Percutaneous management of left ventricular assist device outflow graft obstruction

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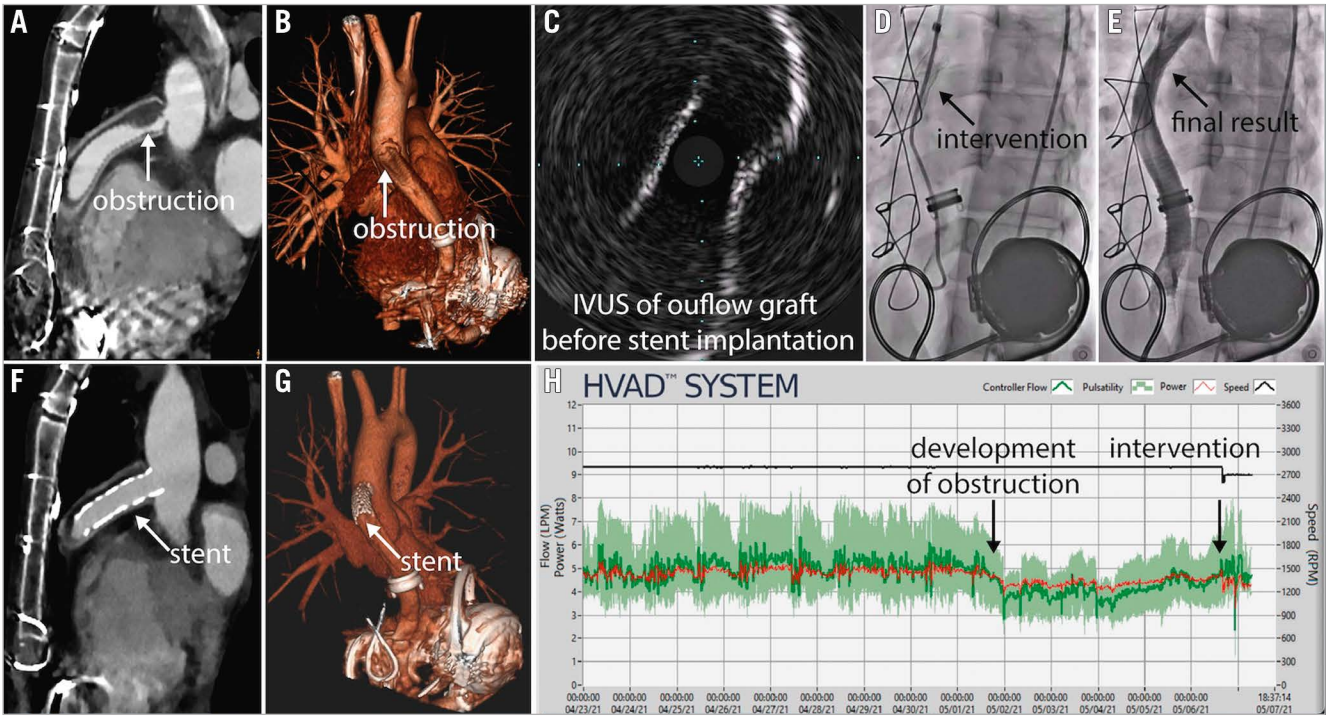

Figure 1. *Multimodality imaging and treatment of left ventricular assist device (LVAD) outflow graft obstruction. A 37-year-old man who received a HeartWare ventricular assist device (HVAD) due to a pheochromocytoma with stress-induced, non-reversible cardiomyopathy four years earlier was admitted due to general malaise and low-flow alarms. Computed tomography (CT) angiography demonstrated HVAD outflow graft obstruction (A: white arrow; B: white arrow), which was confirmed with intravascular ultrasound (IVUS; C). Peak-to-peak pressure gradient was 75 mmHg. The stenosis was treated with a balloon-expandable covered stent (D: black arrow; Advanta V12, 12 mm×41 mm), leading to an increase in LVAD flow to 3.5 L/min. The control angiography showed a good procedural result (E: black arrow), which was confirmed by CT (F: white arrow; G: white arrow). The HVAD log showed a sudden decrease in pump flow four days prior to the procedure and restored normal flow following the intervention (H).*

