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Transarterial embolization of type 2 endoleak using coils and N-butyl cyanoacrylate: The importance of treating the nidus and sac branches

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ABSTRACT

Background: Transarterial embolization (TAE) of the nidus and branches prevents aneurysm sac growth due to type 2 endoleaks (T2EL). Embolization materials include coils and liquid embolic substances such as N-butyl-2-cyanoacrylate (NBCA) glue, a type of liquid embolic glue. However, when the nidus is characterized by heterogeneous perigraft opacity on computed tomography imaging with an ill-defined boundary within the sac, although reaching the nidus is possible, thoroughly packing it with embolic agents may prove challenging, sometimes leading to the alternative of embolizing the associated branches. This approach involves embolizing the branches close to the nidus and not distal from it.

Objectives: Therefore, we aim to evaluate the efficacy of TAE for the endoleak nidus and its associated branches versus embolizing its associated branches alone directly connected to the nidus in preventing aneurysm sac enlargement after T2EL, comparing mid-term follow-up results.

Material and Methods: In a single-center retrospective cohort study, we reviewed consecutive 59 patients who underwent TAE for T2EL from September 2017 to August 2022. After excluding cases with <6 months follow-up or without abdominal aortic aneurysm, 40 patients were included in the analysis. Initial treatment for all patients included attempts at direct embolization of the endoleak nidus and side branches using coils and NBCA glue. Even if the nidus was reached, if embolization of the nidus proved difficult, the directly connected branches were embolized instead. Data were analyzed using the Kaplan–Meier curve for estimating sac enlargement freedom, with the primary outcome being aneurysm sac diameter change post-T2EL embolization.

Results: No visible endoleak nidus was detected in any patient after TAE. Of all patients (n = 40), 60% (n = 24) underwent embolization through direct cannulation to the nidus. Direct TAE involving the nidus and main branches with coils, supplemented with NBCA glue, considerably hindered sac enlargement (P < 0.0001). Of 14 patients with sac enlargement, 72% (10 patients) had unsuccessful direct TAE, resulting in a significant association (P = 0.006). On the other hand, 77% (20 of 26 patients) without sac enlargement experienced successful direct TAE. Three patients displayed sac enlargement even after successful direct TAE using only NBCA glue (P = 0.04).

Conclusion: Direct TAE of the endoleak nidus, using coils and supplemented with NBCA glue as necessary, is effective in preventing sac enlargement after T2EL embolization.

Keywords: Coils, Embolization, N-butyl-2-cyanoacrylate glue, Type 2 endoleak

INTRODUCTION

Endovascular abdominal aortic aneurysm repair ‘endovascular abdominal (EVAR) has gained global popularity as a preferred treatment option due to its lower perioperative mortality and complications than those of surgery.[1-3] However, the most prevalent post-EVAR complication is known as type 2 endoleak (T2EL), occurring in 8–44% of patients following EVAR.[4-9] Although T2EL is generally considered a benign complication, it carries a potential risk of sac expansion and rupture.[8,10,11] The natural history and treatment of T2EL remain subject to ongoing debate.[12] Typically, T2EL is typically managed conservatively, as many cases resolve spontaneously.[8,13,14] Various methods of embolizing T2EL have been documented.[15] While transarterial embolization (TAE) is a minimally invasive option, systematic reviews and meta-analyses indicate that its effectiveness is variable and not consistently superior to conservative treatments.[16-18]

However, the previous studies have yielded inconclusive regarding the relationship between the embolic material and the detailed levels of embolization. Moreover, existing evidence might underestimate the efficacy of additional treatment for persistent T2EL. In a recent multicenter study, moyamoya endoleak, a hard-to-embolize nidus, was identified as a predictor of reduced efficacy of TAE.[19] Even when access to the nidus is achieved, in cases such as moyamoya endoleak, completely filling the nidus with embolic material may not be possible, leaving embolization of the directly connected branches as the only option. However, it remains unclear whether embolizing the branches alone is effective without distal embolization from the nidus. Considering these perspectives, it is essential to conduct comprehensive medium- to long-term evaluations and large-scale studies that delve into the complexities of these procedures. Therefore, this study aims to compare the mid-term outcomes of embolizing both the endoleak nidus and its branches versus the branches alone in preventing aneurysm sac enlargement following T2EL. In addition, this study assesses the impact of different embolic materials used in these techniques.

MATERIAL AND METHODS

Patients

This study was conducted according to the ethical standards of the Institutional and National Research Committee and the 1975 Helsinki Declaration, revised in 2000, regarding human experimentation. The Institutional Review Board approved this retrospective cohort study, and the need for informed consent was waived. A review of the medical records and imaging studies was conducted for consecutive 59 patients who underwent TAE for T2EL between September 2017 and August 2022. Data from before the stent graft implantation was utilized as the medical record. One patient with Marfan syndrome and another with infection were excluded from the study. Eleven patients with <6 months of follow-up duration and six without abdominal aortic aneurysm (AAA) were excluded from the study.

