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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Efficacy of endovascular circulating false lumen occlusion in chronic aneurysmal descending aortic dissections

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PURPOSE

To evaluate the efficacy of endovascular circulating false lumen occlusion (CFLO) in inducing positive aortic remodeling in chronic aneurysmal descending aortic dissection (AD).

METHODS

This retrospective monocentric study included patients treated by CFLO between 2003 and 2022 in the context of chronic AD with progressive descending aneurysmal evolution and persistent circulating false lumen (FL). The procedure was achieved with coils, plugs, and/or glue at the entry tear or in the FL and/or with covered stenting in the supra-aortic trunk. The primary endpoint evaluated the positive aortic remodeling, defined as stabilization or a decrease in the aortic diameter on a computed tomography scan at the 1-year follow-up after the procedure. The FL circulating status, safety, and occurrence of aneurysm events during follow-up were also evaluated.

RESULTS

Twenty patients [median age: 65.4 years, interquartile range (IQR): 58.4–69.9; 13 men] were included, with a median duration from an acute AD of 32.5 months (IQR: 8.8–76.5). Twelve patients (60%) achieved complete FL thrombosis after CFLO, whereas 8/20 patients (40.0%) experienced partial thrombosis. Additionally, positive aortic remodeling was observed in 13 patients (65%). Following the procedure, the aneurysmal aortic diameter decreased in 8/20 patients (40.0%) and remained stable in 5/20 patients (25.0%). Two patients (10%) had complications related to the procedure. Two patients (10%) had secondary aneurysm events during follow-up.

CONCLUSION

CFLO is a feasible and efficient method to induce FL thrombosis and reduce aneurysmal progression in chronic AD.

CLINICAL SIGNIFICANCE

The positive outcomes observed highlight the potential of this technique to improve patient management in complex aortic pathologies. This approach offers a valuable option in the management of chronic AD and emphasizes the importance of endovascular interventions in enhancing patient outcomes.

KEYWORDS

Chronic aortic dissection, false lumen, true lumen, entry tear, endovascular occlusion, circulating false aortic lumen, embolization, coils, plugs, glue, stent, thoracic endovascular aortic repair, false lumen thrombosis, aortic aneurysm

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Aortic dissection (AD) is a serious pathology with a high mortality rate of 11%–25% in the acute phase.[1] One third of dissections develop an aneurysm requiring reintervention within 4 years.[2,3] A persistent patent false lumen (FL) fed by an entry tear (ET) is associated with a relatively high risk of long-term mortality and late aortic events in patients with AD;[4] however, complete FL thrombosis limits this risk.[5] The development of chronic diastolic aortic hypertension[6,7] contributes to elevated pressure within the expanding FL, increasing the risk of aortic rupture.[8]

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In chronic dissection, optimal antihypertensive therapy is recommended,[9] but the chronic aneurysmal evolution may require open surgical repair[10] or thoracic endovascular aortic repair (TEVAR).[11] These two approaches do not always result in FL thrombosis, which continues to circulate in 80%–90% of patients after isolated proximal surgical repair[12] and in up to 43% of patients treated using TEVAR.[13] By targeting the ET feeding the circulation of the FL, endovascular circulating false lumen occlusion (CFLO) using embolization material (coils, glue, and plugs) or an uncovered stent can be an effective approach. This other endovascular method may be a valuable alternative or a complementary option when the FL remains patent and is supplied by an accessible ET. This treatment enables personalized targeted embolization for each patient to achieve FL thrombosis, thereby limiting aneurysmal evolution and reducing the risk of aortic rupture. Although TEVAR is now considered the gold standard for this indication,[14] the risk of spinal cord ischemia, although low (approximately 8%), remains a serious concern with serious consequences (approximately 1.5% incidence of paraplegia).[15] Currently, no comparative efficacy studies exist regarding CFLO and traditional TEVAR. The advantage of CFLO treatment may lie in the fact that it is considered a less invasive option than the placement of an aortic stent graft and can avoid the associated complications. Moreover, CFLO could reduce the risk of spinal cord ischemia associated with TEVAR by maintaining the patency of certain intercostal arteries.

Main points

- Chronic aortic dissection (AD) often leads to persistent patent false lumen (FL) circulation, which increases the risk of aneurysmal progression and aortic rupture.
- Thoracic endovascular aortic repair is now the standard treatment for AD but does not always achieve complete thrombosis of the FL (43% remains patent) and may fail in cases with unfavorable anatomy.
- This study evaluates the efficacy of endovascular circulating false lumen occlusion (CFLO), using coils, glue, plugs, and an uncovered stent, in achieving FL thrombosis and inducing positive aortic remodeling, aiming to promote these techniques within the therapeutic arsenal.
- Complete FL thrombosis was achieved in 60% of patients, and positive aortic remodeling was obtained in 65% of patients.
- The feared consequences and complications were minimal compared with the underlying pathology, with no reported cases of spinal cord ischemia associated with CFLO.

