European Heart Journal - Case Reports (2025) **9**, ytaf094
https://doi.org/10.1093/ehjcr/ytaf094

CASE REPORT
Cardiovascular surgery

Balloon-expandable stent and self-expandable stent combined to treat coarctation of the aorta with descending aortic aneurysm: a case report

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Received 5 May 2024; revised 21 November 2024; accepted 12 February 2025; online publish-ahead-of-print 18 March 2025

Background Coarctation of the aorta is often associated with aortic dilatation, presenting a complex challenge for stent-based interventions. To address this, we have developed a novel combination of stent treatments to manage this dual pathology effectively.

Case summary A 29-year-old hypertensive patient with a coarctation of the aorta and a descending thoracic aortic aneurysm was evaluated for treatment. Contrast-enhanced computed tomography angiography (CTA) revealed significant narrowing at the aortic arch (Zone 2, proximal to the left subclavian artery) with a diameter of 5.04 mm. Additionally, the descending aorta had an aneurysmal dilation measuring 29.65 mm. We applied an innovative approach combining a balloon-expandable stent (BES) with a self-expandable stent (SES). Post-procedure CTA demonstrated favourable aortic remodelling, with the narrowest point of the aorta expanding from 5.04 to 15.95 mm.

Discussion This novel technique of implanting a BES within an SES effectively addresses both the aortic coarctation and the descending aortic aneurysm. By tripling the diameter of the coarctation, the approach maximizes aortic expansion while protecting the aorta. Moreover, the combination of these stents enhances overall stability, reducing the risk of stent migration or displacement.

Keywords Case report • Aortic disease • Coarctation of aorta • Descending aneurysm • Stent • Balloon-expandable stent • Self-expandable stent

ESC curriculum 9.1 Aortic disease • 7.5 Cardiac surgery

Learning points

- Coarctation of the aorta (CoA) with descending thoracic aorta aneurysm is a rare and complicated conventional heart disease that we should be aware of the stent-related complications.
- The use of two type stents combined to treat complicated CoA is an innovative and safe strategy, which can avoid acute stent-related complications and have a positive prognosis.

Introduction

Stent implantation is the preferred treatment for aortic coarctation (CoA) in both adults and children.[1,2] Despite its widespread use, several challenges remain in optimizing outcomes for these patients. Key issues include selecting the appropriate stent for secure anchorage; minimizing the risk of stent displacement, fracture, and vessel injury; and addressing the management of descending aortic aneurysms while

