3D Navigation in Complex TEVAR

A case report demonstrating the benefits of a three-dimensional endovascular guiding system.

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Endovascular aneurysm repair has become the treatment of choice for the majority of thoracic aneurysms due to the procedure's excellent clinical outcomes and low perioperative morbidity and mortality rates. One of the keystones of a successful thoracic endovascular aneurysm repair (TEVAR) is correct deployment of the endograft, with the fabric of the stent graft at the desired anatomical take-off to avoid any endoleak that could potentially pressurize the sac and without covering essential side branches. Visualization of these take-offs and landing zones is often very challenging due to the anatomy of thoracic (arch) aneurysms, limitations of current imaging techniques, and parallax errors. In this article, we report a case of successful TEVAR and additional endovascular treatment of a type I endoleak with three-dimensional (3D) navigation in a hybrid operating room (OR) with the Artis Zeego system (Siemens Healthcare, Malvern, PA).

Figure 1. A CT scan showing an aortic arch aneurysm with penetrating ulcer distal from the left subclavian artery.

CASE REPORT

In 2010, an 80-year-old man presented to the emergency department with acute interscapular back pain. He had significant cardiovascular and pulmonary comorbidities. His initial workup with computed tomography (CT) revealed a descending aortic aneurysm with a penetrating ulcer distal from the left subclavian artery (Figure 1). The maximum diameter of the aneurysm was 57 mm, and there was an acceptable sealing zone of 2 cm between the origin of the aneurysm and the left subclavian artery. He underwent urgent endovascular repair of the descending aorta with two overlapping Valiant stent grafts (Medtronic, Inc., Minneapolis, MN). The proximal Valiant stent graft was deployed with the FreeFlo stent-crown overlying, but not occluding, the subclavian artery ostium. The second stent graft was deployed distally with a sealing overlap (Figure 2). The patient recovered uneventfully, and postoperative CT scans at 1, 3, 6, and 12 months showed complete exclusion and discrete volume shrinkage of the aneurysm.

Two years later, the patient was readmitted at our emergency department with precordial pain radiating to his back. A CT scan showed expansion of his descending aortic aneurysm due to a type I endoleak (Figure 3). There was no migration of the stent graft noted, but the diameter of the proximal subclavian artery had significantly increased during the past 2 years, leading to direct flow into the aneurysmal sac.

We planned an endovascular repair with perioperative 3D navigation in our hybrid OR with the Artis Zeego system. A Valiant thoracic stent graft (Medtronic, Inc.) was advanced into the descending

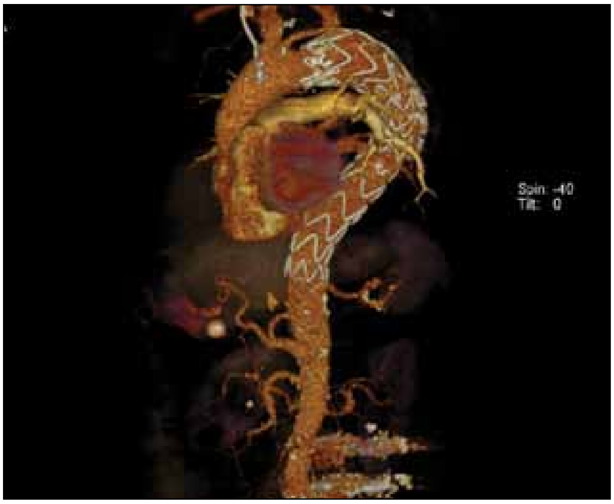

Figure 2. A CT scan showing successful exclusion of the arch aneurysm with a Valiant endoprosthesis.

Figure 3. A CT scan showing a type I endoleak 2 years after stent graft implantation.

aorta via the right femoral approach, and a pigtail catheter was positioned in the ascending aorta. With the stent graft delivery system in place, perioperative 3D rotational angiography with cone-beam CT (DynaCT, Siemens Healthcare) was performed by injection of 40 mL of contrast (Figure 4). Three-plane analysis of the aortic arch allowed us to mark the ideal perpendicular take-off plane for deployment of the extension graft with its fabric adjacent to the common ostium of the brachiocephalic trunk and the left common carotid artery. This ideal plane was visible in real time as a circle on the live fluoroscopy screen by markers encircling the aorta. The guiding ring changed according to the position of the robotic C-arm in relation to the patient. The 3D endovascular guiding ring marks the ideal/projected landing zones during deployment of the graft and corrects any parallax error when transformed into a single line by rotation of the robotic C-arm. Balloon dilatation of the stent graft was performed with a Reliant stent graft balloon catheter (Medtronic, Inc.) to improve the conformability with the aortic wall and previously implanted graft. There was no visible type I endoleak on final angiography. Postoperative CT confirmed good positioning of the extension graft adjacent to the left common carotid ostium and sealing with the previous implanted grafts but revealed a persistent endoleak through the dilated root of the left subclavian artery (Figure 5). The patient remained symptomatic in the days after the procedure, so an additional intervention was necessary.

