Novel chimney balloon technique to safeguard cerebral blood flow during total endovascular aortic arch repair

Yu Lun, MD, PhD, Han Jiang, MD, PhD, *and* Jian Zhang, MD, PhD, *Shenyang, China*

ABSTRACT

During endovascular total aortic arch repair by in situ fenestration, extra procedures are needed to sustain cerebral blood flow when targeting all three supra-aortic branches. Recently, our group successfully interposed a chimney balloon between the greater curvature of the aortic arch and an aortic stent to safeguard cerebral blood flow during total endovascular aortic arch repair. (J Vasc Surg Cases Innov Tech 2024;10:101489.)

Keywords: Balloon; Cerebral perfusion; Fenestration

An in situ fenestration technique for reconstructing supra-aortic branch vessels has the advantages of improved patency, fewer endoleaks, and aortic stent graft stability.[1] The chief issue in this regard is ensuring cerebral perfusion, especially if all three arterial branches are jointly targeted. Recently, our group successfully interposed a chimney balloon between the greater curvature of the aortic arch and an aortic stent as a method of artificial shunting. This maneuver temporarily maintains carotid blood flow during stent delivery along the arch, covering all three supra-aortic branches. The institutional review board of the First Hospital of China Medical University approved the study protocol and publication of the data. The patient provided written informed consent.

TECHNIQUES

We performed our novel procedure in a hybrid operating room, with the patient supine and under general anesthesia. Cut downs of both supraclavicular common carotid arteries (CCAs) and of the left brachial artery (LBA) were required. After initiating heparinization, retrograde punctures of both common femoral arteries (CFAs) were undertaken, deploying two access devices (Perclose ProGlide; Abbott Vascular) via the right CFA and inserting a 22F, 28-cm sheath (DrySeal Flex; W.L. Gore & Associates) over a 0.035-in. stiff guidewire (Lunderquist; Cook Medical Inc) after angiography of the aorta (Fig 1, *A*) and the circle of Willis (Fig 1, *B*). A 12F, 45-cm sheath (DrySeal Flex) was then inserted via the LBA, placing the sheath tip in the descending aorta on the ventral side of the Lunderquist guidewire. Both CCAs were subsequently punctured, and two 11F, 16-cm sheaths (Radifocus Introducer II; Terumo Corp) were inserted and directed toward the aortic arch. Next, a retrograde puncture of the right brachial artery was done for placement of a 6F, 55-cm sheath (Cook Medical Inc), which was positioned at the orifice of the right subclavian artery. Using this sheath, another 0.035-in. stiff guidewire (Supra Core 35; Abbott Vascular) was placed in the ascending aorta, along with the chimney balloon (8-mm × 80-mm EverCross; ev3 Inc, Medtronic). The tip of the chimney balloon rested in the ascending aorta, beyond the anticipated proximal aortic stent landing zone. Its end remained in the innominate artery (IA) and never extended into the right subclavian artery. Given the differing diameters of the balloon (8 mm) and IA (12-14 mm), IA blood flow would be sustained at full balloon inflation.

Having established all arterial access points and preinstalling the chimney balloon, two thoracic stent grafts (Gore TAG; 31 mm × 150 mm distally, 37 mm × 200 mm proximally; W.L. Gore & Associates) were consecutively advanced through the right CFA to fully cover an existing aortic arch aneurysm. We inflated the chimney balloon immediately after deploying the proximal thoracic stent graft (Fig 2, *A and B*). This balloon created a small gap between the aortic stent and the aorta, allowing blood to flow through this gap into the IA. Subsequent angiography verified sustained blood flow of IA, right CCA, and right vertebral artery. Although visualization of the right vertebral artery was achieved, considering its slender nature, it might exert a certain influence on the posterior circulation blood supply (Fig 2, *C*).

A puncture needle (ViziShot aspiration needle; Olympus America) was immediately fed into the 11F sheath within the left CCA for in situ fenestration, passing a 0.018-in. guidewire over it into ascending aorta. On verifying the true lumen, a series of balloons (4-, 6-, and

From the Department of Vascular Surgery, The First Hospital, China Medical University.

