	Transarterial (n=15)	Chi-square test
Success (n)	10	13	p=0.74 (N.S.)

*N.S.: not significant

0.05 indicated a statistically significant difference. Complications during the procedures were also evaluated.

Results

The mean procedure time of embolization for an endoleak was 100 min (range: 53-170 min) per embolic site by a direct approach, which was significantly shorter than the mean of 191 min (76-275 min) by a transarterial approach. A similar tendency was observed when the analysis was restricted to cases of repair after EVAR or TEVAR (**Table 3**). The mean amount of contrast media used for the embolic procedure was 12.8 ml (3-25 ml) per embolic site by a direct approach, which was significantly less than the mean of 71.8 ml (30-180 ml) by a transarterial approach. The mean amount of contrast media was also similar between patients
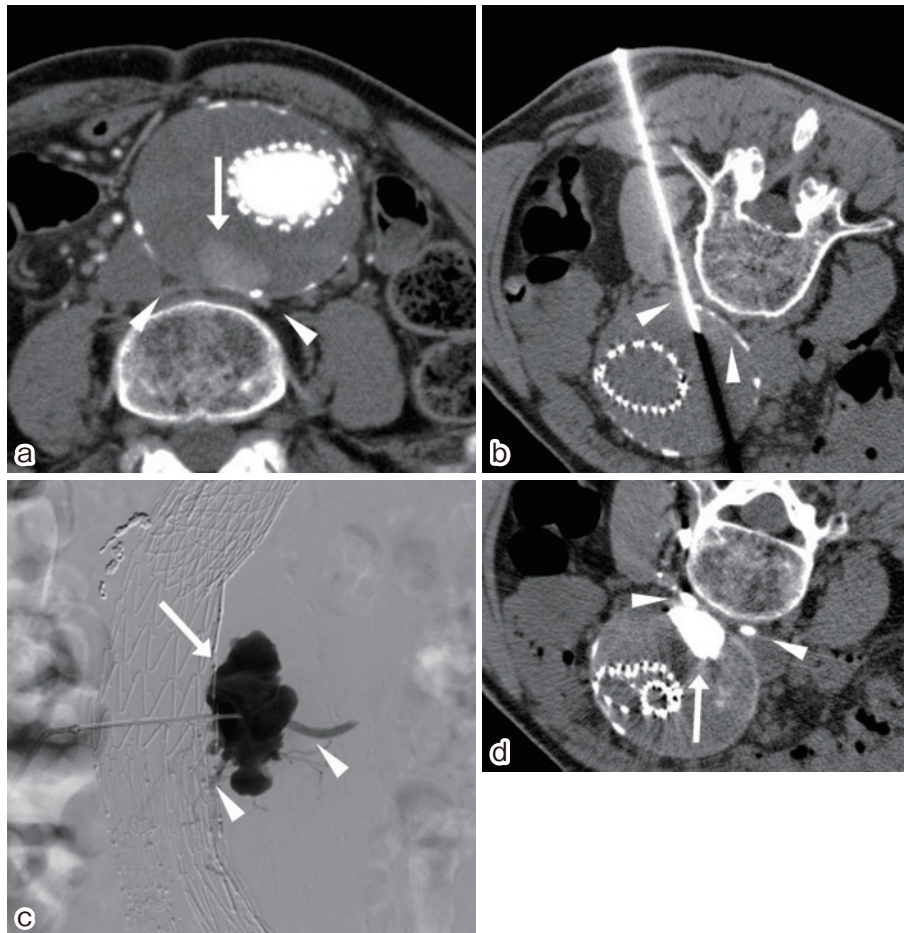
Figure 1. Direct percutaneous approach and embolization with NBCA for a type II endoleak from the lumbar artery in a 76-year-old man. (a) Contrast-enhanced CT shows a type II endoleak in the aneurysmal sac (arrow). The feeding/drainage vessels are the bilateral 4th lumbar arteries (arrowheads). (b) The aneurysmal sac near the orifice of the bilateral 4th lumbar artery (arrowheads) is punctured directly from the left back region using an 18 G PTCD needle under CT guidance. (c) After DSA/CTA to assess the distribution of contrast media to the aneurysmal sac (arrow) and bilateral 4th lumbar arteries (arrowhead), embolization using 8 ml of an NBCA-lipiodol mixture at a ratio of 1:1 under fluoroscopic guidance is performed. (d) Unenhanced CT immediately after embolization shows NBCA-lipiodol deposition at the aneurysmal sac (arrow) and at the proximal side of the bilateral 4th lumbar arteries (arrowheads). The procedure time was 80 min, and the amount of contrast media used for the embolic procedure was 5 ml. There was no increase in the size of the aneurysmal sac by follow-up CT after embolization. Complications were not observed either during or after embolization.