Technical success was defined as the absence of detectable endoleaks during the completion angiogram at TAE (Details of technical success are available in the next section). No patient had concurrent endoleak types other than T2EL. Overall, 40 patients [31 men and 9 women, median age, 80 years (interquartile ranges [IQR] 75–85 years)] who underwent TAE for T2EL following EVAR were enrolled. The decision to perform TAE for T2EL after EVAR was based on the presence of persistent T2EL with sac enlargement of >5 mm in all cases.

TAE procedure

The treatment strategy involves successful catheter advancement and embolization of the endoleak nidus and main feeding or drainage branches. In this study, the term “direct TAE” refers to the insertion of the catheter into the nidus through the arterial route followed by TAE. Moreover, indirect TAE is defined as procedures that do not directly embolize the nidus. During angiography, when drainage branches from the endoleak nidus in the aneurysm were identified, these branches were selected and embolized with coils. Subsequently, embolization of the endoleak nidus and feeding branches was performed sequentially. The endoleak nidus and its associated branches were embolized using N-butyl-2-cyanoacrylate (NBCA) glue or coils. Indirect embolization refers to the practice of embolizing the main branches when it is not feasible to access the endoleak nidus or when the endoleak nidus is too small to accommodate the use of liquid embolization material without the risk of reflux. The patent aortic branches connecting to the endoleak nidus serving as feeding or drainage arteries for T2EL were identified through pre-procedural contrast-enhanced computed tomography (CT) scans, with a slice thickness of 0.63-mm–1.25-mm and angiograms conducted during the TAE procedure. The presence of coexisting endoleak types, other than T2EL, was checked utilizing the pre-procedural contrast-enhanced CT scans and intraoperative angiograms.

To address T2EL originating from the inferior mesenteric artery (IMA), access was gained to the middle colic artery through the superior mesenteric artery. The IMA was then cannulated through the arc of Riolan or the marginal artery. To address T2EL originating from the lumbar artery, the iliolumbar arteries were accessed through the internal iliac arteries followed by retrograde cannulation of the lumbar artery.

A 1.9-Fr non-tapered microcatheter (Carnelian MARVEL NT; Tokai Medical Product, Aichi, Japan) was advanced to the endoleak nidus through a 2.9-Fr microcatheter (Leonis Mova; SB Kawasumi, Kanagawa, Japan), coaxially introduced through a 4–5-Fr catheter. The embolization was performed using coils and NBCA glue. Specifically, coil embolization was performed using hydrogel-coated coils (Azur Soft 3D; Terumo, Tokyo, Japan) or detachable non-fibered coils (ED and i-ED COIL; Kaneka, Osaka, Japan). NBCA glue consists of a mixture of NBCA (Histoacryl; B. Braun, Melsungen, Germany) and iodized oil (Lipiodol; Guerbet, Aulnay-sous-Bois, France). The attending interventional radiologist determined the selection of embolization materials and the specified NBCA/Lipiodol ratio (16–50%) based on the target vessel anatomy. It was defined that successful embolization using coils and NBCA glue was achieved when the nidus was completely occluded by coils and NBCA glue, or if the nidus was embolized with NBCA glue, up to two associated branches could be successfully occluded using coils on the initial embolization. If the embolization using coils was deemed not easy, an embolization using only NBCA glue technique was performed; this was observed in only three cases, where the concentration of NBCA glue used ranged from 16% to 25%. The procedural endpoint (technical success) was the absence of remarkably detectable endoleak nidus during the completion angiogram. No patients with substantial residual nidus during the completion angiogram were included in this study. The results and specific details of the TAE procedures were collected from the operative reports.

Follow-up protocol

Following the initial TAE, unenhanced CT scans were routinely performed at 1, 6, and 12 months, with subsequent annual scans if no sac enlargement was identified. Contrast-enhanced CT scans were conducted when sac enlargement, stent-graft migration, or sealing-zone shortening was identified. However, contrast media administration was avoided in patients with renal dysfunction or contrast medium intolerance.

Imaging outcomes

Two radiologists with 10–20 years of experience conducted pre-procedural and follow-up evaluations using CT scans and conventional angiograms, blind to the outcomes. Consensus was reached to resolve all discrepancies. The assessment included the measurement of the maximum aneurysmal sac diameter, moyamoya endoleak [Figure 1], and determination of endoleak presence and type. A moyamoya endoleak was defined by its heterogeneous opacity with a faint and ill-defined edge. The final diagnosis was reached through a consensus. Maximum aneurysmal sac diameter was defined as the external diameter in the axial images. Aneurysmal sac enlargement was defined as a >5 mm increase in the maximum diameter compared to the sac diameter during the initial TAE.