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Left ventricular assist devices (LVAD) improve survival in patients with advanced heart failure[1]. LVAD outflow graft obstruction (OGO) is a potentially fatal complication, with the estimated incidence of 0.03 events per patient-year[2]. Percutaneous OGO management offers a less invasive alternative to surgery[3]. We present our experience based on five patients with OGO, who underwent percutaneous treatment. Patient baseline characteristics and procedural details are summarised in **Supplementary Table 1**. Three patients had a HeartMate 3 (Abbott) and two patients had a HeartWare (Medtronic) ventricular assist device. The mean time from LVAD implantation or replacement to OGO was 2.4 years.

Clinical presentation included general malaise with low-flow alarms, progressive dyspnoea, acute decompensated heart failure, cardiogenic shock and out-of-hospital cardiac arrest (OHCA). Review of LVAD data log files showed various patterns of flow changes, including progressive decrease followed by sudden significant decrease in one patient, sudden decrease in two patients, sudden drop in flow in a patient who presented with OHCA and an increase followed by a decrease of flow in one patient. Intraluminal stenosis was diagnosed using computed tomography angiography (CTA) in four patients, except for one, who presented with OHCA and was transferred directly to the catheterisation laboratory. Before the intervention, all patients were discussed by the Heart Team and provided informed consent for the off-label use of peripheral endovascular equipment. All procedures were performed via a femoral artery approach (8 Fr-14 Fr) with conscious sedation. The outflow graft was engaged with an angled-tip catheter (multipurpose or pigtail) in a left anterior oblique (LAO) 40° view. A 0.035 wire was advanced into the outflow graft, with care taken to avoid wire interaction with the pump impeller. In all cases, angiography confirmed significant stenosis of the outflow graft with peak-to-peak gradients from 40 to 80 mmHg. In four cases, we proceeded directly from angiography to stenting. In one case, when graft twisting was suspected, balloon "graftoplasty" was performed with a 10 mm non-compliant balloon prior to stenting to ensure the feasibility of stent deployment (Advance; Cook Medical)[4,5]. We used balloon-expandable covered stents with a diameter of 10-18 mm (Advanta V12 [Getinge], n=4; BeGraft [Bentley], n=4). After stent deployment, we repeated angiography to evaluate for migration of the obstruction. In two patients, intravascular ultrasound (IVUS) was used to differentiate between the external and internal obstruction and confirm the adequate lumen diameter[5]. In a patient with diffuse obstruction, a cerebral embolic protection device was used (TriGUARD 3; Keystone Heart), followed by implantation of three balloon-expandable covered stents. Post-dilation was performed with a non-compliant balloon (Advance). The femoral artery puncture site was closed with a percutaneous closure device (Perclose ProGlide; Abbott). Control CTA was performed to evaluate the effect of the intervention. Three patients were discharged from the hospital: two following stenting and one following surgical replacement. Images of CTA, IVUS and/or angiography showing OGO diagnosis and treatment are shown in **Figure 1**, **Supplementary Figure 1**-**Supplementary Figure 4**. Based on our experience, percutaneous OGO management is a feasible and less invasive alternative compared to surgical revision. Although we used balloon-expandable covered stents due to their availability, external obstructions may be treated with a self-expanding, uncovered stent, allowing the sheath size to be decreased and the procedure to be performed using a single long stent. The safety and efficacy of percutaneous OGO management should be evaluated in future clinical trials.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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Supplementary data

Supplementary Table 1. Patient baseline characteristics and procedural details.

Supplementary Figure 1. Diagnostic work-up and percutaneous management of LVAD outflow graft obstruction.