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Correspondence: Jian Zhang, MD, PhD, Department of Vascular Surgery, The First Hospital, China Medical University, Nanjing Bei St 155, Shenyang 110001, China (e-mail: jianzhang@cmu.edu.cn).

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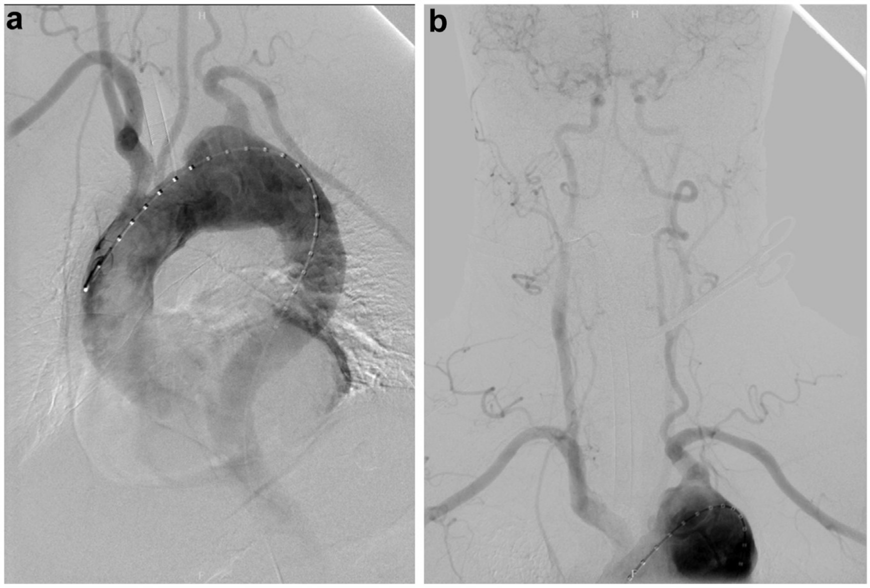

Fig 1. A, Angiographic confirmation of aortic arch aneurysm. **B,** Angiography of the circle of Willis.