undergoing repair after EVAR and those undergoing repair after TEVAR (**Table 4**).With regard to the technical success of the embolic procedure (**Table 5**), 10 of 11 embolic sites were reached and embolized by the direct approach (**Figure 1**), and 13 of 15 embolic sites were reached and embolized by the transarterial approach (**Figure 2**). One site was reached but was embolized unsuccessfully (inadequate lipiodol-deposition) by each of the direct and transarterial approaches, and 1 site could not be reached or embolized by the transarterial approach. There were no significant differences in technical success between the procedures. Each of the 7 embolic procedures by a direct or transarterial approach could be successfully followed by CT after embolization for more than 2 months. The aneurysmal sac was in-

creased in size by 5 mm along the short axis in each of 2 cases. No statistically significant changes were observed in either of the approaches (**Table 6**). Complications during the embolic procedure by the direct percutaneous approach consisted of a mesenteric hematoma caused by arterial injury of the mesenteric branch in one case and migration of embolic agent into the aortic lumen in one case with a type I endoleak. The former was treated conservatively, but the latter was treated with an additional stent placement. In the transarterial approach, a small arterial injury of the iliolumbar artery was observed in one case, which was conservatively treated. Neither aneurysmal rupture/perianeurysmal hematoma nor neurological dysfunction was observed.
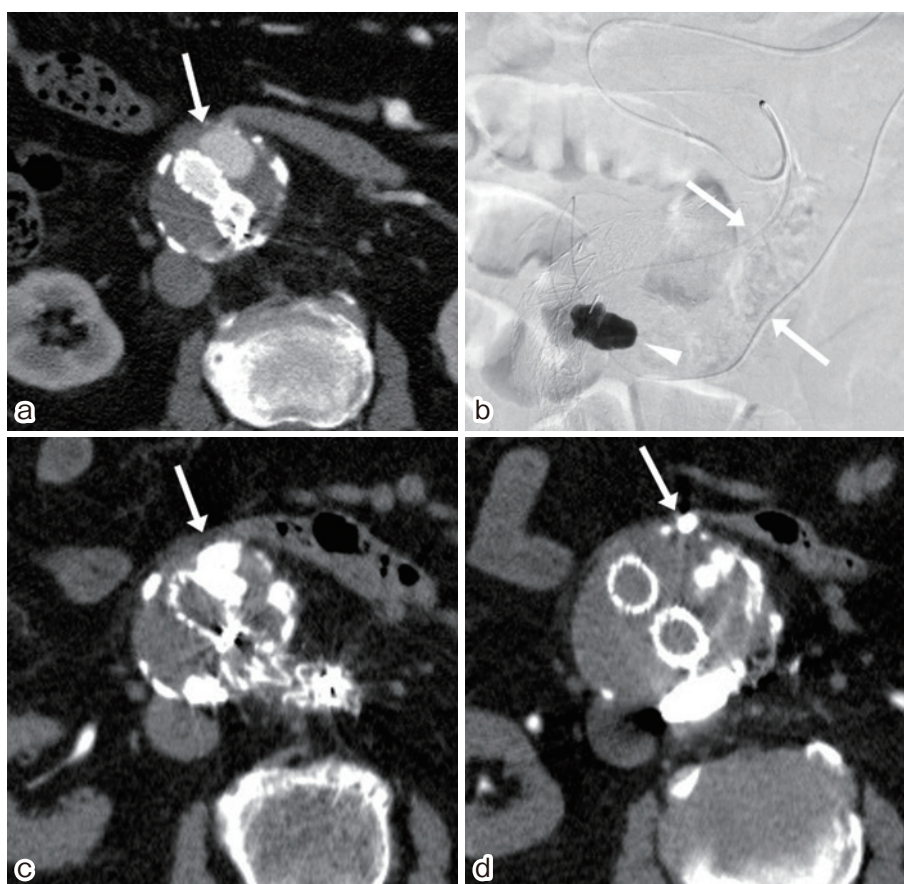
Figure 2. Transarterial approach and embolization with NBCA for a type II endoleak from the inferior mesenteric and lumbar arteries in an 80-year-old man. (a) Contrast-enhanced CT shows a type II endoleak from the inferior mesenteric artery (arrow). (b) The femoral artery is punctured, and selective catheterization of the aneurysmal sac via Riolan arcade is successful using co-axial systems (arrow); embolization is performed successfully using 4 ml of NBCA-lipiodol mixture at a ratio of 1:3 (arrowhead). (c) (d) Unenhanced CT immediately after embolization shows NBCA-lipiodol deposition at the aneurysmal sac (c, arrow) and proximal side of the inferior mesenteric artery (d, arrow). An endoleak from the left 4th lumbar artery is also embolized by the transarterial approach via the left deep circumflex iliac artery. The time required for these two embolic procedures was 249 min (124.5 min/embolic site), and the amount of contrast media used for the embolization was 80 ml (40 ml/embolic site). There was no increase in the size of the aneurysmal sac by follow-up CT after embolization. No complications were observed during or after embolization.