Supplementary Figure 2. Computed tomography angiography and interventional treatment of LVAD outflow graft obstruction.

Supplementary Figure 3. LVAD outflow graft obstruction due to twisting, treated with stent implantation.

Supplementary Figure 4. Stent implantation to the distal part of LVAD outflow graft and migration of the obstruction to the proximal part.

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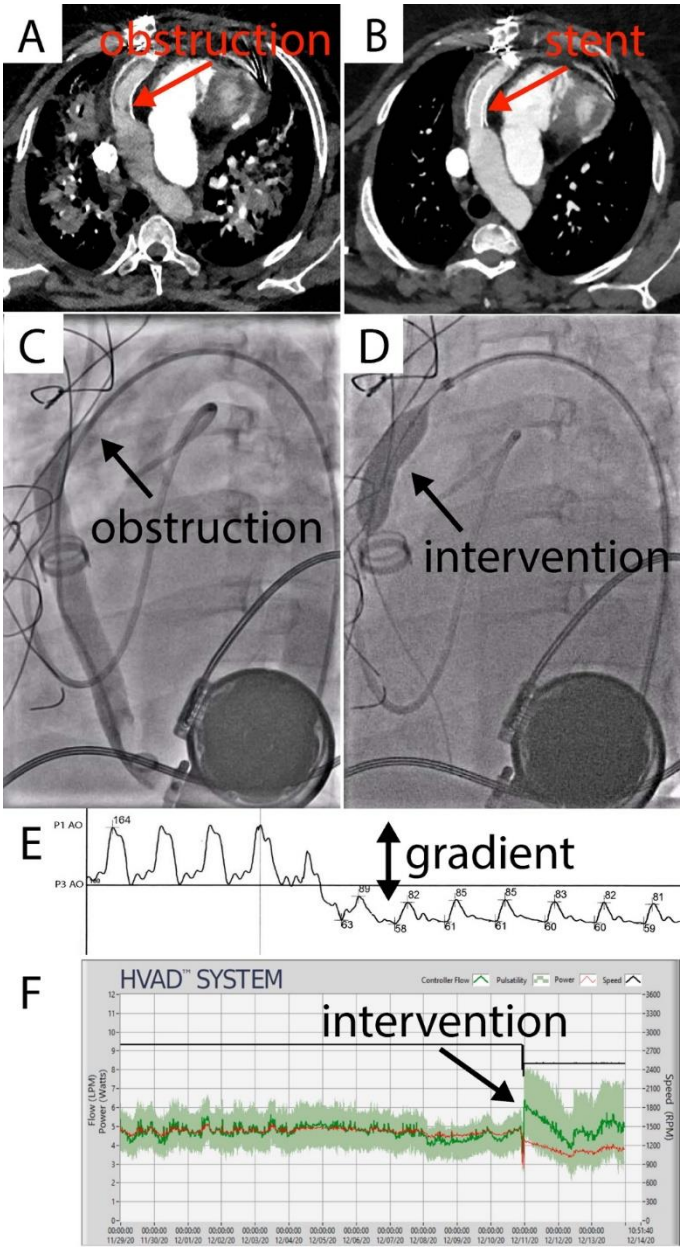
Supplementary data

Supplementary Table 1. Patient baseline characteristics and procedural details.