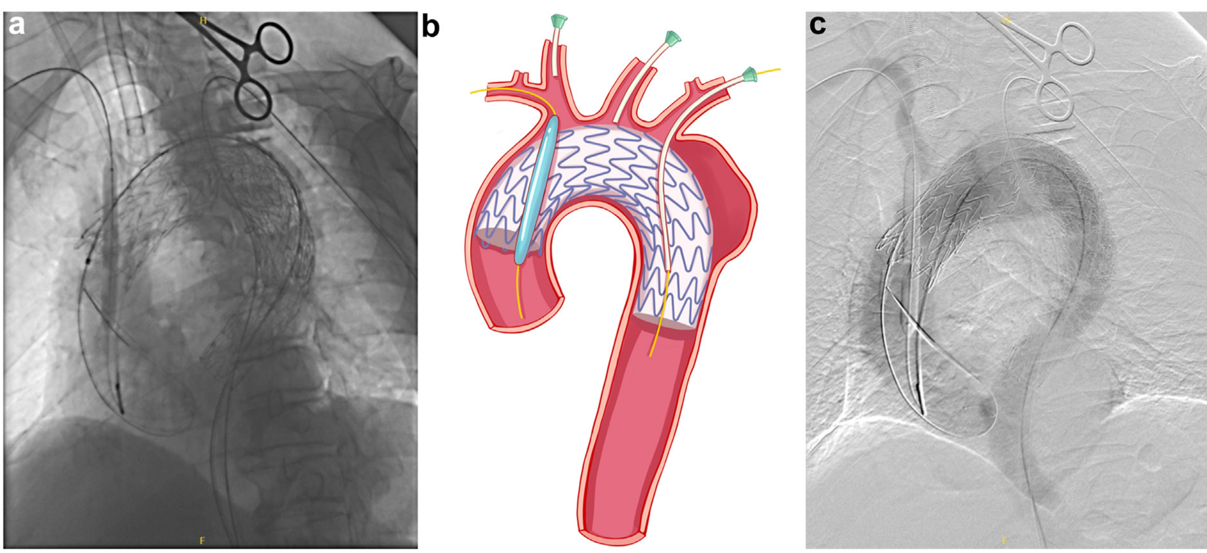

Fig 2. A,B, Chimney balloon interposed between greater curvature of aortic arch and aortic stent. **C,** Blood flow to innominate artery (IA) temporarily maintained while an aortic stent covers three supra-aortic branches.

8-mm diameter) were positioned to gradually expand the opening (Fig 3, *A and B*). A covered stent (8-mm × 37-mm LifeStream; BD) was ultimately implanted to complete reconstruction of the left CCA (Fig 3, *C and D*). From release of the aortic stent graft to completion of 4 mm of balloon dilation, the left CCA blood flow was completely obstructed for 5 minutes.

The IA was similarly reconstructed by way of the right CCA (Fig 4, *A and B*). After withdrawal of the chimney balloon, we used a 10-mm diameter balloon to expand the hole for the IA (Fig 4, *C and D*). Placement of a covered stent (12-mm × 37-mm LifeStream; BD) served to complete the reconstruction. Satisfactory blood flow to the IA and left CCA was again confirmed by aortography (Fig 4, *E and F*).

Next, the long 12F sheath within the LBA and descending aorta was withdrawn to the ostium of the left subclavian artery (LSA), while holding the 0.035-in. stiff guidewire inside, which was still placed in the descending aorta to directionally adjust the 12F sheath. A puncture needle was inserted parallel to the stiff guidewire. After in situ fenestration, followed by balloon dilation, a covered stent