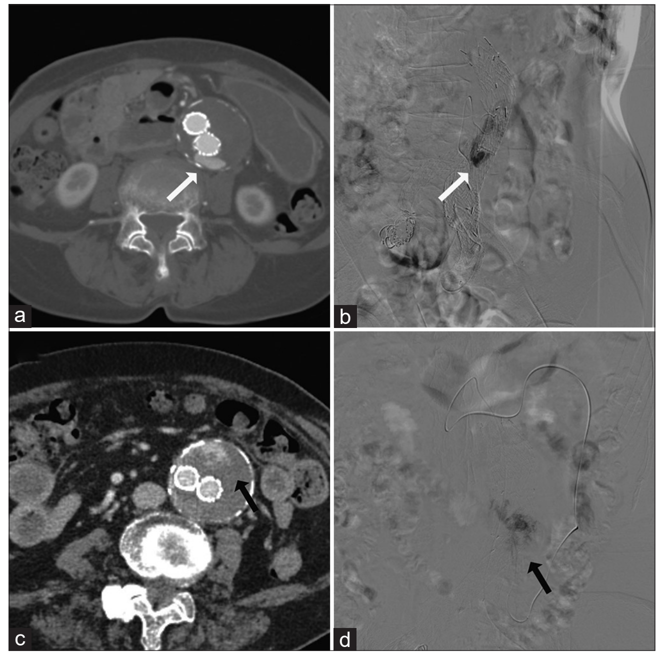

Figure 1: Illustrative examples of a 81-year-old female with uniform, well-defined type II and a 85-year-old female with moyamoya endoleaks. (a) Type II endoleak originating from the lumbar artery. The endoleak opacity is homogeneous, with a clearly defined edge on dynamic CT imaging (white arrow) (b) During the digital subtraction angiography, contrast agent flow within a large cavity can be observed (white arrow). (c) Type II endoleak supplied from the inferior mesenteric artery. The endoleak opacity was heterogeneous with a faint and ill-defined edge (black arrow). This type of endoleak is defined as a Moyamoya endoleak. (d) During the digital subtraction angiography, the contrast agent infiltrating through the gaps in the thrombus can be observed (black arrow).

Predictors of sac enlargement after TAE for T2EL

Patient characteristics and clinical factors were evaluated to investigate their potential association with sac enlargement following TAE. These included pre-procedural demographics, clinical characteristics, smoking status, history of antiplatelet and anticoagulant use, and the type of EVAR device used. Others include aneurysmal sac diameter at the time of EVAR and initial TAE, the interval and sac growth between EVAR and initial TAE, follow-up duration following TAE, the number of patent aortic branches at the initial TAE, and the procedures of embolization. The embolization procedures were categorized into three groups as follows: Direct TAE involving the nidus and its associated branches using coils incorporating NBCA glue as needed; direct TAE incorporating the nidus and its associated branches, utilizing only NBCA glue; and indirect TAE of associated branches, without nidus packing, using both coils incorporating NBCA glue as needed. No cases have been reported in which coils have been used for embolization of the nidus before the branches have been embolized with NBCA glue.

Statistical analysis

In cases of missing data or loss to follow-up, the last observation carried forward method was employed to impute missing values. Categorical variables were summarized using frequencies and percentages, while continuous variables were expressed using median and IQRs. Fisher's exact test was utilized to analyze clinical and TAE features (categorical variables). The Mann–Whitney test was used to analyze age, sac diameter, and the interval between EVAR and the first TAE. The Kaplan–Meier curve was utilized to estimate freedom from sac enlargement and reintervention rate, while the log-rank test was used for comparison. Statistical analyses were performed using GraphPad Software (Version 9.5.1 for Mac, San Diego, USA). $P < 0.05$ was considered statistically significant.

RESULTS

TAE technique

All patients exhibited attenuation of the nidus on the completion angiogram following TAE. Of these, 60% ($n = 24$) underwent embolization through direct cannulation to the nidus. In comparison, for the remaining 40% ($n = 16$), even if access to the nidus was achieved, embolization of the nidus itself was challenging, so embolization was performed on the branches directly connected to the nidus, targeting as many involved branches as possible. Among the patients who underwent nidus cannulation, 53% ($n = 21$) were embolized using a combination of coils and NBCA glue, while the remaining 7% ($n = 3$) were embolized solely with NBCA glue [Table 1].

Table 1: Patient demographics, comorbidities, and results of transarterial embolization procedure.