We performed intraoperative 3D analysis with selective occlusion of the endoleak through left brachial access. Three-dimensional analysis allowed identification of the origin of the endoleak and accurate intraoperative catheterization (Figure 6). The 3D overlay

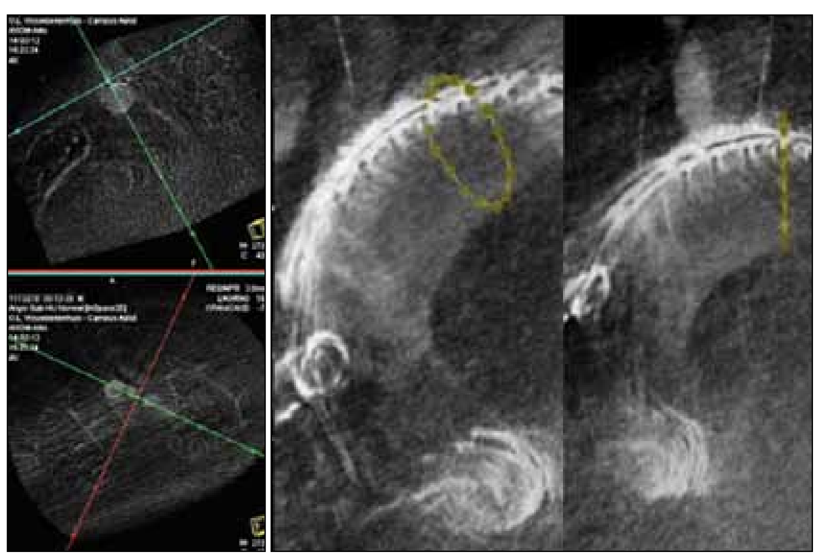

Figure 4. Three-dimensional rotational angiography and a 3D endovascular guidance system. Three-dimensional analysis of the DynaCT images results in the marking of the ideal take-off plane for the aortic extension endograft by a "dotted circle," which then becomes visible on live fluoroscopy. This marking circle allows accurate placement and parallax correction during graft deployment.

roadmap adapts to the position of the C-arm, which allowed us to insert the first detachable coil (Azur, Terumo Interventional Systems, Inc., Somerset, NJ) distally into the endoleak of the aneurysm and then close the root of the subclavian artery with two more Azur coils. The tortuous anatomy of the subclavian artery was permanently visible on screen, and the ostium of the vertebral artery was marked by a ring to avoid damage to the collateral circulation. At the end of the procedure, complete occlusion of the subclavian root was achieved. A week later, the patient was free of symptoms, and a postoperative CT scan confirmed total exclusion of the aneurysm without endoleak (Figure 7).

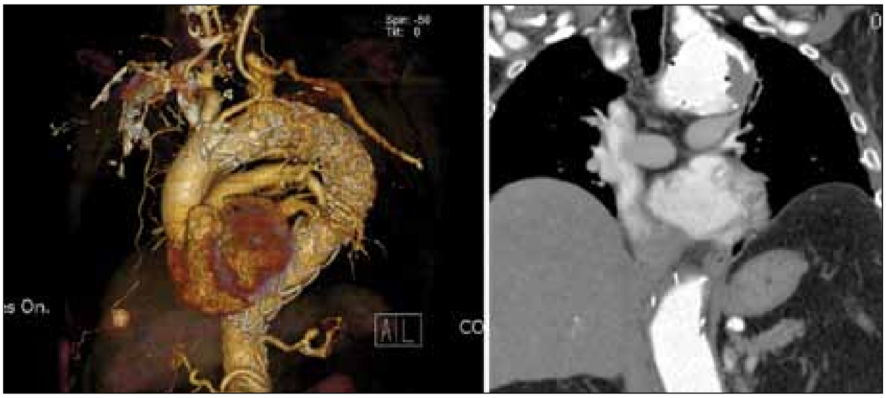

Figure 5. A CT scan postextension of the previously implanted graft reveals a persistent endoleak through the dilated left subclavian artery root.