The main objective of this study was to evaluate the efficacy of CFLO on mid-term positive aortic remodeling in chronic aneurysmal descending AD. In addition, particular attention has been given to the safety of this treatment by investigating the associated adverse effects associated with the intervention.

Methods

Patients

This monocentric retrospective study was conducted between 2003 and 2022 at the University Hospital of Grenoble Alpes (France). The inclusion criteria (Figure 1) were patients who underwent CFLO for chronic (i.e., >90 days)[16] persistent descending AD (type A after surgery or B with or without previous TEVAR) in the context of pejorative aneurysmal evolution with a patent FL fed by an ET unable to be treated by TEVAR and the following: 1) an aortic descending diameter >55 mm; and/or 2) aortic descending diameter progress >5 mm/year; and/or 3) TEVAR failure with a persistent untreated punctiform entry tear (PET) far from the prothesis and retrograde false lumen flow (RFLF). The exclusion criteria were no imaging follow-up >12 months, no imaging at baseline, traumatic AD, or aneurysm without AD or from infectious etiology. Aneurysmal evolution treated by isolated TEVAR or the treatment of a perigraft leak in the context of TEVAR were also excluded. All procedures performed were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the Comité d'Ethique pour la Recherche en Imagerie Médicale (approval no: CRM-2107-194, date: 09/2021) For this type of retrospective study, informed consent is not required. A declaration of informed non-opposition was required for each enrolled participant.

Pathologic aortic evaluation

Imaging follow-up was performed using computed tomography (CT) scans to explore the aorta from the supra-aortic trunks (SATs) to the common femoral arteries, performed with and without contrast material enhancement. Aortic diameters were evaluated using the latest available imaging before CFLO (baseline CT scan) and the latest available imaging after CFLO (follow-up CT scan), which was defined as the end of follow-up.

The Ishimaru classification[17] was utilized to localize the aortic aneurysm level and the ETs (Table 1) on CT scans. This classification divides the aorta into several zones, allowing for the precise identification of lesions: zone 0 involves the origin of the innominate artery; zone 1, the origin of the left common carotid artery; zone 2, the origin of the left subclavian artery; zone 3, the proximal descending thoracic aorta down to the T4 vertebral body (aortic isthmus); and zone 4, the remainder of the thoracic aorta.

To increase reproducibility and avoid cross-sectional effects, the aortic diameter was measured by the largest short-axial diameter of the outer contour of the aneurysm and, in the aortic arch, by the largest diameter perpendicular to the curvature.[18] Measurement was performed by a single observer and controlled by intraobserver reproducibility measurements.

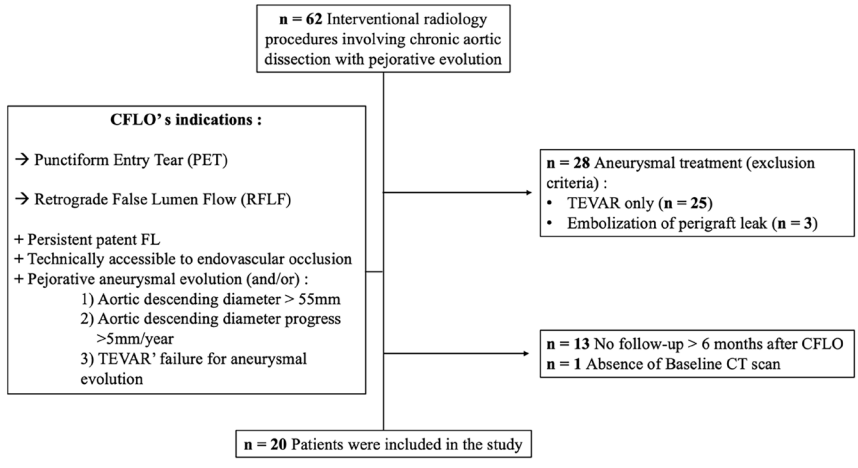

Figure 1. Study flowchart. CFLO, circulating false lumen occlusion; FL, false lumen; TEVAR, thoracic endovascular aortic repair; CT, computed tomography.