Variables		All patients, *n*=40
Age		80 (76–85)
Male sex		31 (78)
CAD/DM/CKD/PAD		8 (20)/5 (13)/7 (18)/8 (20)
Hypertension		37 (93)
Dyslipidemia		29 (73)
Smoking; Current/Former/Never		3 (8)/23 (58)/14 (35)
Anticoagulation		5 (13)
Antiplatelet		24 60)
Sac diameter at EVAR, mm		51 (45–56)
Sac diameter at 1st TAE, mm		57 (51–62)
EVAR device; Excluder/Zenith/Endurant/AFX		25 (63)/2 (5)/11 (28)/2 (5)
Sac enlargement		14 (35)
Interval between EVAR and 1st TAE, m		41 (30–69)
Follow-up duration after 1st TAE, y		1.7 (0.9–2.8)
Number of patent aortic branches at 1st TAE; 1/2/3/4		15 (38)/13 (32)/10 (25)/2 (5)
Number of cases requiring 2 or more TAE		13 (33)
Embolization details		
Embolization target*	**Materials**	-
Branches with nidus	Coil with/without NBCA glue	21 (53)
	Only NBCA glue	3 (7)
Branches without nidus	Coil with/without NBCA glue	16 (40)

Data are presented as counts (percentages) for the categorical variables or median (interquartile ranges) for the continuous variables. *Embolization procedures were classified based on whether the nidus was embolized and the type of embolic material used: either NBCA glue only or a combination of coils and NBCA glue as needed. There have been no cases where the nidus has been embolized with coils followed by embolization of the branches with NBCA glue. CAD: Coronary artery disease, DM: Diabetes mellitus, CKD: Chronic kidney disease, PAD: Peripheral artery disease, EVAR: Endovascular abdominal aortic aneurysm repair, TAE: Transarterial embolization, NBCA: N-butyl-2-cyanoacrylate, AFX: name of a stent graft (trademarked).

Imaging outcomes

The median sac diameter at the time of EVAR was 51 mm (IQR: 45–56), while the median sac diameter at the first TAE was 57 mm (IQR: 51–62). In 33% of patients ($n = 13$), two or more TAE procedures were required. Sac enlargement of >5 mm following TAE was observed in 35% of patients ($n = 14$). The sac non-enlargement rates at 1, 3, and 5 years were 93%, 68%, and 65%, respectively [Figure 2].

Clinical outcomes

The median follow-up period was 1.7 years (IQR: 0.9–2.8 years) after the first TAE. Among the patients who underwent direct TAE for nidus and branches using a coil with or without NBCA glue ($n = 24$, 60%), the rates of sac non-expansion were 100%, 95%, and 95% at 1, 3, and 5 years, respectively [Figures 3 and 4]. In all patients ($n = 3$, 100%) in whom nidus with branches embolized exclusively using NBCA glue, sac enlargement was observed within 2 years, and the NBCA glue had disappeared in the images [Figure 5]. For patients who underwent embolization specifically for branches without direct TAE of the endoleak nidus ($n = 16$, 40%) [Figure 6], the rates of remaining free from sac enlargement were 81%, 44%, and 38% at 1, 3, and 5 years, respectively [Figure 3].

Factors related to moyamoya endoleak

As detailed in Table 2, in the group with moyamoya endoleak, a higher percentage of patients were administered antiplatelet medication than those without it (14 [82%] vs. 10 [43%], $P = 0.02$). The interval between EVAR and the first TAE was relatively longer in the group with moyamoya endoleak (52 days, IQR: 31–78) than in the group without it (37 days, IQR: 26–54). However, this difference was not

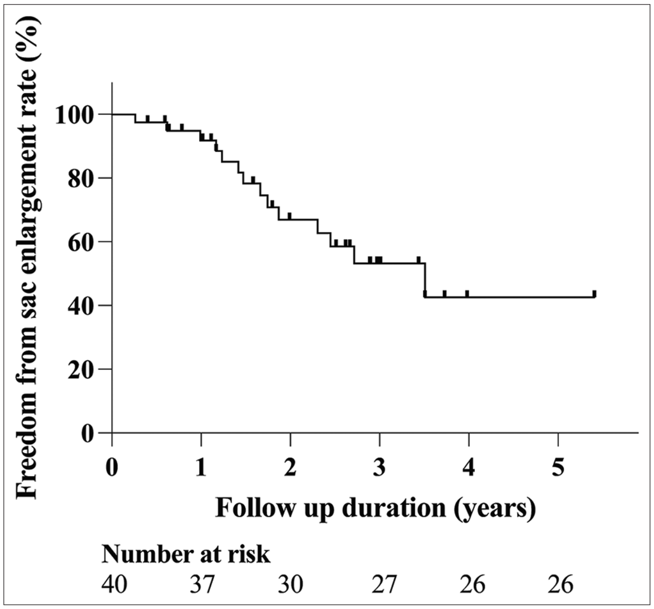

Figure 2: Kaplan–Meier curve revealing freedom from aneurysm expansion following embolization in 40 patients. Number at risk: These numbers indicate the count of patients at each follow-up point who have not yet experienced an enlargement of 5mm or more.

statistically significant (P = 0.07). Moyamoya endoleak occurred significantly less frequently in the group that underwent direct TAE using coils, incorporating NBCA glue as needed (29%, n = 5), than in the opposite group (70%, n = 16, P = 0.02).