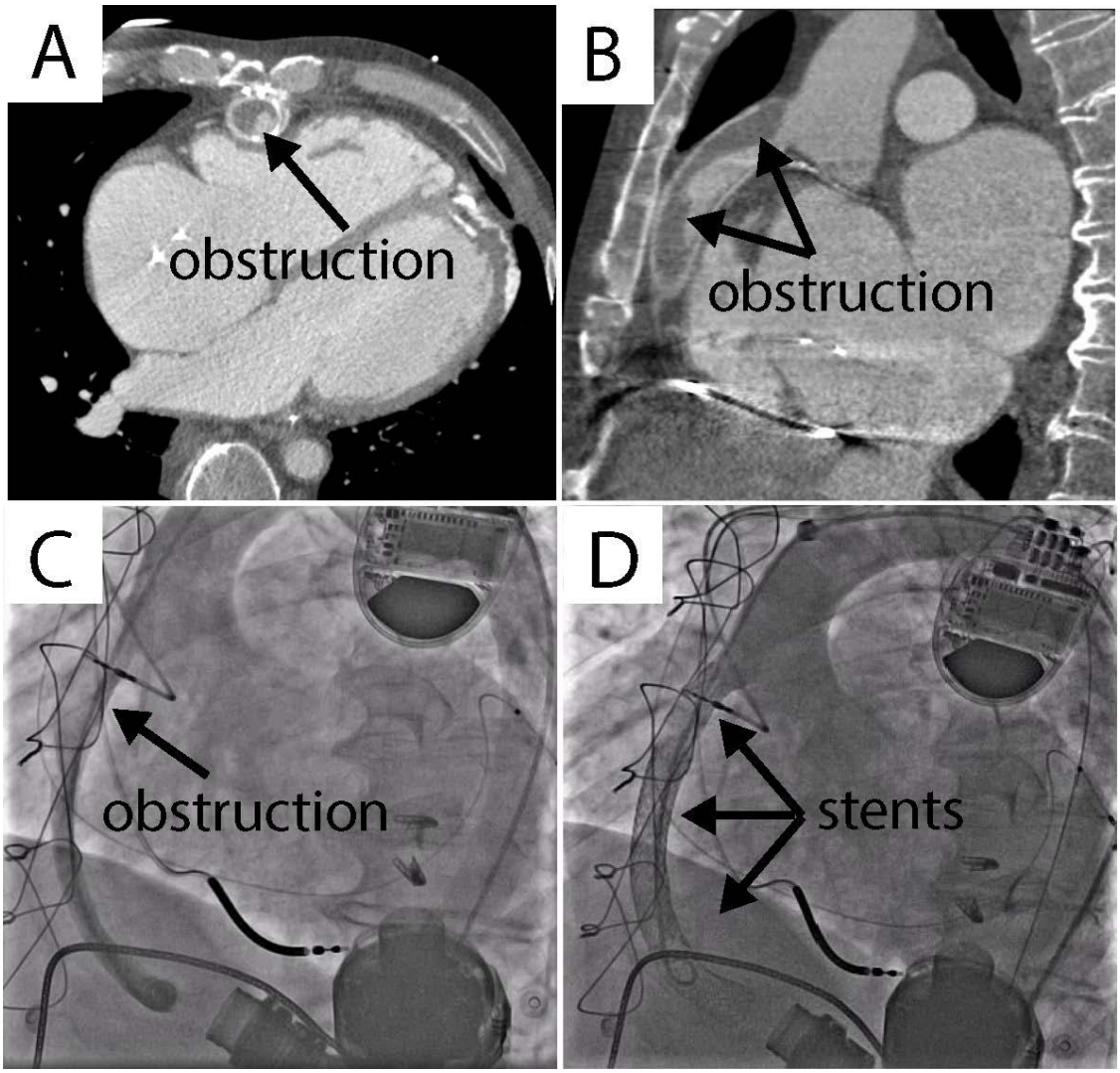
	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Baseline characteristics					
Age, years	31	51	49	54	37
Gender	Female	Male	Male	Male	Male
Type CMP	Ischaemic	Dilated	Ischaemic	Ischaemic	Catecholamine-induced
LVAD type	HVAD	HM3	HM3	HM3	HVAD
Time to OGO*, years	1	4	2	1	4
Prior LVAD replacement	Yes	No	No	Yes	No
Procedural details					
Access	FA 8 Fr	FA 14 Fr	FA 8 Fr	FA 8 Fr	FA 8 Fr
Predilation	-	-	10x20 mm	-	-
Stent	Advanta V12[1] 10×38 mm	BeGraft[2] 16x38 mm 18x38 mm 18x48 mm	Advanta V12[1] 12x61 mm	Advanta V12[1] 12x61 mm	Advanta V12[1] 12x41 mm
Post-dilation	10x20 mm	-	-	-	-
Need for surgical reintervention	No	No	No	No	Yes
Survival to discharge	Yes	No	Yes	No	Yes
Outcomes	6-month follow-up: screening for heart transplantation	-	Patient discharged for palliative care, died on post-procedural day 4	-	4-month follow-up: awaiting heart transplantation