Angiography and embolization techniques

The procedures were performed in an angiography department (Allura Integris 15, Philips Medical systems, Best, Netherlands, and Artis Zeego, Siemens, Erlangen, Germany) by three interventional radiologists with 8 (M.F.), 18 (M.R.), and 30 (F.T.) years of experience. The CFLO was performed using different embolization materials, such as coils (AZUR® Peripheral HydroCoil, Terumo, Rueil-Malmaison, France; Nester Embolization Coil, Cook Medical Europe LTD, Limerick, Ireland), glue (Onyx® Liquid Embolic Agent, Medtronic, Paris, France; Hystoacril®, B. Braun Medical SA, Granges-Paccot, Schweiz), and plugs (Amplatzer® Vascular Plug II, Abbot Medical, Issy-les-Moulineaux, France). Covered (WallGraft®, Boston Scientific, Marlborough, MA, USA; AdvantaV12®, Atrium Medical Corporation, Hudson, NH, USA) or uncovered (SmartControl®, Cordis, Issy-les-Moulineaux, France; Zilver®, Cook Medical Europe LTD, Limerick, Ireland) stents were also utilized to prevent reinjection from an ET in the SAT. These materials were used separately (CFLO single technique) or in combination (CFLO combined technique).

The patients' cases were reviewed prior to the procedure to determine the most appropriate strategy. The precise description of the conditions for the use of embolic materials is challenging, as each case requires personalized embolization that considers various parameters, such as the location, size, shape and number of ETs, dimensions of the FL, and blood flow velocity. Similarly, the overall morphology of the aorta and the potential access routes should be considered, as not all types of materials can be implanted. Plugs, for example, can sometimes be difficult to insert, making it necessary to prioritize the remaining tool options. Some of these cases have been illustrated as examples in Figures 2, 3, and 4, and the entire range of embolization tools should be considered, especially the liquid agents, as illustrated by the column relating to glue in Figure 4.

Several key FL embolization scenarios are described here, although it is challenging to be more precise in this complex pathology. For SAT PETs, stenting was preferred to cover the ET, redirecting the flow into the trunk lumen. Punctiform ET occlusion can be performed directly by placing a plug with one fin in the true lumen (TL) and the rest of the materials in the FL. There is a risk of coil or glue migration in the case of rapid flow in the FL, which can be reduced by the combined use of these materials (for example, a framework of large coils sealed by glue). Any RFLF can be managed using glue, with the natural retrograde flow directed toward the aneurysm.

Under local anesthesia, radiologic percutaneous arterial (femoral, radial, or humeral) access was performed using a 4–6F introducer sheath. Digital subtraction angiography was performed within the aorta to identify the ET targeted on the CT scan. The end of the procedure was characterized by the absence of opacification of the FL on the final angiogram. Sometimes, if the benefit–risk ratio of the technique becomes unfavorable, the FL is allowed to circulate weakly, leading to secondary thrombosis. An additional procedure could be performed in the case of a persistent increase in aortic diameter control imaging.

Study endpoints

The primary objective of this study was to evaluate the efficacy of CFLO in the aortic remodeling at the thoracic level. The primary outcome was defined by positive aortic remodeling[16] described as a reduction in or the stability of the total aortic maximal diameter on the follow-up CT scan at the 1-year follow-up along with a reduction in the FL diameter and/or expansion of the TL. An increase in the aortic maximal diameter at the 1-year follow-up was considered to represent worsening aortic remodeling. In the follow-up CT scan, measurement of the descending aortic diameter was performed at the same maximum aortic level as at baseline. An aortic diameter decrease was defined as a decrease >2 mm on the follow-up CT scan. A diameter increase was defined as an increase >2 mm. Stability was defined as a constant diameter without any increase or decrease. The maximum aortic diameter, the diameter of the FL, and the diameter of the TL are the main parameters monitored in patients with chronic dissection, regardless of whether the FL is perfused or not.

Secondary objectives were to evaluate the efficacy of CFLO on the circulation of the FL (technical success), the safety of the pro-

Table 1. Demographics and aortic pathologic data

Variables	n = 20
Age (years), median (IQR)	65.4 (58.4–69.9)
Gender (male), n (%)	13 (65.0)
Hypertension, n (%)	12 (60.0)
Type of dissection*, n (%)	
A	16 (80.0)
B	4 (20.0)
Type of initial treatment before CFLO, n (%)	
Bentall	6 (30.0)
Tirone David	1 (5.0)
Aorto-aortic tube	9 (45.0)
TEVAR	7 (35.0)
Surgical SAT reimplantation	4 (20.0)
Aortic aneurysm level, n (%)	
Zone 3	12 (60.0)
Zone 4	8 (40.0)
Location of ET, n (% of total ET)	
SAT	8/32 (25.0)
Distal surgical anastomosis	8/32 (25.0)
Zone 1	2/32 (6.3)
Zone 2	3/32 (9.4)
Zone 3	5/32 (15.6)
Zone 4	6/32 (18.8)
Indications for CFLO, n (%)	
Punctiform entry tear	16 (80.0)
Retrograde false lumen flow	4 (20.0)