Factors contributing to sac enlargement after TAE for T2EL

We analyzed 28 factors associated with sac enlargement of >5 mm following TAE. Univariate analysis revealed that variables associated with sac enlargement (those with P < 0.05) included the specific procedures (embolization with NBCA glue only and TAE for branches without nidus) and two or more TAE procedures [Table 3]. Among the 14 patients who experienced sac enlargement, direct nidus TAE was unsuccessful in 10 (72%) (P = 0.006). Conversely, among the group of 26 patients who did not experience sac enlargement, 20 (77%) underwent successful embolization of the nidus and main branch using coils, incorporating NBCA glue as needed (P < 0.0001). Furthermore, sac enlargement was observed in three patients who, despite having undergone successful direct TAE of the nidus and branches, were exclusively embolized with NBCA glue (P = 0.04).

Table 2: Univariate comparison of factors associated with Moyamoya Endoleak.

Variables		Moyamoya Endoleak		*P*-value
		Yes *n*=17	No *n*=23	
Age		84 (78–86)	79 (74–83)	0.04
Male sex		13 (76)	18 (78)	>0.99
CAD/DM/CKD/PAD		3 (18)/3 (18)/4 (24)/4 (24)	5 (22)/2 (9)/3 (13)/4 (17)	>0.99/0.63/0.43/0.70
Hypertension		17 (100)	20 (87)	0.25
Dyslipidemia		15 (88)	14 (61)	0.08
Smoking; Current/Former/Never		1 (6)/10 (59)/6 (35)	2 (9)/13 (57)/8 (35)	>0.99
Anticoagulation		1 (6)	4 (17)	0.37
Antiplatelet		14 (82)	10 (43)	0.02
Sac diameter at EVAR, mm		50 (45–55)	53 (43–58)	0.54
Sac diameter at 1st TAE, mm		56 (53–58)	58 (49–62)	0.72
EVAR device; Excluder/Zenith/Endurant/AFX		12 (71)/1 (6)/3 (18)/1 (6)	13 (57)/1 (4)/8 (35)/1 (4)	0.51/>0.99/0.30/>0.99
Sac enlargement		8 (47)	6 (26)	0.31
Interval between EVAR and 1st TAE, m		52 (31–78)	37 (26–54)	0.07
Number of patent aortic branches at 1st TAE; 1/2/3/4		6 (35)/7 (41)/4 (24)/0 (0)	10 (43)/5 (22)/6 (26)/2 (9)	0.75/0.30/>0.99/>0.99
Number of cases requiring 2 or more TAE		7 (41)	6 (26)	0.49
Embolization details				
Embolization target*	**Material**	-	-	-
Branches with nidus	Coil with/without NBCA glue	5 (29)	16 (70)	0.02
	Only NBCA glue	2 (12)	1 (4)	0.56
Branches without nidus	Coil with/without NBCA glue	10 (59)	6 (26)	0.053

Data are presented as counts (percentages) for the categorical variables or median (interquartile ranges) for the continuous variables. *Embolization procedures were classified based on whether the nidus was embolized and the type of embolic material used: Either NBCA glue only or a combination of coils and NBCA glue as needed. There have been no cases where the nidus has been embolized with coils followed by embolization of the branches with NBCA glue. CAD: Coronary artery disease, DM: Diabetes mellitus, CKD: Chronic kidney disease, PAD: Peripheral artery disease, EVAR: Endovascular abdominal aortic aneurysm repair, TAE: Transarterial embolization, NBCA: N-butyl-2-cyanoacrylate