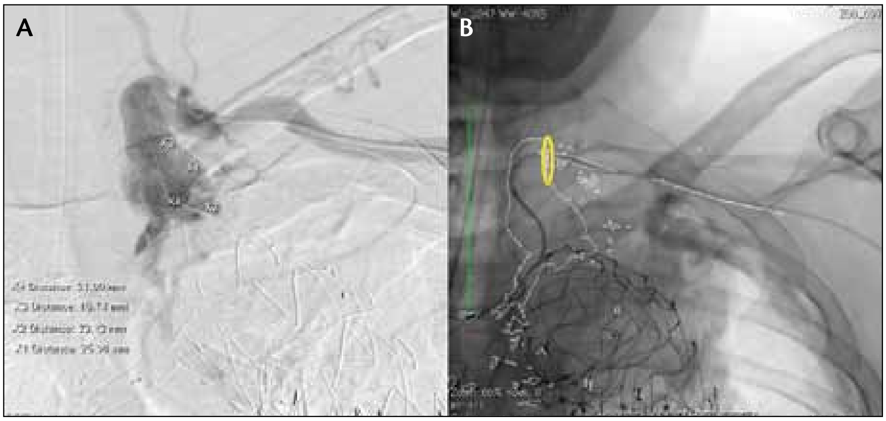

Figure 6. Intraoperative quantitative analysis of the left subclavian artery root based on subtraction angiography (A). Intraoperative 3D analysis of the left subclavian artery root with live 3D roadmap projection on the fluoroscopy screen and live marking of the limit for coiling to avoid collateral artery damage (vertebral artery) (B).

DISCUSSION

The anatomy of an aneurysmal aortic arch remains one of the most challenging for stent graft engineers and implanting physicians. The complex configuration of the arch and its side branches in different planes can make it very difficult to predict the actual position of a fully deployed stent graft in relation to the graft in the delivery system. Partial deployment of a top stent and recapturing can allow corrective action with some selected devices, but durable results depend mostly on accurate deployment at the ideal takeoff plane. The use of a hybrid OR with 3D imaging and perioperative guidance allows the physician to evaluate the patient's anatomy in a new dimension: after insertion of the graft delivery system over the stiff wire, intraoperative 3D angiography reflects the possible anatomical changes and distortion due to the large-bore devices and stiff wires. Perpendicular planes can be quantified along the centerline of the aorta during the operation and used as markers for accurate deployment, taking into account these anatomical changes of the aorta. Partial stent graft deployment allows alignment of the guiding planes with stent graft markers to avoid parallax errors. Ostia of aortic side branches and vessel contours can be marked for navigation and move along in the 3D images even when changing the position of the C-arm.

A minority of post-TEVAR patients develop type I or significant type II endoleaks. Sizing mismatch, malpositioning, migration, and aneurysm progression are leading causes for type I endoleaks. In the presented case, progression of aneurysmal disease caused the endoleak. Recent guidelines[1] support the immediate treatment of type I endoleak due to the high rupture risk of the pressurized aneurysm sac. Endoleak diagnosis is commonly made with conventional intravenous contrast CT angiography, but the precise origin of an endoleak is often not visible. Three-dimensional rotational angiography and cone-beam CT are very powerful tools to detect the feeders of different endoleaks and guide endovascular treatment. For a type I endoleak found during follow-up after TEVAR, the initial endovascular approach is placement of an extension cuff or stent graft if there is a sufficient sealing segment

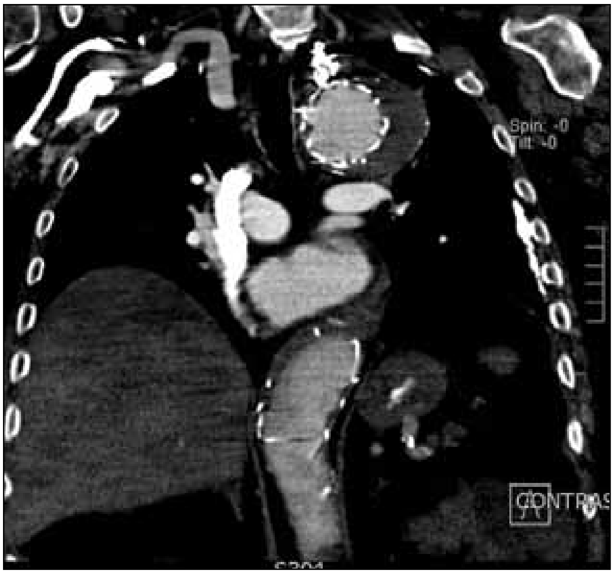

Figure 7. A CT scan showing the final result after successful treatment of a type I endoleak post-TEVAR. An extension graft was deployed proximally, and the endoleak nidus out of the subclavian artery root was coiled.

between the implanted graft and the supra-aortic vessels. If there is insufficient space, a Palmaz stent (Cordis Corporation, Bridgewater, NJ) can provide adequate sealing, or hybrid procedures can be considered. When the inflow of the supra-aortic vessels is secured by debranching bypass surgery, the complete aortic arch is relined with a stent graft, and all possible feeders into the aneurysmal sac coming from the supra-aortic vessels can be closed.

CONCLUSION

Three-dimensional endovascular guidance offers a new perspective during TEVAR. Marking of the aortic arch improves the accuracy of graft deployment and guides the physician through the challenging arch anatomy. This system may improve long-term TEVAR results by decreasing type I endoleaks and support diagnosis and treatment of postoperative endoleaks, as demonstrated in the presented case. ■

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