*Stanford classification; n, number; IQR, interquartile range; CFLO, circulating false lumen occlusion; TEVAR, thoracic endovascular aortic repair; SAT, supra-aortic trunk; ET: entry tear.

cedure, and the occurrence of aortic events during follow-up. The technical success of CFLO was defined as complete FL thrombosis at the thoracic level, assessed by the absence of opacification of the FL on the follow-up CT scan (delayed contrast enhanced ≥80 s) at 3 months, in the two areas described by the Ishimaru classification on the descending aorta: zones 3 and 4. The FL was evaluated as partially thrombosed (neither patent nor thrombosed, defined as a clot within the FL with a residual circulating flow channel) or patent (similar to the baseline CT scan). The safety of CFLO was assessed by monitoring the occurrence of complications during follow-up, with data collected according to the European Society of Cardiovascular and Interventional Radiology.[19]

Statistical analysis

Standard descriptive statistics were used for continuous quantitative variables, presented as medians with interquartile ranges (IQRs), and for qualitative variables, presented as numbers and percentages. Regarding aortic measurements, a paired-sample mean comparison analysis was performed using Student's t-test. Standard descriptive statistics were used to describe aortic remodeling, technical success, and safety, with a calculation of the corresponding number and percentages. Regarding intraobserver reproducibility, the intraclass correlation coefficient was analyzed using the Pearson correlation test for quantitative variables. The analyses were conducted using Jamovi® (version 1.6.23.0). A *P* value <0.05 was considered significant.

Results

Population characteristics

During the study period, 62 patients underwent procedures for aneurysmal pathology of the thoracic descending aorta (Figure 1). Twenty-five patients (40.3%) were excluded due to isolated TEVAR treatment and three patients (4.8%) for the embolization of perigraft leaks related to TEVAR. Thirteen patients (21%) were excluded for having less than 12 months of follow-up, and one patient (1.6%) was excluded due to the lack of a baseline CT scan. Twenty patients (32.3%) were finally included and underwent CFLO to prevent pejorative aortic remodeling.

The study included 7 women (35%) and 13 men (65%), with a median age of 65.4 years (IQR: 58.4–69.9) (Table 1). Sixteen patients (80%) had type A dissection, and four patients (20%) had type B dissection. Additionally, seven patients (35%) had a history of previous TEVAR. The median duration from AD to CFLO was 32.5 months (IQR: 8.8–76.5), with the majority of aortic aneurysms located in zone 3 (60%), the isthmic segment. A total of 32 ETs were identified in 20 patients, including 8 in the SAT (25%) and 8 at the distal surgical anastomosis level (25%).

The median total number of CFLO sessions was approximately 1.5 (IQR: 1.0–2.3). Ten patients (50%) underwent two or more CFLO sessions, and ten patients (50%) received isolated CFLO without prior or additional TEVAR. The embolization agents used are summarized in Table 2.

Efficacy

False lumen circulatory status

At the 1-year follow-up, 12 patients (60%) achieved technical success with complete FL thrombosis after CFLO (Table 3), whereas 8 patients (40%) had partial thrombosis. No patients had a patent FL on the follow-up CT scan. Complete thrombosis was achieved in the isthmic segment in zone 3 in 17 patients (85%). Thirteen patients (65%) had thrombosis in zone 4, including 12 patients who also had thrombosis in zone 3. One patient had thrombosis only in the distal third of the thoracic aorta without proximal thrombosis.