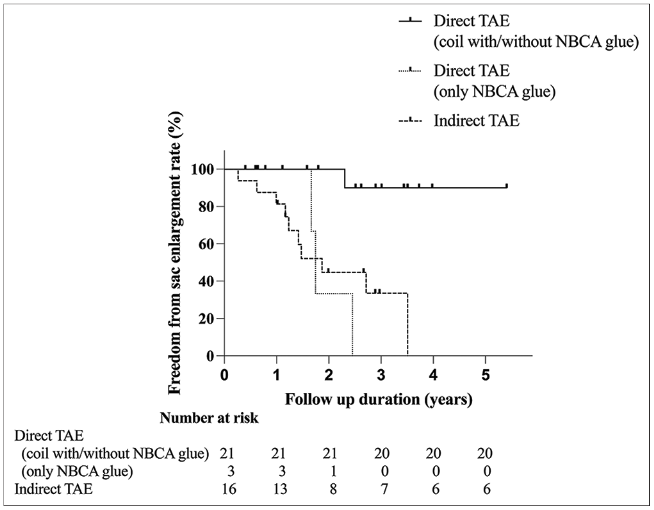

Figure 3: Comparing sac enlargement freedom rates across three methods. The rate of freedom from sac enlargement is compared among three nidus and branch embolization methods: direct transarterial embolization using coils with or without NBCA glue, direct transarterial embolization using NBCA glue only, and indirect transarterial embolization. The insertion of the catheter into the nidus through the arterial route followed by transarterial embolization defined as direct transarterial embolization. On the other hand, procedures that do not directly embolize the nidus are defined as indirect transarterial embolization. Kaplan–Meier curve comparing the freedom from sac enlargement rates among the three embolization methods: Direct embolization using coils with or without NBCA glue, direct embolization using NBCA glue only, and indirect embolization. (TAE: Transarterial embolization, NBCA: N-butyl-2-cyanoacrylate.)

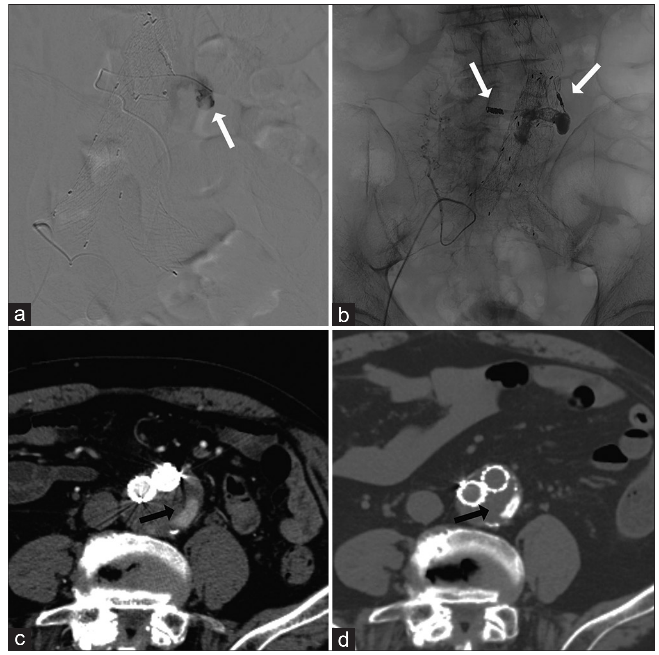

Figure 4: Illustrative examples of a-69-year-old male with direct transarterial embolization with coils and N-butyl cyanoacrylate glue. (a) The nidus was reached and a digital subtraction angiography image was acquired. The nidus (white arrow) was visualized. (b) After embolization, N-butyl cyanoacrylate glue remained in the nidus and coils in the lumbar and inferior mesenteric arteries (white arrow). (c) An endoleak is observed in the computed tomography (CT) image before embolization (black arrow). (d) In the CT scan performed 5.4 years later, the N-butyl cyanoacrylate glue was still visible (black arrow), and there was no observed increase in the aneurysm diameter.

DISCUSSION

This study examined embolization methods for T2EL after endovascular aneurysm repair (EVAR). Results showed significant sac diameter reduction when successful direct TAE of both the nidus and its associated branches was achieved. Among patients who underwent successful direct TAE, sac non-expansion rates were 100%, 95%, and 95% at 1, 3, and 5 years, respectively. However, the few cases using only NBCA glue for embolization showed aneurysm sac enlargement within 3 years.

The previous reports suggested that pre-embolization sac size affects TAE success,[20] with dyslipidemia, antiplatelet use, smoking, and moyamoya endoleak – the term for unclear nidus boundaries – diminishing its effectiveness.[16,19,21] Our research found that successful direct TAE of the nidus and branches, using coils and NBCA glue when needed, was key to reducing sac diameter. Moreover, the larger the thrombus volume in the sac, the more effectively it inhibited the increase in sac diameter.[22] The results of the present study suggested that moyamoya endoleak was associated with the use of antiplatelet agents, suggesting that inadequate thrombosis of the aneurysm may lead to moyamoya endoleak. Although achieving effective embolization in the presence of moyamoya endoleak is challenging,[19] it is speculated that the antiplatelets effects, in addition to the small size of the nidus making it difficult to embolize, may contribute to the reduced efficacy of the embolization process.

Based on this study, two critical factors for successful endoleak embolization were identified: direct embolization of the nidus and the non-necessity of branch embolization if the nidus is adequately addressed, aligning with previous findings.[23-26] Direct puncture embolization of the nidus has shown a higher success rate than TAE, attributed to the direct embolization approach.[23] Conversely, branch-only embolization was associated with increased sac diameter, underscoring the necessity of targeting the nidus.[16] Overall, the study reinforces the importance of direct TAE of both nidus and branches in preventing aneurysm sac enlargement.