Discussion

In this study, we evaluated the procedure time, the amount of contrast media used during the procedure, the therapeutic effect, and the complications of embolization for endoleaks after EVAR/TEVAR by a direct percutaneous versus a transarterial approach [2]. There have been only three articles that have compared the therapeutic effects and complications of embolization by the two approaches [14-16].

The procedure time of embolization by a direct percutaneous approach was significantly shorter than that by a transarterial approach. A study by Yang et al. similarly reported significantly shorter fluoroscopic and procedural times for a direct percutaneous approach compared with a transarterial approach [16]. Our results support their findings. In the case

of a direct percutaneous approach, we should directly puncture the aneurysmal sac by CT or US guidance, carefully avoiding any major vessels or organs. However, the access route is simple, linear, and permits easy access to the aneurysmal sac (**Figure 3**). On the other hand, when using a transarterial approach, the access route runs along feeding/drainage vessels that are peripherally anastomosed with the superior mesenteric artery, iliolumbar artery, or intercostal artery. The anastomosis, which is obscure in the normal state and apparent after EVAR/TEVAR, is very thin and tortuous. Thus, we must attempt catheterization via a thin and tortuous route using a double or triple coaxial system. A high level of technical capability and a large amount of time are required to complete this procedure. In one case in the present study, we were not able to access the aneurysmal sac via a superior-inferior mesenteric route by the transarte-

Table 6. **Clinical course after embolization for endoleaks by the direct and transarterial approaches**

	Direct (n=7)	Transarterial (n=7)	Chi-square test
Duration (day)	65-743 (median: 560)	67-1344 (median: 511)	
Increase in size of aneurysmal sac (n)	2/7	2/7	P=1 (N.S.*)

*N.S.: not significant

rial approach despite working for more than 3 hours. However, during an additional session using the direct percutaneous approach on a later date, we succeeded in accessing the aneurysmal sac and embolization in 1.5 hours.

In addition, the amount of contrast media required during the embolic procedure by the direct percutaneous approach was significantly smaller than that required by the transarterial approach. When attempting to access the aneurysmal sac by the direct percutaneous approach, we were able to recognize the linear access route by image guidance without contrast media. Contrast media was only used to confirm that the aneurysmal sac had been reached and to confirm its distribution to the aneurysmal sac and feeding/drainage vessels. On the other hand, the access route by a transarterial approach is long and tortuous. Numerous DSA using contrast media must be obtained in order to ascertain the relationship between the catheter tip and the tortuous access route, which results in the administration of a large amount of contrast media. Aortic aneurysm is mainly caused by arteriosclerotic change of vessels, and patients with aortic aneurysm often also have renal dysfunction due to renal arterial sclerosis. In this study, the mean eGFR of patients was 42 (ml/min/1.73 mm2), which was clearly lower than the normal value. Therefore, minimizing the amount of contrast media during the procedure would be preferable in such patients.