Impact on aortic remodeling

After the procedure, 13 patients (65%) exhibited positive aortic remodeling at the 1-year follow-up imaging, including 8 patients with decreased aneurysmal aortic diameter and 5 patients with stabilized diameters (Table 3). In the subgroup with complete FL occlusion, 75% exhibited positive remodeling. The median maximal aortic diameter on the baseline CT scan was 52.5 mm (IQR: 43.8–59.8) compared with 54.0 mm (IQR: 41.8–68.5) on the follow-up CT scan ($P = 0.115$). The median FL diameter significantly decreased at 1 year compared with the baseline CT [16.0 (IQR: 10.3–26.8) vs. 25.0 mm (IQR: 19.5–33.0); $P = 0.044$]. Among the 10 patients with isolated CFLO, 6 achieved

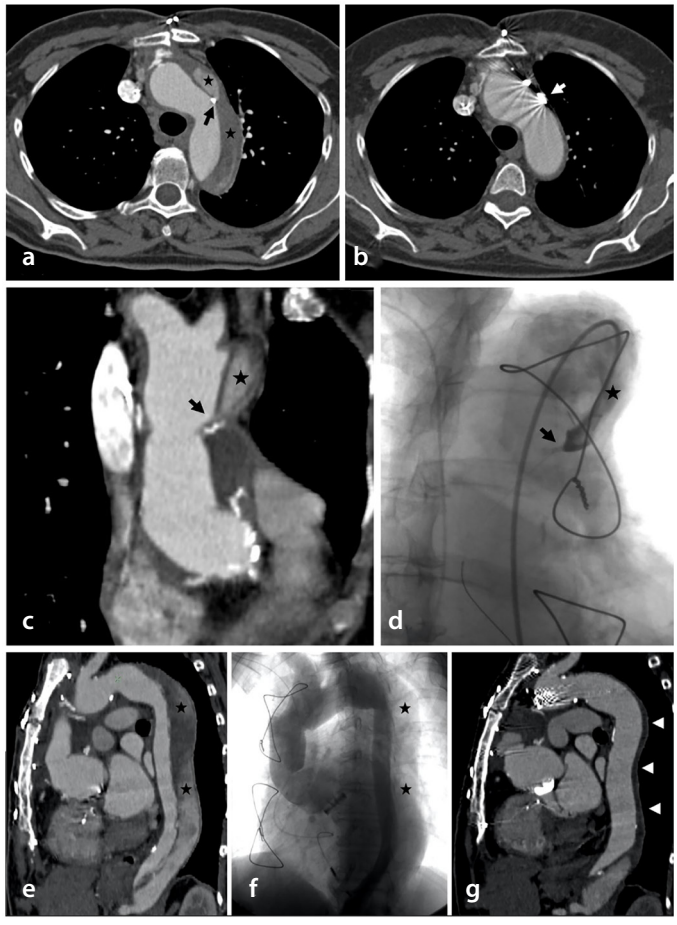

Figure 2. Treatment of a thoracic chronic dissecting aortic aneurysm after Bentall surgery in a 73-year-old patient with a history of chronic aortic dissection by coiling of the proximal portal of entry. The target entry tear (ET, black arrows) is located within segment 2, feeding the false lumen (FL, black stars). The coils (white arrows) indirectly occlude the ET, allowing thrombosis and regression of the FL (white arrowheads). Computed tomography scan with injection at arterial time before **(a, c, e)** and after **(b, g)** embolization. Serigraphy with injection and locating the ET by retrograde catheterization of the FL **(d)** and the true lumen **(f)**.

FL thrombosis and 9 (90%) achieved positive aortic remodeling. The intraclass correlation coefficient for the intraobserver reproducibility of the aortic diameter measurements was 0.997 (95% confidence interval: 0.995, 0.998).

Safety and aortic events

The median follow-up was 4.7 years (IQR: 2.9–12.4). After CFLO, five patients (25%) experienced transient post-embolization syndrome, characterized by increased pain (lasting approximately 10 days) and a temporary increase in C-reactive protein levels, related to large FL thrombosis; these symptoms were resolved within 3 months (grade I). Two patients (10%) had complications associated with CFLO: one transient ischemic stroke (grade II) and one coil migration that could be recaptured (grade I). Four patients (20%) required additional TEVAR during follow-up. Among the seven patients with a persistent patent FL, two had secondary aortic events related to aneurysmal evolution (Table 4), but no patients with complete FL occlusion experienced aortic events during follow-up. No cases of spinal cord ischemia were reported in connection with the CFLO procedure.

Discussion

This study demonstrated satisfactory CFLO results in inducing positive aortic remodeling in chronic aneurysmal descending AD in 13 out of 20 patients (65%), with a decreased aneurysmal aortic diameter observed in 40% of patients. Additionally, for 25% of patients, the diameter remained stable, associated with either a decrease in FL size or an increase in TL size. Moreover, 60% of patients had technical success with complete FL thrombosis after CFLO. These results are encouraging when considering that the blood flow circulation in the FL is the key risk factor for aortic enlargement, associated with a significant and significantly higher aortic mean growth rate, as described by Sueyoshi et al.[18] The natural evolution of a patent FL is not toward thrombosis, and the authors demonstrated that only one third of FL cases progressed to complete thrombosis without the need for interventional treatment. In cases where FL patency persists, abdominal-level embolization may be appropriate but should be considered with caution, as this further complicates treatment given that the thrombus may extend to the mesenteric arteries in cases of extensive dissection.

