Circulation: Cardiovascular Imaging

CARDIOVASCULAR IMAGES

Computer Simulation Model May Prevent Thoracic Stent-Graft Collapse Complication

Lucie Derycke, MD; Stephane Avril, PhD; David Perrin, PhD; Jean-Noël Albertini, MD, PhD; Frederic Cochennec, MD, PhD

A 71-year-old man with a history of hypertension, hypercholesterolemia, and arteriopathy was referred for a 60 mm aortic arch aneurysm. No adequate sealing zone in zone 1 or 2 could be identified on the preoperative aortic computed tomography angiography (slice thickness=0.6 mm; pixel size=0.9×0.9 mm). Since this patient was deemed to be at risk for open repair, we decided to treat him using a custom-made double branch Relay device (Terumo Aortic, Sunrise). A left common carotid artery to left subclavian artery prosthetic bypass was performed during a first step procedure. The double branch stent-graft was deployed one month after. No technical problem was noticed during the procedure. During the early postoperative course, the patient presented with severe acute limb ischemia related to an iliac occlusion, a cardiogenic shock, a renal failure requiring dialysis and a complete paraplegia. Despite emergent iliac thrombectomy, a major amputation was required 15 days after TEVAR. He died 5 months after surgery.

The postoperative aortic computed tomography angiography (slice thickness=3 mm, pixel size=0.7×0.7 mm) revealed a collapse of the device located at the level of the distal end of the valley dedicated to incorporate branches to the innominate artery and left common carotid artery. This collapse was deemed to be the main cause of postoperative complications.

Anatomic data extracted from the preop CT-scan as well as mechanical and geometric characteristics of the double branch device were used to simulate stent-graft deployment using finite element technology (Figure 1). This work was based on proprietary algorithms (Predi-Surge, Saint-Etienne, France) developed to simulate deployment of endovascular devices in patient-specific aortic aneurysms models and previously described for the aortic arch.[1] Algorithms used for analysis were those from commercially available finite element solver Abaqus/Explicit v6.14 (Dassault Systèmes, Paris, France). When compared with post op CT-scan images, the 3-dimensional simulation model extracted from the numerical analysis reproduced the collapse of the stent-graft, at the same location of the fabric and predicted the collapse of the exact same three stent rings seen on the postoperative CT-scan located distally to the fenestration zone. Major deformations of the 3 stent rings distal to the valley were well predicted (Figure 2).

Personalized medicine has a potential to improve endovascular treatment of patients with aortic arch disease. Despite design improvements and increased surgeon technical skills, accurate prediction of device behavior in complex anatomies remains a challenge. Procedure planning is currently limited to CT-scan imaging reconstruction softwares. One of the main limitations is the inability to provide realistic information on the interaction between the aortic wall and stent-grafts. The Finite-element analysis is a numerical method for solving mechanical problems and finite element simulation studies performed on aortic valves and aortic stent-graft have highlight the potential of this technology for predicting patient-specific behavior of aortic devices.[2–4] This technique offers several potential advantages over currently used methods of preoperative planning with direct assessment of a stent-graft deployed in a personalized aortic anatomy.

Such personalization during preoperative planning may be helpful to improve patient selection, type of stent-graft choice, allowing testing different stent-graft designs, and intervention strategies. This may result in a reduction of intraoperative technical issues and

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Correspondence to: Lucie Derycke, MD, 51 Avenue du Maréchal de Lattre de Tassigny, 94010 Créteil, France. Email lucie.derycke@aphp.fr
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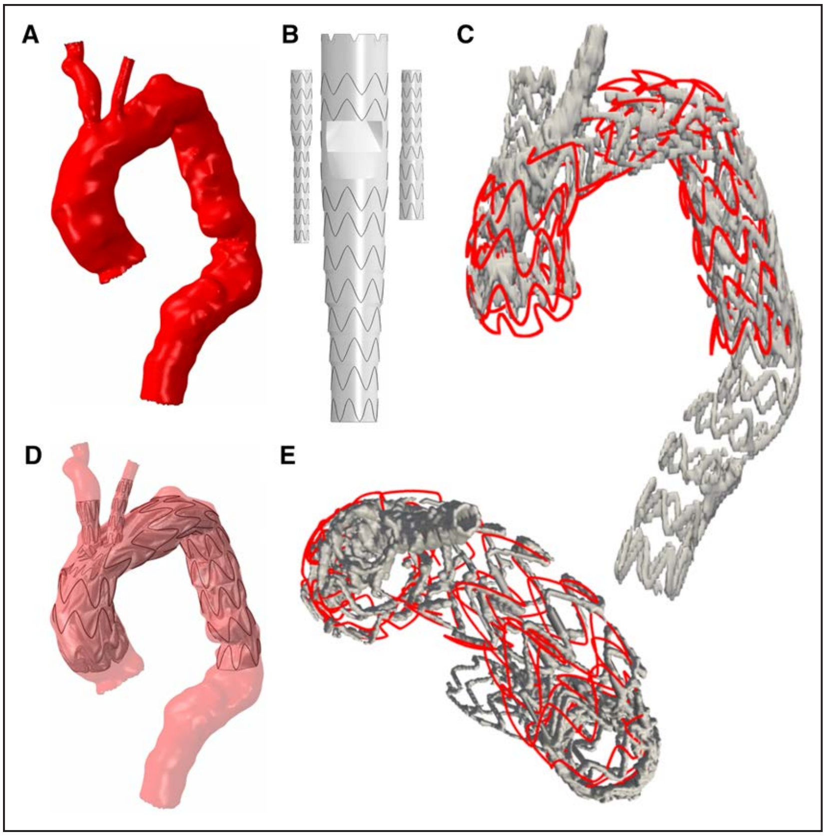