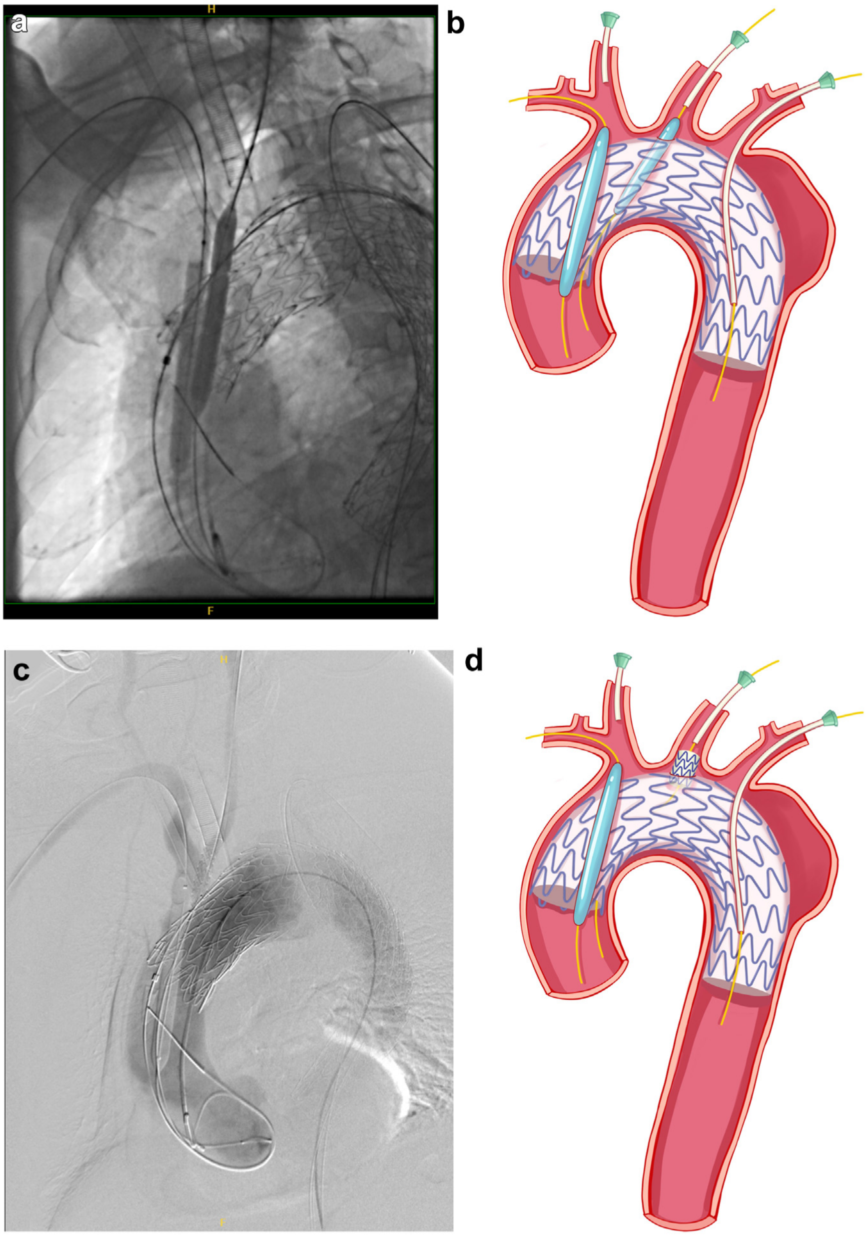

Fig 3. In situ fenestration for left common carotid artery (CCA). **A,B,** Balloon inflated to expand the opening for the left CCA. **C,D,** Angiography after covered stent reconstruction of the left CCA showing a patent innominate artery (IA) and left CCA.

was implanted (10-mm × 50-mm Viabahn; W.L. Gore & Associates) in accordance with image-based measurements. From the release of the aortic stent graft to completion of the LSA reconstruction, the total occlusion time for the LSA and left vertebral artery was 1.5 hours.

Aortography confirmed complete coverage of the lesion, with satisfactory three-branch blood flow. There was a small endoleak in the branch stent of the IA, but it did not affect isolation of the aortic aneurysm, and, thus, no further intervention was pursued (Fig 5, *A and B*). Finally, the sheaths were removed and the punctures sutured. The patient had an uneventful postoperative recovery. At the 3-month follow-up visit, the IA, left CCA, and LSA were demonstrably patent by computed tomography angiography, with the aneurysm no longer visible (Fig 5, *C*).

DISCUSSION

At present, several endovascular methods are available for reconstructing supra-aortic branch vessels, including the stent chimney technique, customized or physician-modified branched or fenestrated stent grafts, and in situ fenestration.[2] All types of aortic arch lesions are theoretically treatable by these methods, used individually or