Direct FL occlusion was first described by Loubert et al.[20] as the "cork in the bottle neck"

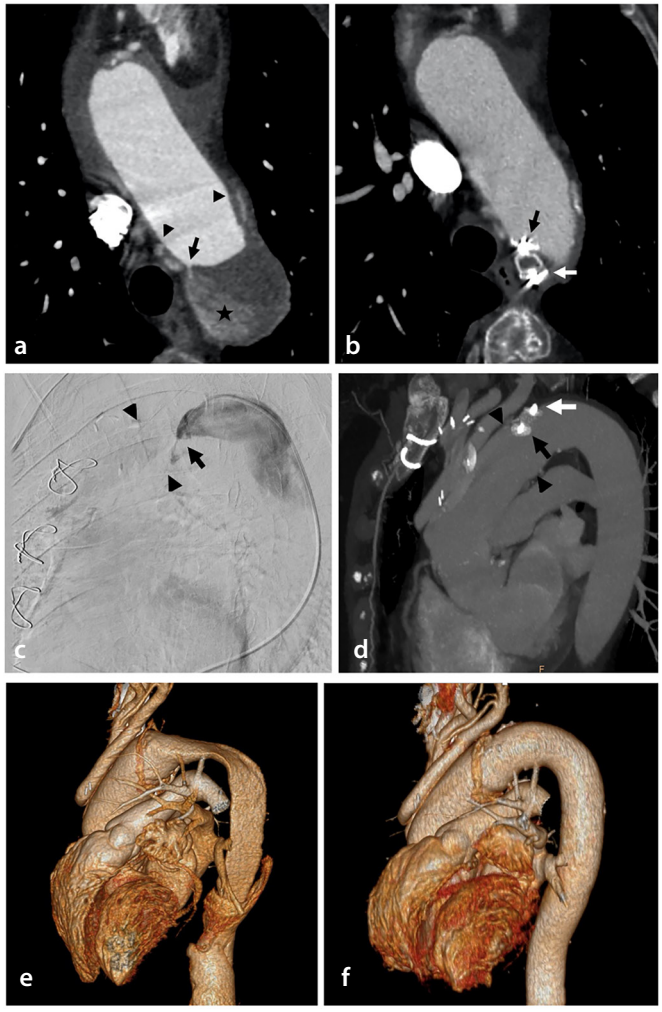

Figure 3. Plug treatment of chronic aortic dissection with aneurysmal progression at the thoracic level in a patient after Bentall surgery. The entry tear (ET, black arrow) is located at the distal anastomosis (arrowheads) of the ascending aortic surgical prothesis. A type II plug (white arrow) is deployed through the ET. The proximal wing is in the true lumen (TL), and the body and distal wing are in the false lumen (FL). Axial computed tomography scan with injection at arterial time before **(a)** and after **(b)** embolization. Serigraphy with injection **(c)** identifying the ET. Maximum intensity projection reconstruction scans **(d)** after embolization. Three-dimensional reconstruction at arterial time before **(e)** and after **(f)** embolization. After treatment: regression of the FL, re-expansion of the TL, and decrease in the aortic diameter.