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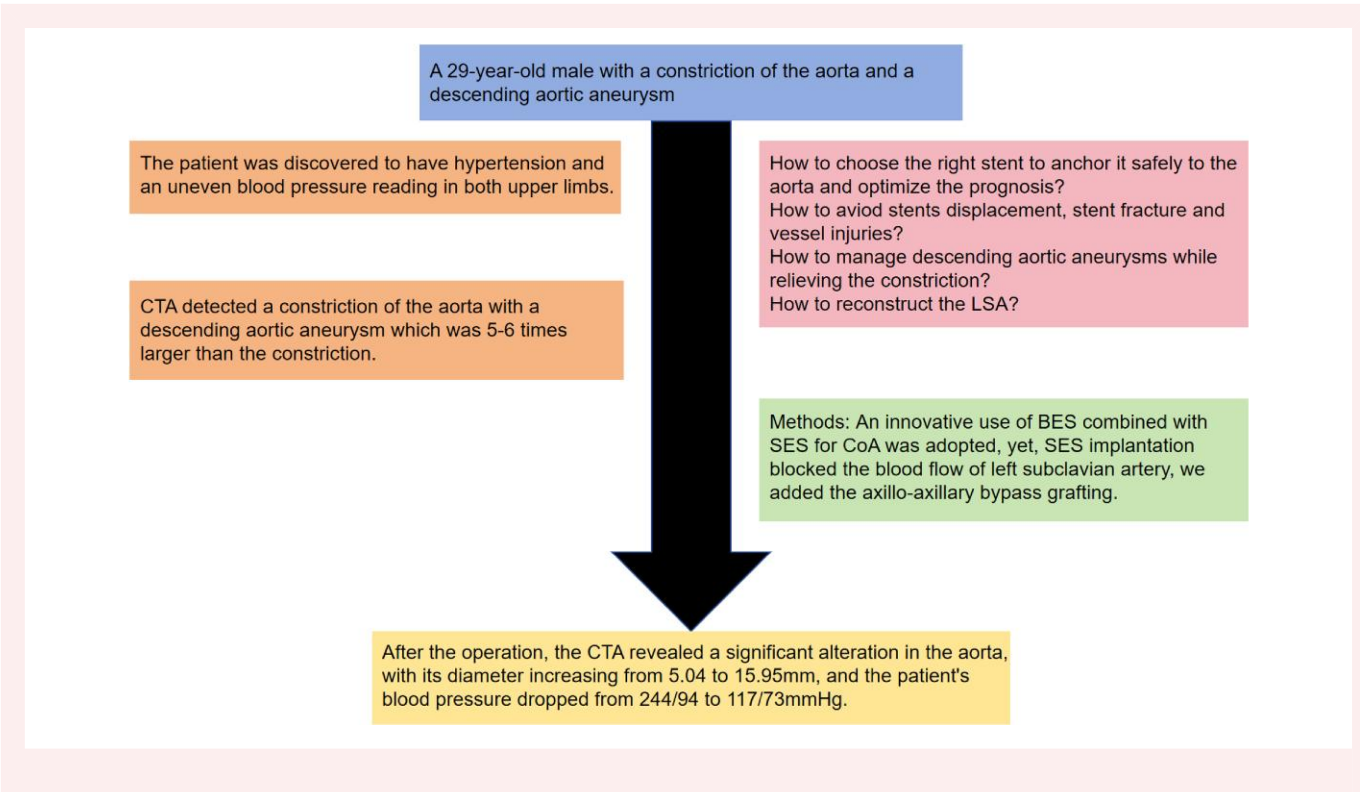
Handling Editor: Claudio Montalto
Peer-reviewers: Denizhan Ozdemir; Andriana Anagnostopoulou
Compliance Editor: Piera Ricci

alleviating the aortic constriction. Additionally, the reconstruction of the left subclavian artery (LSA) presents a significant surgical consideration.

Summary figure



Case presentation

A 29-year-old male was admitted to our hospital with a complaint of left arm numbness lasting for 1 week on 6 October 2023. During physical examination, he was found to have hypertension, with significantly differing blood pressure readings between the upper limbs: 200/68 mmHg in the right arm and 125/90 mmHg in the left arm. Computed tomography angiography (CTA) revealed a marked stenosis at the aortic arch (Zone 2, just before the LSA), with a narrowed diameter of 5.04 mm, and a dilated descending aorta measuring 29.65 mm in diameter (*Figure 1*).

The planned treatment approach for CoA with a Cheatham–Platinum stent (CP stent) presented several challenges. The location of the stenosis, situated at the junction between the aortic arch and the descending aorta, involved a sharp 90-degree angle, increasing the risk of stent fracture due to high blood flow forces. Additionally, the stenosis was highly restrictive, which raised concerns that a single stent might not fully correct the narrowing. The distal descending aorta's diameter was 5–6 times larger than the stenosed segment, complicating the potential for proper sealing of the stent and increasing the risk of stent migration or embolization. The dilated aorta also heightened the risk of aortic dissection, rupture, and pseudoaneurysm formation. While conventional stents have been effective for discrete CoA, the combination of severe stenosis and distal aortic ectasia required a more tailored approach.