The study highlighted the effectiveness of coils in preventing migration of embolic materials within the nidus during TAE, a noted issue when using liquid embolic, despite their utility

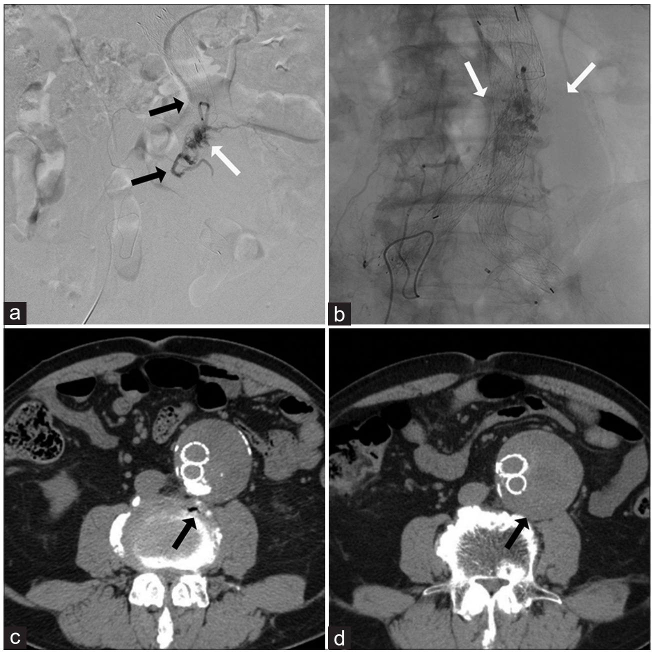

Figure 5: Illustrative examples of a-72-year-old male with direct transarterial embolization with N-butyl cyanoacrylate glue. (a) The nidus was reached and a digital subtraction angiography image was acquired. The nidus (white arrow) and its branches (lumbar artery; black arrow) were visualized. (b) After injecting N-butyl cyanoacrylate glue, the glue flowed into the nidus and branches, where it remained (white arrow). (c) In the computed tomography (CT) scan performed immediately after embolization, the glue remains in the nidus (black arrow), and no endoleak was observed. (d) In the CT scan performed 1.5 years later, the N-butyl cyanoacrylate glue was dissipated (black arrow), and an increase in aneurysm diameter was observed.

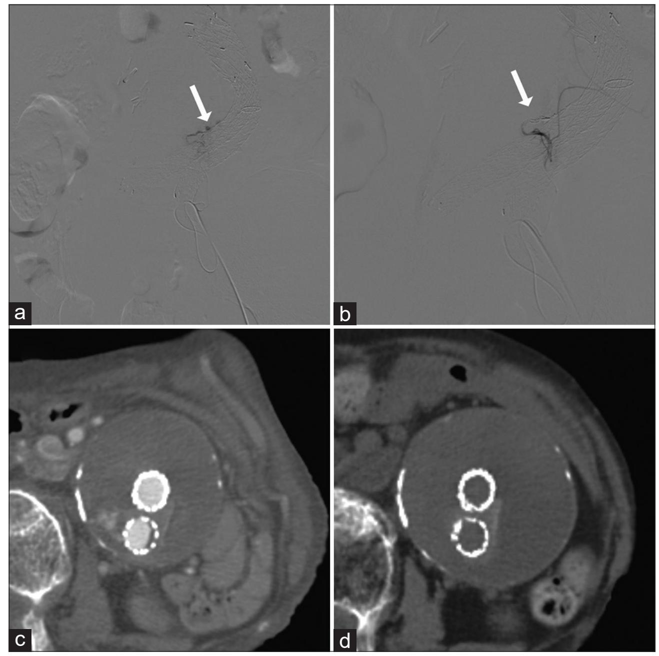

Figure 6: Illustrative examples of a-86-year-old female with indirect transarterial embolization. (a) Although it reached the nidus, a digital subtraction angiography image suggested that injection of N-butyl cyanoacrylate glue would likely cause reflux (white arrow). (b) Only coiling of the lumbar artery (white arrow), which was one of the branches close to and not distal from the nidus, was performed. (c) Dynamic computed tomography (CT) scan immediately before embolization. (d) For 3.3 years, the diameter of the aorta increased by >5 mm, as observed in a dynamic CT scan.

in T2EL embolization reported over a 2-year follow-up.[27] Short-term benefits were also seen with coil use in nidus and branch embolization over roughly 1 year.[28] However, embolizing branches alone with NBCA glue led to increased sac diameter, suggesting that permanent materials like coils in the nidus and branches may help inhibit sac growth. Thus, non-dissipating embolic in nidus embolization could be key to preventing aneurysm sac enlargement. The data indicate that successful endoleak embolization relies on targeting both the nidus and its branches to prevent washout, using both NBCA glue and coils. Direct puncture of the nidus can be challenging when its lumen is small, and accessing the branch may also be difficult. Thus, there may be opportunities where a transarterial approach to the nidus has advantages.