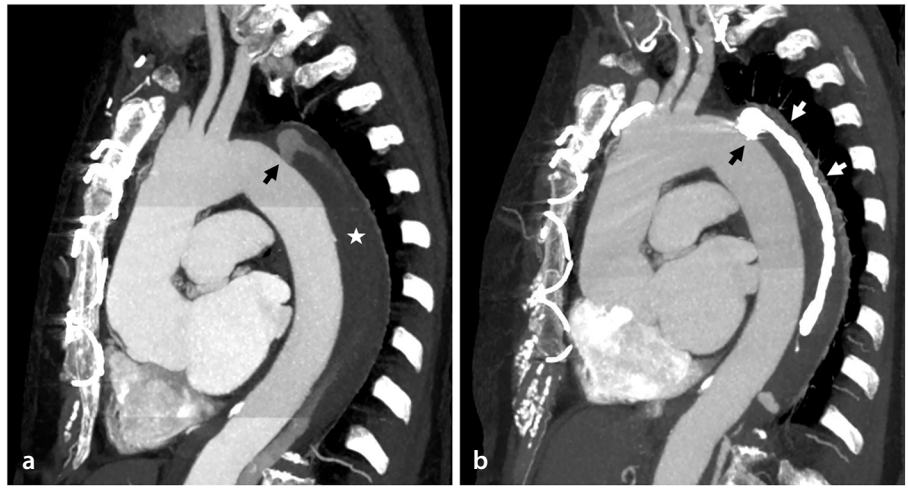

Figure 4. Treatment of a chronic aneurysmal dissection at the thoracic level using glue. Sagittal maximum intensity projection reconstruction scans before **(a)** and after **(b)** glue embolization (white arrows). Occlusion of the entry tear (black arrow) allows thrombosis of the false lumen (white star).

strategy. A few studies have been conducted on embolization agents using coils and cyanoacrylate glue[21,22] or plugs;[23,24] these have been concomitant or with prior TEVAR but in small cohorts. Even if indications of CFLO differ with TEVAR, aortic diameter control has been reported in 65% of patients managed with isolated TEVAR.[25] In the present study, the results suggest that CFLO may improve TEVAR results and that this technique can be an effective option when TEVAR cannot be performed because of anatomical contraindications. The retrograde expansion of dissection often requires extended methods, such as a covering stent,[26] to achieve sufficient sealing and avoid inadvertently covering the SAT with the stent graft.

This study did not reveal a significant reduction in aortic diameter ($P = 0.115$). Although the optimal timing for the embolization procedure is unclear, it seems more effective in the subacute period (14 to 90 days),[27] as the aorta is less likely to reshape in the chronic phase.[3] In this study, the average time from AD to CFLO was 33 months, indicating that earlier intervention might have led to improved outcomes. Additionally, assessing aortic diameters at 1 year may underestimate the long-term effects of this condition. Thrombus reduction in the FL may take time, emphasizing the need for a longer follow-up to observe these effects. In cases with a large thrombotic FL, the thrombus does not decrease in size, which means there is no overall reduction in aortic diameter.

Of course, the retrospective character of this study leads to missing data, and the monocentric design is a limitation, but this study was conducted in a single specialized university hospital, reducing the risk of patients being treated in another close geographical center. The number of patients included allowed inter-individual variability and was sufficient for this type of intervention. Due to the rarity of these cases, our study offers an additional contribution to the literature, which could be valuable for future guidance on the subject. The absence of a control group is a limitation but ethically justifiable, as the natural course of the pathology is well understood. The association of CFLO and TEVAR techniques is common and, unfortunately, limits the demonstration of the effectiveness of the isolated CFLO technique. Nevertheless, the isolated CFLO technique was used with approximately 50% of our study population and produced satisfying results, achieving 60% complete thrombosis and 90% positive aortic remodeling, demonstrating its effectiveness when performed alone. In the literature, CFLO achieves complete FL thrombosis in 60% of patients compared with 40% for isolated TEVAR at the 2-year follow-up[28] and 60%–80% for combined CFLO and TEVAR in a review conducted by Spanos et al. involving 101 patients.[29]

Table 2. Angiographic data

Variables	n = 20
Duration from AD (months), median (IQR)	32.5 (8.8–76.5)
Procedure duration (min), median (IQR)	124.0 (78.5–158.5)
Scopy duration (min), median (IQR)	17.4 (12.1–24.3)
Dose (Gy.cm^2), median (IQR)	175.2 (59.1–319.2)
CFLO single technique, n (%)	7 (35.0)
CFLO combined technique, n (%)	13 (65.0)
Occlusion material used*, n (%)	
Coil	5 (25.0)
Coil + glue	2 (10.0)
Coil + plug	3 (15.0)
Coil + SAT stenting	2 (10.0)
Glue + plug	2 (10.0)
Plug + SAT stenting	2 (10.0)
Plug	2 (10.0)
Coil + glue + plug	2 (10.0)
Total number of CFLO sessions, median (IQR)	1.5 (1.0–2.3)
Patients with ≥2 CFLO sessions, n (%)	10 (50.0)
Isolated CFLO**	10 (50.0)
Additional TEVAR treatment after CFLO, n (%)	4 (20.0)
Interval to CFLO after TEVAR (months), median (IQR)	6.6 (1.5–16.7)
Interval to TEVAR after CFLO (months), median (IQR)	10.2 (4.9–16.9)

*Considering all CFLO sessions; **isolated CFLO = CFLO without prior or additional TEVAR; n, number; AD, aortic dissection; IQR, interquartile range; CFLO, circulating false lumen occlusion; SAT, supra-aortic trunk; TEVAR, thoracic endovascular aortic repair.