To address these challenges, we adopted an innovative strategy combining a balloon-expandable stent (BES) with a self-expanding stent (SES) for the treatment of CoA. Placement of the SES will occlude the LSA, so an axillary-axillary artery bypass needs to be established before the main operation. The incision is made 1 cm below the left and right clavicles, after which subcutaneous tissue and muscles are carefully separated in layers. The bilateral axillary arteries are then exposed and prepared for subsequent use. Following heparinization, blood flow is temporarily occluded, and an 8 mm synthetic graft is anastomosed end-to-side. A long, curved vascular forceps is employed to create a subcutaneous tunnel near the left axillary artery to facilitate the end-to-side anastomosis. Intraoperative imaging confirmed the patency of the aortic arch and the left common carotid artery proximal to the stenosis. The stenosed segment measured 5.04 mm in diameter. A self-expanding stent (Medtronic®, 30-30-195 mm) was first inserted via the right femoral artery and positioned distally to the left common carotid artery with slowly dilating (*Figure 2B*). The 14 F sheath was then exchanged, and a BES (NuMed® CP) was placed at the site of the stenosis (*Figure 2C*). Both internal and external balloons (NuMed® BIB, 16–45 mm) were inflated simultaneously, effectively dilating the stenotic region (*Figure 2D*). After satisfactory position and expansion, both the internal and external balloons and the stent were simultaneously released. This step was completed in 47 s, and angiography showed a significant improvement in the stenosis, with the diameter increasing to 15.95 mm (*Figure 2E*). Post-procedure, the stenosis at the distal end of the left common carotid artery was successfully relieved, confirming a positive outcome (*Figure 2F*).

During the procedure, arterial blood pressure was recorded at 5-min intervals. The trends in systolic blood pressure, diastolic blood pressure, and peak-to-peak values are illustrated in *Figure 3*. As shown in *Figure 3*, both systolic and diastolic blood pressures exhibited a significant decrease following the implantation of SES and BES. After the deployment of both stents, the arterial blood pressure dropped from 244/94 mmHg to a normal value of 117/73 mmHg. The peak-to-peak value

Figure 1 Patient's pre-operative computed tomography angiography performance: computed tomography angiography showed significant narrowing of the aortic arch, with diameters of 5.04 mm, accompanied by distinct dilatation of the descending aorta measuring 29.65 mm in diameter.