*Time since LVAD implantation/replacement. [1] Advanta V12, Getinge; [2] BeGraft, Bentley.
CMP: cardiomyopathy; FA: femoral artery; HM3: HeartMate 3; HVAD: HeartWare ventricular assist device; LVAD: left ventricular assist device; OGO: outflow graft obstruction

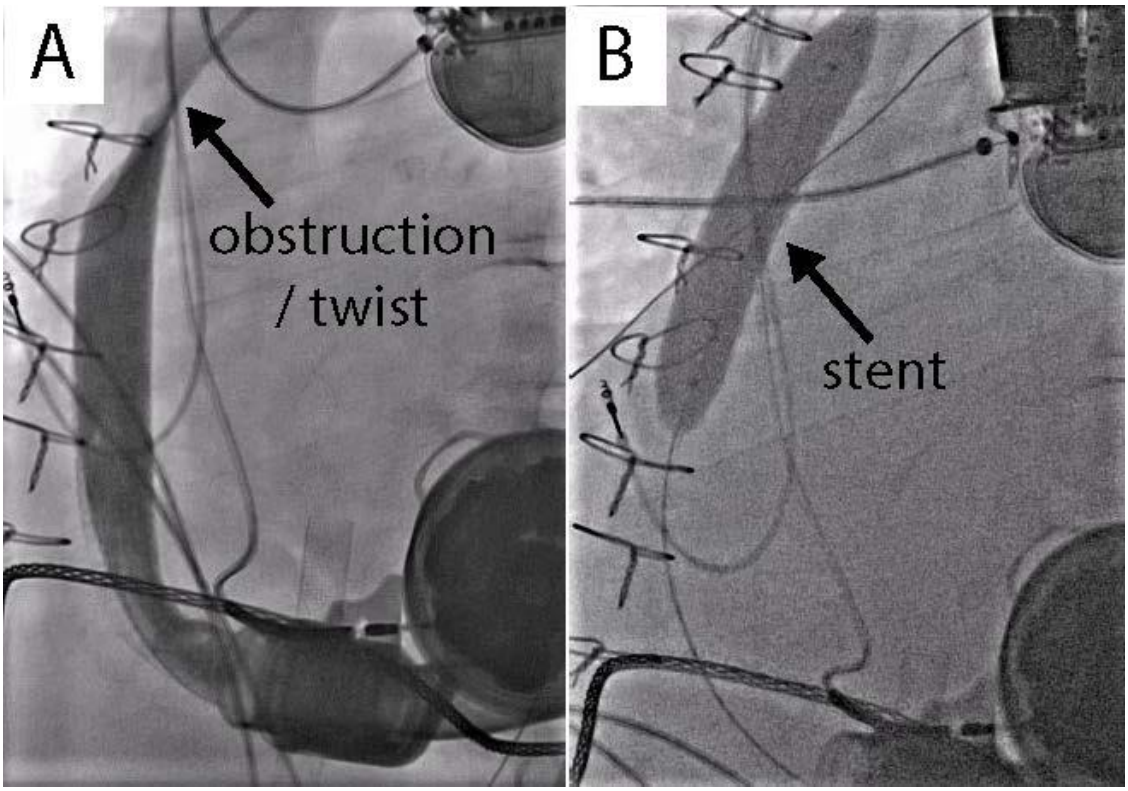


Supplementary Figure 1. Diagnostic work-up and percutaneous management of LVAD outflow graft obstruction.