Table 3. Imaging follow-up

Variables	n = 20
Duration from baseline CT scan to CFLO (days), median (IQR)	51.0 (110.8–10.3)
Patient follow-up (years), median (IQR)	4.7 (2.9–12.4)
Follow-up aortic diameter evolution, n (%)	
Decrease	8 (40.0)
Stable	5 (25.0)
Increase	7 (35.0)
Baseline CT scan aortic diameter (mm), median (IQR)	52.5 (43.8–59.8)
1-year CT scan aortic diameter (mm), median (IQR)	54.0 (41.8–68.5)
Baseline CT scan FL diameter (mm), median (IQR)	25.0 (19.5–33.0)
1-year CT scan FL diameter (mm), median (IQR)	16.0 (10.3–26.8)
1-year CT scan FL circulatory status, n (%)	
Thrombosed	12 (60.0)
Partially thrombosed	8 (40.0)
1-year CT scan frequencies of complete thrombosis, n (%)	
Zone 3	17 (85.0)
Zone 4	13 (65.0)

n, number; CT, computed tomography; CFLO, circulating false lumen occlusion; IQR, interquartile range; FL, false lumen.

Table 4. Symptoms and complications reported after CFLO

Variables	n = 20
Complications after CFLO, n (%)	
Grade I, n (%)	
Pre-embolization coil migration	1 (5.0)
Post-embolization syndrome	5 (25.0)
Grade II, n (%)	
Transient ischemic stroke	1 (5.0)
Secondary aneurysm event*, n (%)	
Aneurysm chronic infection	1 (5.0)
Aneurysm infection with aorto-esophageal fistula	1 (5.0)

*Not directly related to CFLO; n, number; according to the European Society of Cardiovascular and Interventional Radiology classification system for complications; CFLO, circulating false lumen occlusion; 1 patient contracted an aortic aneurysm infection complicated by an aortic fissure and esophago-aortic fistula; 16 patients did not present any complications or secondary aneurysm events.

The anticipated consequences and complications were minimal compared with the underlying pathology. Therefore, CFLO can be considered relatively safe considering the absence of complications in 90% of patients, whereas TEVAR has a 30-day morbidity rate of 36.5%.[29] In comparison to TEVAR, no cases of spinal cord ischemia or associated complications have been reported with the use of CFLO, which could be a decisive advantage when choosing between the two techniques.

As mentioned previously, the precise description of the conditions for the use of embolic materials is challenging, and many parameters must be considered in the selection of the embolization material to be used. The small sample size of patients and the study design unfortunately did not allow for additional statistical tests to identify favorable or unfavorable predictive factors that influence the effectiveness of embolization in achieving either complete or partial FL thrombosis. One factor that appears to contribute to the failure of remodeling is the presence of calcifications on the wall of the FL. However, future efforts should focus on identifying these predictive factors, and further studies are needed to support and refine the indications for CFLO.

The CFLO is a technically complicated procedure with multiple parameters to be managed. The success of this treatment depends on several factors, including the experience of the operator, and must be performed in close collaboration with medical–surgical teams. A high level of understanding of aortic pathology and fluid mechanics is required. These results promote the use of CFLO techniques in the future, as they are currently not included in the guidelines.

This study highlights the potential of CFLO as a valuable addition to the therapeutic arsenal for chronic AD, particularly when traditional methods such as TEVAR do not achieve complete FL thrombosis. This technique offers a promising alternative for patients who do not respond fully to existing treatments and could reduce the risk of aneurysmal progression and aortic rupture, ultimately improving long-term patient outcomes. By targeting the ET and using various embolization materials (coils, glue, and plugs) or uncovered stents, CFLO allows for a tailored treatment approach that can be adapted to individual patient anatomy and pathology, enhancing treatment efficacy and safety. The study suggests that CFLO may reduce the incidence of complications related to persistent FL circulation, such as aneurysmal progression, thereby potentially decreasing the need for more invasive procedures. No cases of spinal cord ischemia were reported with this procedure, which may provide a significant advantage when comparing CFLO to TEVAR. It is important to emphasize that this management should be multidisciplinary and performed in close collaboration with cardiac surgery and cardiology teams.

In conclusion, this study supports the efficacy and safety of endovascular occlusion in the management of chronic AD. Further studies are needed to define the exact place and most opportune timing of this procedure in the management algorithm for patients with aneurysmal evolution following AD.

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Footnotes

Conflict of interest disclosure

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