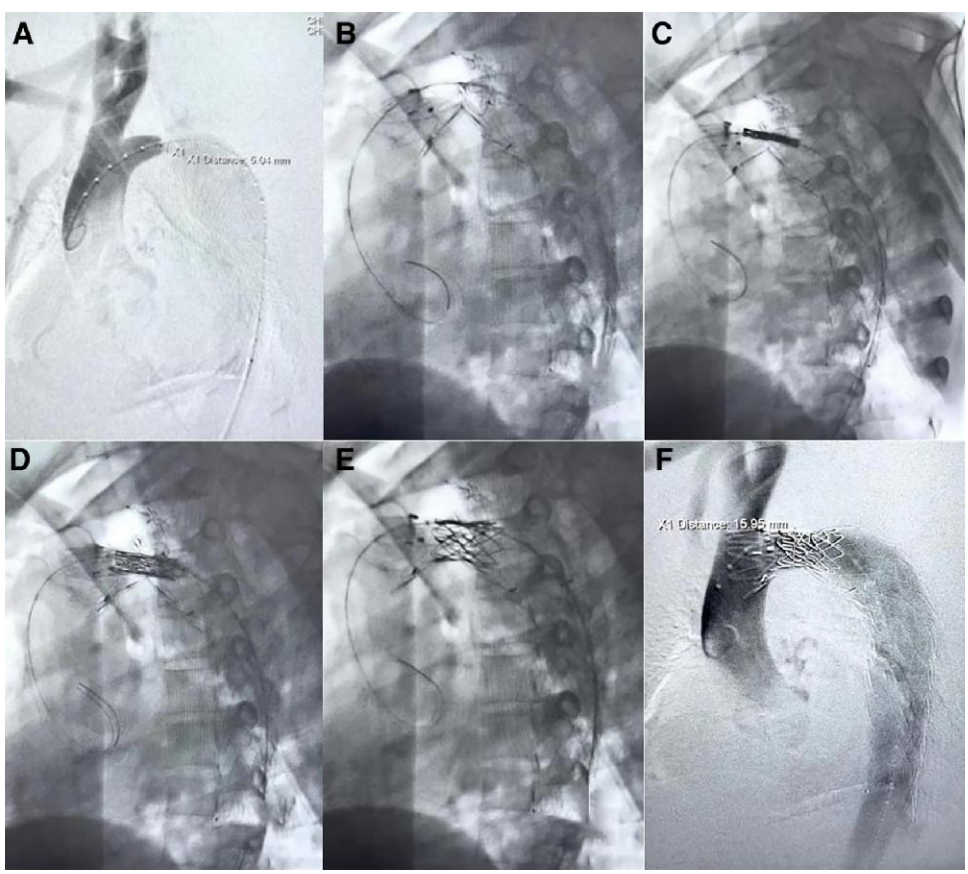


Figure 2 The process of operation: (*A*) intraoperative imaging showed that the aortic arch and left common carotid artery opened proximal to the stenosis. The diameter of the stenosed vessel was 5.04 mm. (*B*) A self-expanded stent (Medtronic®, 30-30-195 mm) was inserted into the aorta. (*C*) A balloon-expanded stent (NuMed® CP) was inserted into the sheath, and the stent was positioned at the stenosis site. (*D*) The internal and external balloons (NuMed® BIB balloon diameter length, 16–45 mm) were released. (*E*) The angiography showed a significant improvement in the stenosis site, with a stenosis diameter of 15.95 mm. (*F*) After the procedure, the stenosis was released indicating a positive outcome from the procedure.

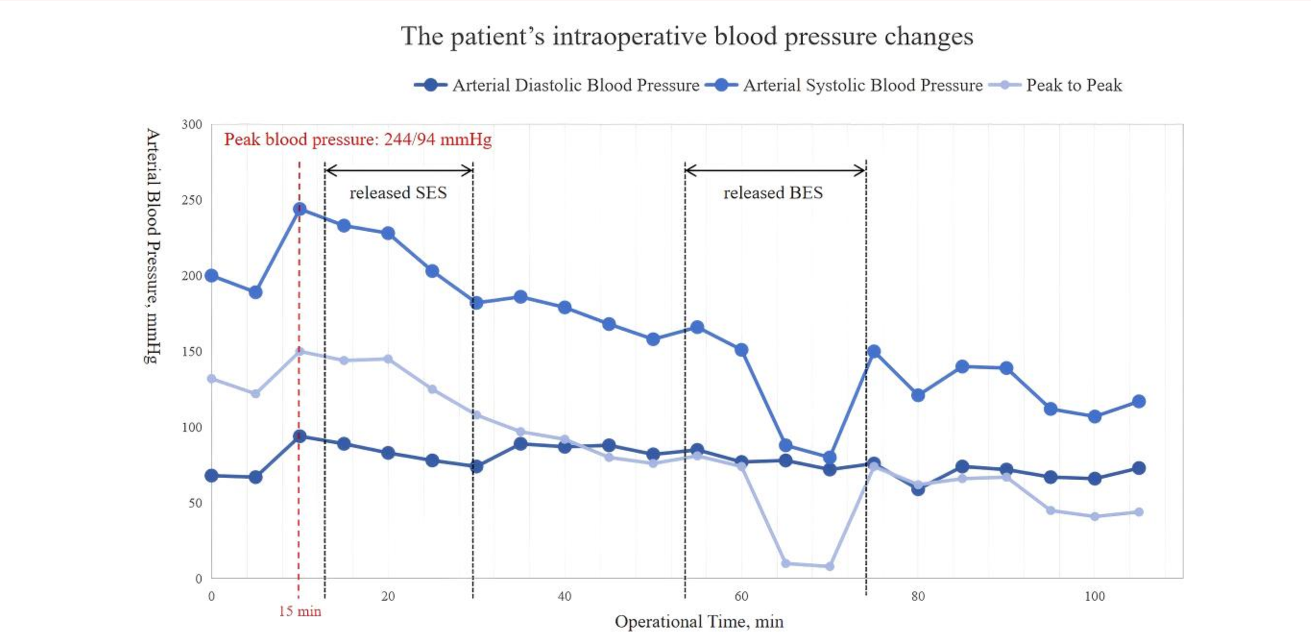


Figure 3 The patient's intraoperative blood pressure changes: the patient's blood pressure significantly decreased in the operation with the self-expanding stent and subsequent balloon-expandable stent implantation. The patient's highest intraoperative blood pressure was 244/94 mmHg; after stenting, the blood pressure was 117/73 mmHg.