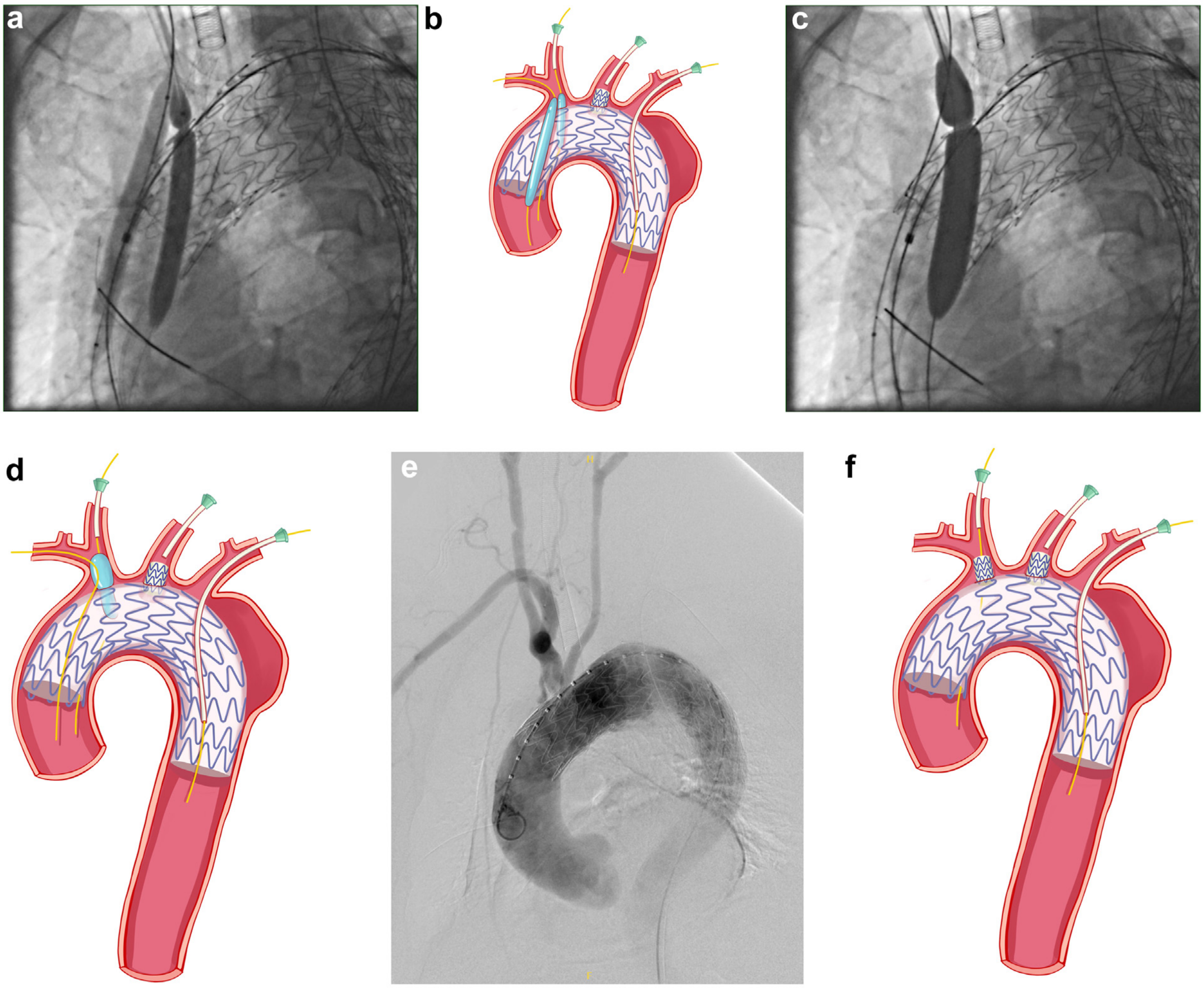

Fig 4. In situ fenestration for the innominate artery (IA). **A,B,** An 8-mm balloon was used to expand the hole for the IA via the right common carotid artery (CCA), with the chimney balloon inflated. **C,D,** Chimney balloon withdrawn before hole expansion (10- to 12-mm diameter balloon). **E,F,** Angiography showing both IA and left CCA were patent after covered stent reconstruction.

together, in conjunction with traditional aortic stent grafts. In terms of related safety, feasibility, and economy, an in situ fenestration approach has distinct advantages and in large part preserves the original vascular anatomy.

During endovascular total aortic arch repair by in situ fenestration, extra procedures are needed to sustain cerebral blood flow when targeting all three supra-aortic branches. Extracorporeal circulation is the customary solution, which entails added surgical incisions and high-dose anticoagulation. Other options include an extra-anatomic prosthetic bypass and a sheath—shunt technique.[3,4] Aside from the greater cost and procedural time required, these alternatives impose their own risks, such as incision hematoma and sheath or extension tube thrombosis.