This study had some limitations. First, owing to its retrospective and limited-scale design, the relatively small size of the patient subgroups poses a challenge for robust statistical interpretation, potentially affecting the generalizability of the results. Second, accurately determining T2EL-associated branches may be challenging due to the inability to perform contrast-enhanced CT scans in certain patient categories, including those with renal dysfunction, contrast medium intolerance, or absence of sac enlargement. Moreover, angiographic visualization through a 1.9 Fr catheter typically fails to adequately opacify the nidus and the entirety of inflow/outflow branches, potentially obscuring the true anatomical and pathophysiological details of the endoleak. Should two or more branch vessels remain patent, the specific embolic agent used within the nidus and/or branch vessels may be inconsequential, as persistent flow can facilitate aneurysmal growth and allow the embolic material to displace from its initial placement. Therefore, this study does not assert the efficacy of using NBCA alone to embolize all potentially nidus-related inflow/outflow branches. Consequently, this study may underrepresent the occlusive efficacy of NBCA when used as the sole embolic agent. Third, it is important to note that this study followed the Japanese guidelines, focusing on EVAR treatment for smaller AAAs. This could introduce a bias into this results, as the European Society for Vascular Surgery guidelines recommend considering larger AAA sizes. Hence, given that aneurysmal sac diameter is known to influence natural growth rates, this discrepancy could potentially affect T2EL efficacy outcomes in larger

Table 3: Univariate comparison of factors associated with sac enlargement.

Variables		Sac enlargement		*P*-value
		Yes *n*=14	No *n*=26	
Age		82 (76–84)	79 (74–83)	>0.99
Male sex		11 (79)	20 (77)	0.69
CAD/DM/CKD/PAD		2 (14)/1 (7)/3 (21)/2 (14)	6 (23)/6 (23)/4 (15)/6 (23)	0.64/0.41/0.28/0.69
Hypertension		12 (86)	25 (96)	0.47
Dyslipidemia		9 (64)	20 (77)	0.69
Smoking; Current/Former/Never		1 (7)/7 (50)/6 (43)	2 (8)/16 (62)/8 (31)	>0.99
Anticoagulation		3 (21)	2 (8)	0.33
Antiplatelet		10 (71)	14 (54)	>0.99
Sac diameter at EVAR, mm		51 (48–56)	50 (44–57)	0.53
Sac diameter at 1st TAE, mm		57 (55–63)	57 (49–62)	0.46
EVAR device; Excluder/Zenith/Endurant/AFX		11 (79)/1 (7)/2 (14)/0 (0)	14 (54)/1 (4)/9 (35)/2 (8)	0.18/>0.99/0.27/0.63
Interval between EVAR and 1st TAE, m		42 (26–75)	40 (30–60)	0.81
Number of patent aortic branches at 1st TAE; 1/2/3/4		3 (21)/5 (36)/6 (43)/0 (0)	12 (46)/8 (31)/4 (15)/2 (8)	0.18/>0.99/0.12/0.53
Number of cases requiring 2 or more TAE		8 (57)	5 (19)	0.03
Embolization details				
Embolization target*	**Material**	-	-	-
Branches with nidus	Coil with/without NBCA glue	1 (7)	20 (77)	<0.0001
	Only NBCA glue	3 (21)	0 (0)	0.04
Branches without nidus	Coil with/without NBCA glue	10 (72)	6 (23)	0.006

Data are presented as counts (percentages) for the categorical variables or median (interquartile ranges) for the continuous variables. *Embolization procedures were classified based on whether the nidus was embolized and the type of embolic material used: either NBCA glue only or a combination of coils and NBCA glue as needed. There have been no cases where the nidus has been embolized with coils followed by embolization of the branches with NBCA glue. CAD: Coronary artery disease, DM: Diabetes mellitus, CKD: Chronic kidney disease, PAD: Peripheral artery disease, EVAR: Endovascular abdominal aortic aneurysm repair, TAE: Transarterial embolization, NBCA: N-butyl-2-cyanoacrylate

AAAs. Therefore, future studies focusing on larger AAA must verify these preliminary findings.

CONCLUSION

The results indicated that embolization of both the nidus and its associated branches using coils, incorporating NBCA glue as needed, was effective in preventing sac diameter increase in T2EL embolization. Embolization targeting the nidus with embolic agents that will not wash out may be an important therapeutic strategy for preventing aneurysmal expansion due to T2EL.

Ethical approval

The Institutional Review Board approved this retrospective cohort study, approval number 2125-3, dated February 3, 2020.

Declaration of patient consent

Patient's consent is not required as there are no patients in this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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