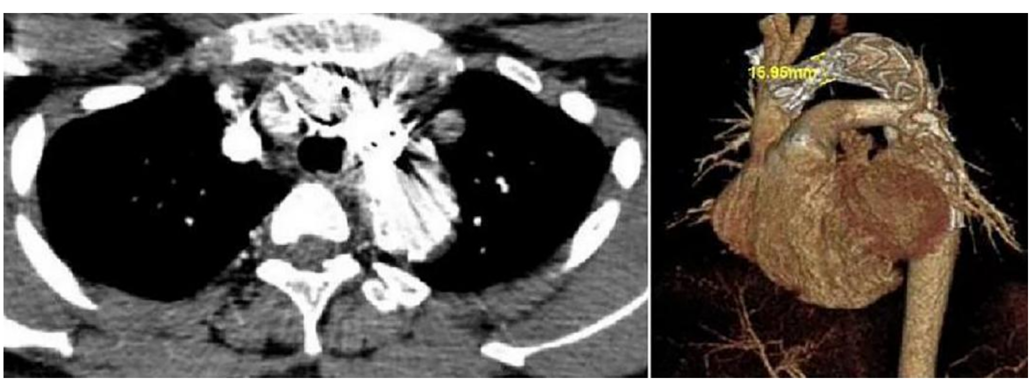


Figure 4 Patient's post-operative computed tomography angiography performance: 4 days after the operation, the computed tomography angiography revealed a significant alteration in the aorta, with its diameter increasing from 5.04 to 15.95 mm and descending aorta protected by aortic stent coverage.

also decreased markedly from 132 to 44 mmHg, reaching its lowest point of 8 mmHg after BES released, and subsequently rising to a normal range of approximately 41 mmHg within a few minutes. The difference between the right radial artery and lower limb pulse was reduced to 2–8 mmHg, indicating improved circulatory dynamics.

The CTA performed 4 days after the procedure showed satisfactory aortic remodelling, with the minimal aortic diameter increasing from 5.04 to 15.95 mm (*Figure 4*). This resulted in a reduction of the patient's blood pressure from 244/94 to 117/73 mmHg. Post-operatively, the patient was started on aspirin therapy to prevent thrombosis for 6 months. Antihypertensive medications were discontinued as blood pressure remained stable. The patient and their family expressed their gratitude to us before discharge, stating that they no longer experienced symptoms such as headaches or dizziness after the operation. They were also pleased that this minimally invasive treatment approach spared them the discomfort associated with open-chest surgery. One month after discharge, the patient came for a follow-up examination, and the CTA showed that the diameter of the stenosed segment of aortic arch was 6.00 mm, indicating that the stents had been mildly dilated one month after implantation. Comparing the CTA at discharge, the implanted stents had not undergone any displacement. According to the patient's daily self-measurement of blood pressure, the blood pressure had been within the normal range, and the pressure difference between the blood pressures of both hands was less than 10 mmHg (*Figure 5*).