To evaluate the therapeutic effects of the embolization, we investigated the local control of the embolic site and the interval change in size of the aneurysm after embolization by the two approaches. There were no significant differences in local control of the embolic site or interval change in the aneurysm size between the two approaches in this study. Several previous studies have examined the differences in the therapeutic effects of embolization for type II endoleaks between a direct percutaneous and a transarterial approach [7-17]. Although numerous differences preclude these reports being directly compared, the results do collectively suggest that local control of the embolic site is better by a direct percutaneous approach than a transarterial approach. A study conducted by Baum et al. compared the efficacy of

the two approaches and reported the ineffectiveness of the transarterial approach [14]. However, in that study, only a single vessel was embolized by a transarterial approach without aneurysmal sac embolization. In most of the present cases involving a transarterial approach, both the aneurysmal sac and vessels were embolized, just as by a direct percutaneous approach, with an NBCA-lipiodol mixture and/or metallic coil. We consider that the therapeutic effects of the embolization may not depend on the approach used but rather on other factors, such as the embolic sites.

There were some complications caused by the direct percutaneous approach in our series, but they were not associated with puncture of the aneurysmal sac. A mesenteric hematoma by unexpected injury of a small arterial branch while accessing the aneurysmal sac was observed and was treated conservatively. In previous reports, there were no severe complications caused by a "translumbar" approach [12-16, 18]. A "transabdominal" approach, as well as a translumbar approach, were used for the direct percutaneous approach in our study. Care must be taken to avoid injury of the major vessels in these cases. In one case treated with a direct percutaneous approach, the NBCA-lipiodol suspension overflowed the sac and poured into the aortic lumen. Retrospective review of DSA and CTA before embolization showed that the contrast media ran from the aneurysmal sac into the aortic lumen, suggesting not a type II but rather a type I or III endoleak. This patient was later treated with an additional stent placement. Strictly speaking, this case should have been excluded from our study population. Careful evaluation is required to ascertain the distribution of contrast media before embolization in order to avoid migration of the embolic agent. In our study, there was no neurological dysfunction in the patients treated with a direct percutaneous approach. We prepared a high concentration of NBCA admixed with lipiodol at a ratio of 1:1-4 for embolization at the proximal side of feeding/drainage vessels, which may have preserved the peripheral branches and prevented organ ischemia and neurological dysfunction.

This study had some limitations that should be men-

Figure 3. Percutaneous direct approach and embolization with NBCA for a type II endoleak from the intercostal artery in a 79-year-old woman. (a) Contrast-enhanced CT shows a type II endoleak (arrow) from the intercostal artery. (b) The aneurysmal sac near the orifice of the left intercostal artery is punctured directly from the left back using an 18 G PTCD needle (arrow) under CT guidance. (c) Embolization is performed successfully using 4 ml of NBCA-lipiodol mixture at a ratio of 1: 4 (arrow). (d) (e) Unenhanced CT immediately after embolization shows NBCA-lipiodol deposition at the aneurysmal sac (d, arrow) and at the proximal side of the right inter costal artery (e, arrow). The time required for the embolic procedures was 105 min, and the amount of contrast media used for the embolization was 3 ml. There was no increase in the size of the aneurysmal sac on follow-up CT after embolization. No complications were observed during or after embolization.

tioned. First, it was a retrospective study, and there were no obvious definitive criteria for the selection of the approach method. At the beginning of this study period, we first selected the cases for the transarterial approach. After we gradually became more familiar with the percutaneous approach, we tried to employ the direct approach because of its easy access to the aneurysmal sac. This could have caused a treatment selection bias. In the future, a prospective study would be helpful in overcoming this issue. Second, the sample size was very small, and thus, we could not conclude that the direct percutaneous approach was equivalent in efficacy to the transarterial approach. Third, the observation period after embolization was not sufficient. In many cases of type II endoleaks after EVAR/TEVAR, the aneurysmal sac increases in size over time. A further follow-up might reveal that the size of the aneurysmal sac had increased in additional cases.

In conclusion, endoleaks after EVAR/TEVAR may be embolized using a smaller amount of contrast media and a shorter treatment time by a direct percutaneous approach than by a transarterial approach. The therapeutic effect of the direct percutaneous approach was acceptable. Obviously, care must be taken to avoid complications such as hematoma along the puncture route or migration of embolic agents. However, we conclude that the direct percutaneous approach is a feasible procedure for embolization of endoleaks after EVAR/TEVAR, especially in patients with renal dysfunction.

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