A 31-year-old woman, two years after HeartWare ventricle assist device (HVAD) implantation for ischaemic cardiomyopathy and one year after HVAD replacement due to pump thrombosis, was admitted with progressive dyspnoea. In the course of hospitalisation, bilateral pneumonia was diagnosed and treatment with antibiotics was initiated. Following the initial stabilisation, the patient had respiratory deterioration and developed cardiogenic shock with a low left ventricular assist device (LVAD) flow. Computed tomography angiography (CTA) demonstrated an outflow graft obstruction (OGO) 2 cm before the anastomosis with the ascending aorta (A: red arrow). Angiography confirmed the obstruction (C: black arrow) with a peak-to-peak gradient of 80 mmHg (E: black arrow). The patient underwent emergency percutaneous intervention using balloon-expandable covered stent (D: black arrow; Advanta V12, 10×38 mm), which resulted in. in an immediate increase in HVAD flow to normal values (F: black arrow). Control CTA demonstrated complete resolution of the OGO (B: red arrow). Further clinical course was uneventful and the patient was discharged home on day 8 after procedure. The six-month follow-up in the outpatient clinic was uneventful. This case has previously been described (Gasecka et al. Netherlands Heart J. 2021:1-2)[6].

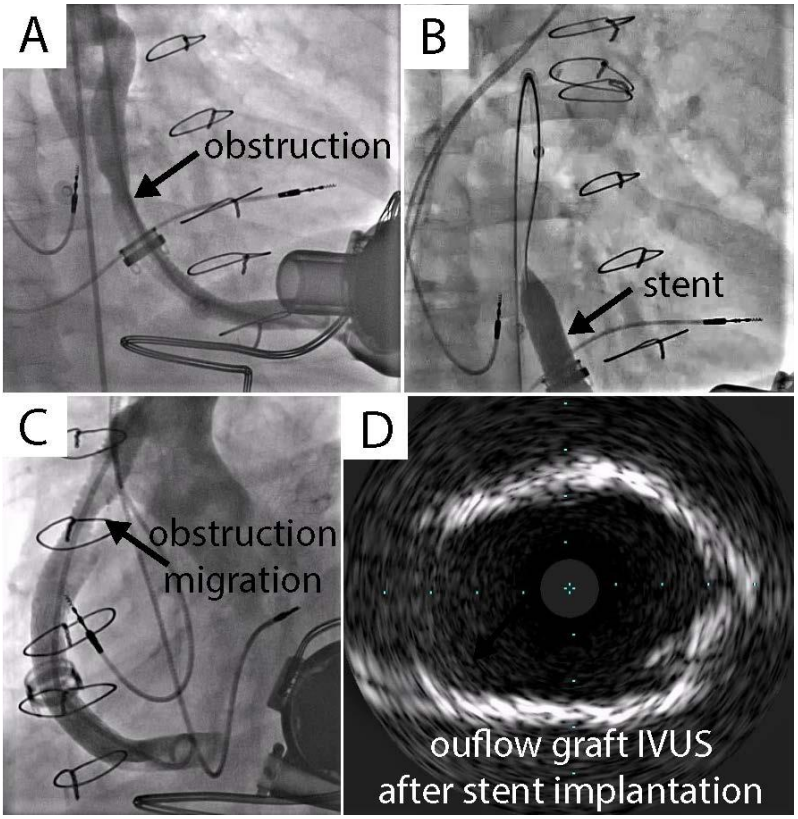


Supplementary Figure 2. Computed tomography angiography and interventional treatment of LVAD outflow graft obstruction.
A 51-year-old man with a history of dilated cardiomyopathy due to LMNA mutation presented with acute decompensated heart failure in conjunction with acute renal failure four years after HeartMate 3 implantation. The patient required inotropic and vasopressor support (noradrenaline, dobutamine, milrinone), as well as transient dialysis. However, he remained haemodynamically unstable and could not be weaned from the haemodynamic support. Computed tomography angiography (CTA) demonstrated extensive stenosis in the mid and distal part of the outflow graft cannula, with nearly complete obstruction just before to the anastomosis with the aorta, likely due to biodebris accumulation (A, B: black arrows). Angiography confirmed an extensive stenosis in the mid and distal part of the outflow graft cannula (C: black arrow). Since the obstruction was diffuse and thrombosis could not be ruled out, a cerebral embolic protection device (TriGUARD 3, Keystone Heart) was used to prevent adverse cerebrovascular events. Subsequently, the obstruction was treated with three balloon-expandable covered stents (D: Bentley; 16x38 mm, 18x38 mm, 18x48 mm). However, the patient remained dependent on inotropic support. He died on day 4 after the procedure.



Supplementary Figure 3. LVAD outflow graft obstruction due to twisting, treated with stent implantation.