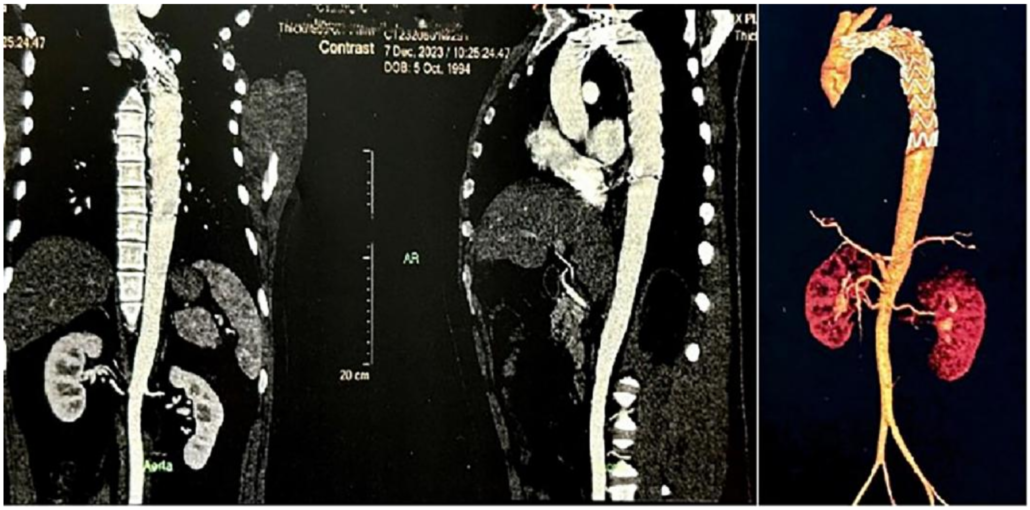


Figure 5 Patient's computed tomography angiography performance 1 month after operation.

Discussion

Coarctation of the aorta is a common congenital heart defect, with an incidence of 0.3–0.4 per 1000 live births.[3–5] It often occurs in isolation but is frequently associated with other congenital anomalies, such as mitral valve abnormalities (60%), aortic arch hypoplasia and other arch defects (18%), ventricular septal defects (13%), and subaortic stenosis (6%).[6]

Treatment options for aortic coarctation include surgery, balloon angioplasty, and stenting.[7] A key observational study by Forbes *et al.* in 2011, conducted by the Consortium for Congenital Cardiovascular Intervention Research, compared the safety and efficacy of these interventions in patients with congenital aortic stenosis. The study found that stenting outperformed both surgical repair and balloon angioplasty in terms of safety and effectiveness, with the balloon angioplasty group experiencing a significantly higher rate of vessel-related complications.[8,9]

Balloon-expandable stents, such as the NuMed CP® stent, are commonly used to treat CoA. These stents are designed to withstand high radial forces, enabling them to effectively expand aortic stenosis. The NuMed CP® stent has the advantages of high support strength, good plasticity, rounded edges to protect the artery, and a low shortening rate, which minimizes the risk of restenosis or stent fracture. However, these same features can lead to complications. The small size and parallel alignment of the proximal and distal ends of the NuMed CP® stent can make it prone to displacement, and the high radial forces can increase the risk of vessel injury, aortic dissection, or pseudoaneurysm. Inspired by a 2022 randomized controlled trial by Sadeghipour *et al.*,[10] which compared SES and BES, we explored a combined approach. The SES serves as a protective cushion, reducing the high radial forces generated by balloon dilation, and also stabilizes the BES, preventing stent migration. This combination allows the BES to fully expand the stenosis while reducing the risk of complications. Additionally, the SES may help prevent restenosis by isolating the stent from the vascular wall, thus reducing endothelial cell migration onto the stent.

In our clinical experience with this combined approach—using a NuMed CP® BES alongside a Medtronic® SES—the results have been promising. We recommend the adoption of this treatment approach for patients who meet the following criteria: (i) age > 65 years; (ii) surgical risk > 6%; (iii) complex aortic anatomy, such as coarctation located at the aortic arch, coexistence of aortic coarctation and aortic dilation, or stenosis at the branching points of the aorta; (iv) stenosis that cannot be resolved by single stent implantation; (v) patients at risk of rupture due to fragile arterial walls or extensive calcified atherosclerotic plaques; and (vi) patients with concurrent aneurysms or aortic dissections. For cases where the stent obstructs blood flow to arterial branches, solutions such as the creation of a bypass or stent fenestration can be employed. However, this approach has only been tested in a single patient, and further experience and long-term follow-up are necessary to fully assess its efficacy and safety.

Lead author biography

Xiaoxue Zhang is a master's student at the Tongji Medical College of Huazhong University of Science and Technology.

Acknowledgements

The authors thank Eduard Quintana for his support in writing the revision.

Consent: The authors confirm that written consent for the submission and publication of this case report, including images and associated text, was obtained from the patient in accordance with the COPE guidelines.

Conflict of interest. None declared.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

All data are incorporated into the article and its online supplementary material.

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