Figure 1. Results of numerical stent-graft deployment simulation.
A, Arterial geometry extracted from the preoperative computed tomography-scan. **B**, Prestressed models of the main stent-graft and the bridging stents. **C**, Sagittal view of the qualitative comparison between simulation (in red) and postoperative CT-scan (in gray). **D**, Simulation result. **E**, Transversal view of the qualitative comparison between simulation (in red) and postoperative CT-scan (in gray).

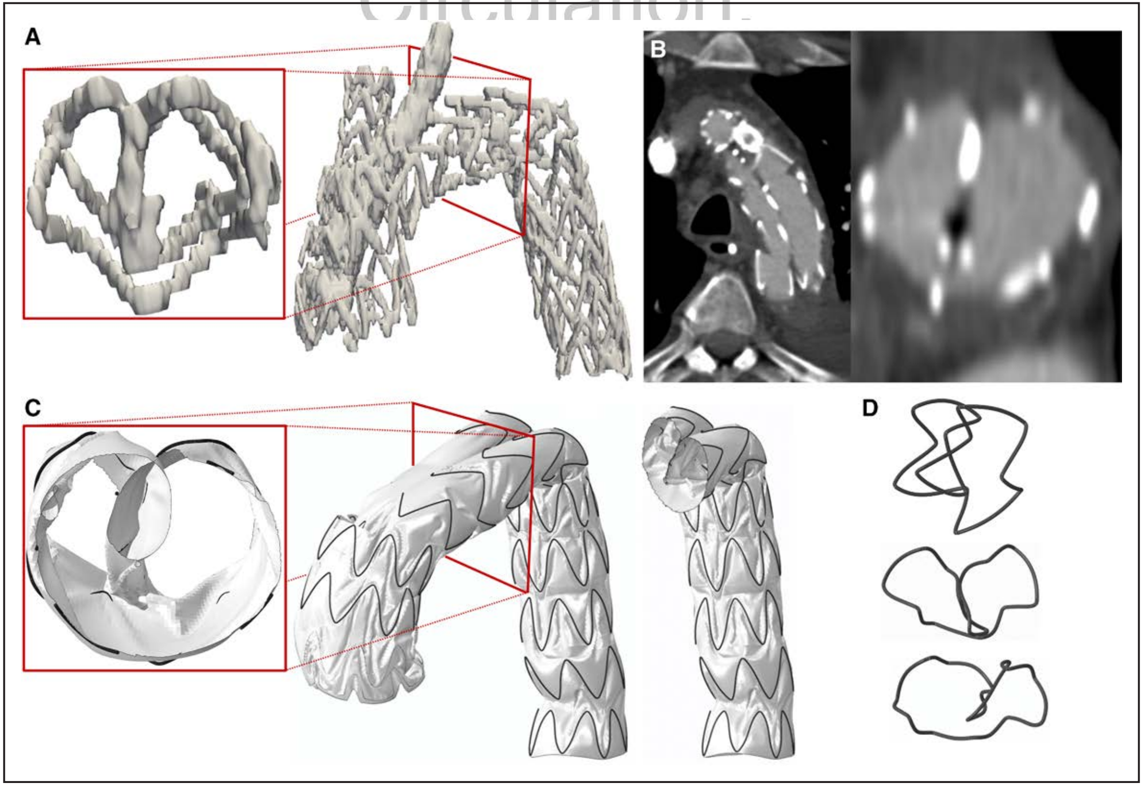

Figure 2. Prediction of the collapse complication by the numerical simulation model.
A, Sagittal view of the stent rings extracted from the postoperative computed tomography-scan and cross-sectional view of the stent rings with failed deployment. **B**, Postoperative transversal and coronal images showing the failed deployment of the 3 stent rings located just after the fenestration zone with a collapse. **C**, Sagittal view and cross-sectional views of the simulation result at the same location showing the same collapse. The arterial surface and the bridging stents were omitted from the overview to facilitate visualization. **D**, Shapes of the 3 deformed stent rings after simulation.

postoperative complications, one of which is illustrated by this case.

ARTICLE INFORMATION

Affiliations

Mines Saint-Etienne, Univ Lyon, Univ Jean Monnet, INSERM, U 1059 Sainbiose, Centre CIS, France (L.D., S.A.). Department of Vascular Surgery, Henri Mondor Hospital, University of Paris XII, Créteil, France (L.D., F.C.). PrediSurge, 3, place Roannelle, France (D.P., J.-N.A.). Service de Chirurgie vasculaire, Centre Hospitalier Régional Universitaire de Saint-Etienne, avenue Albert Raimond, France (J.-N.A.).

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