A 49-year-old man, two years after HeartMate 3 implantation because of an ischaemic cardiomyopathy presented after out-of-hospital cardiac arrest due to asystole. After 45 minutes of cardiopulmonary resuscitation, a return of spontaneous circulation was achieved. The clinical picture, minimal left ventricular assist device (LVAD) flow (1 L/min) and aortic valve opening with every beat on bedside echocardiography raised a suspicion of LVAD dysfunction. Given the haemodynamic instability with massive pulmonary oedema, the patient was transferred directly to the catheterisation laboratory to initiate veno-arterial extracorporeal membrane oxygenation support. Subsequently, outflow graft angiography was performed, showing nearly complete occlusion of the graft anastomosis with the aorta (A: black arrow) with a mean gradient of 100 mm Hg along the outflow graft. Since graft twisting was suspected, balloon "graftoplasty" was performed with a 10 mm non-compliant balloon prior to stenting (Advance; Cook Medical) to ensure the feasibility of stent deployment. Subsequently, a balloon-expandable covered stent (Advanta V12; Getinge, 12 mm×61 mm) was implanted (B: black arrow). This resulted in an immediate increase in LVAD flow and haemodynamic stabilisation of the patient. Control computed tomography angiography demonstrated a patent stent in the outflow graft. Despite haemodynamic improvement, the neurologic status of the patient remained poor and the patient died one day after the procedure.



Supplementary Figure 4. Stent implantation to the distal part of LVAD outflow graft and migration of the obstruction to the proximal part.

A 54-year-old man, six years after HeartMate 3 implantation due to an ischaemic cardiomyopathy presented with cardiogenic shock and low-flow alarms. Patient previously underwent two left ventricular assist device (LVAD) replacements due to pump thrombosis at year 3 and 5 after the initial LVAD implantation, receiving the last LVAD one year prior to this presentation. Due to clinical suspicion of recurrent pump thrombosis, systemic thrombolysis with alteplase was initiated, leading to a decrease in LVAD power, but no increase in LVAD flow (2.0-2.5 L/min). Computed tomography angiography (CTA) showed signs of outflow graft stenosis. Due to the poor clinical condition, concomitant severe right ventricular dysfunction, reduced lung capacity and chronic infection, the patient was deemed inoperable for outflow graft revision and a percutaneous approach was chosen. Angiography confirmed the stenosis with a peak-to-peak gradient of 50 mmHg (A: black arrow). A balloon-expandable covered stent (Advanta V12; Getinge, 12 mm×61 mm) was implanted via a femoral artery approach (B: black arrow). Control angiography following stent deployment showed migration of the obstruction/twist to the proximal part of the outflow graft (C: black arrow), with the residual gradient of 40 mmHg. IVUS confirmed significant migration of extraluminal biodebris (D). Since implantation of the second stent posed a risk of further obstruction migration and occlusion of the anastomosis between the outflow graft and aorta, the procedure was aborted. Conservative management including inotropic support was intensified, albeit unsuccessful. The patient died the next day.