Our novel technique uses the differing diameters of a balloon device and the IA to create a temporary pathway between the greater curvature of the aortic arch and an aortic stent. In essence, a triple fenestration becomes a double fenestration, thereby substantially reducing the risk of cerebral ischemia. Intraoperative cerebral oxygenation monitoring indicated no significant change in right cerebral hemispheric blood flow during chimney balloon interposition. In theory, there also exists a possibility for blood to traverse into the right CCA via the interstice formed by the chimney balloon, particularly in scenarios in which the IA and left CCA share a common trunk or their respective orifices are proximally situated.

This technique has some acknowledged limitations, especially in lesions involving the IA and where the ostia of the IA and left CCA are not closely situated. Hence, it is particularly suited for non-A, non-B aortic dissections involving zone 1 or 2, aortic arch aneurysms, and aortic arch lesions with a common origin of the IA and left CCA. This report summarizes an attempt to preserve cerebral flow using a simple in situ technique rather than

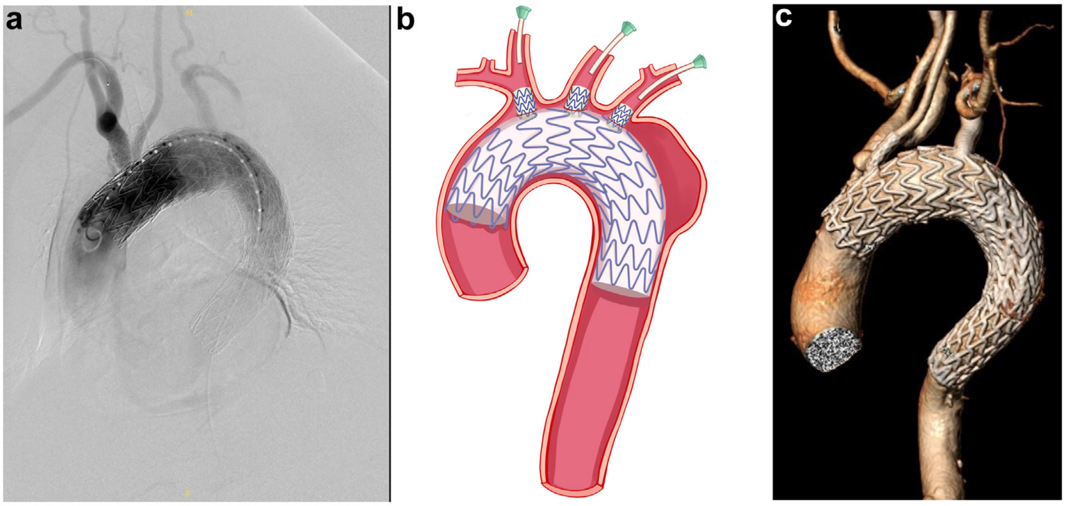

Fig 5. A,B, Completion angiography confirming an entirely covered lesion and satisfactory blood flow to three supra-aortic branches. **C,** Computed tomography angiogram showing fully occluded aneurysm and three patent branches at 3-month follow-up visit.

relying on extracorporeal arterial shunting into the cerebrovascular system or pre-fenestrated aortic endografts. The procedure relies on creating a temporary space of indeterminate size between the aorta and the endograft using a chimney balloon. Success in this solitary case is attributable in large part to the collateral intracerebral flow. Preoperative evaluation of the circle of Willis is essential, preferably by computed tomography angiography or magnetic resonance angiography. The volume of flow around the ascending aorta chimney balloon was not determined before this procedure. In vitro studies are required to ascertain this before adoption of this approach. Further refinement to improve flow into the cerebrovascular circulation such that the flow is sufficient during the three fenestrations of the aortic endograft is required. Comparison with pre-fenestrated aortic endografts or positioning a multiple-hole conduit in the arch that is in continuity with the ascending aorta (before deploying the aortic endografts) is also needed.

CONCLUSIONS

We have reported a novel balloon interposition technique to maintain cerebral perfusion during total supra-arch endovascular reconstruction by in situ triple fenestration. The principles entailed are simple and beneficial; however, long-term monitoring to determine the safety and efficacy is still required.

DISCLOSURES

None.

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