Patient-Specific Simulation of Endovascular Thoracic Aortic Repair: Initial Experience

Liesbeth M. Desender, MD, Isabelle Van Herzeele, MD, PhD, Zoran Rancic, MD, PhD, Colin Bicknell, MD, PhD, Ignatios Zairis, MD, Frank E. Vermassen, MD, PhD, and John H. Rundback, MD

Department of Thoracic and Vascular Surgery, Ghent University Hospital, Ghent, Belgium; Department of Vascular Surgery, Zurich University Hospital, Zurich, Switzerland; Department of Surgery and Cancer, Imperial College London, London, United Kingdom; and Department of Cardiothoracic Surgery and Interventional Institute, Holy Name Medical Center, Teaneck, New Jersey

Purpose. **Endovascular thoracic aortic repair (TEVAR) has become the treatment modality of diverse aortic pathology. We report the use of patient-specific simulation using a dedicated PROcedure Rehearsal Studio (PRS) platform (Simbionix USA Corp, Cleveland, OH) before TEVAR and evaluate the feasibility and realism of this technology.**

Description. **Virtual three-dimensional models of the patient's relevant anatomy were reconstructed from computed tomography data. PRS was used in 2 patients before TEVAR. In a multicenter retrospective study, we evaluated how PRS compares with real TEVAR.**

Evaluation. **PRS before TEVAR was feasible and demonstrated good correlation with the actual procedure. In the retrospective study, 16 patients were reconstructed (median duration, 26 minutes; interquartile range, 21 to 36 minutes). The realism of the simulated angiographies was rated highly (median, 4; interquartile range, 3 to 4). Final angiography revealed type I endoleak in 2 simulated cases and 1 real case.**

Conclusion. **Patient-specific rehearsal before TEVAR is feasible and permits the creation of realistic case studies; however, software updates are required to improve face validity and to foster implementation in clinical practice.**

(Ann Thorac Surg 2017;104:336–41)

Endovascular thoracic aortic repair (TEVAR) has revolutionized the treatment of aneurysms, dissections, and penetrating atherosclerotic ulcers (PAUs) with reduced procedural morbidity and death compared with open operations [1–3]. Because of the anatomic complexity of the aortic arch and supraaortic branches, optimal preparation using cross-sectional images and dedicated three-dimensional (3D) planning software is essential to choose the appropriate access site, endograft, and landing zones. Preoperative planning may also enhance team workflow, resource management, and prevent errors [4].

Planning has become routine, but chances to "practice" endovascular thoracic procedures before treating the real case are limited. Recent advancements in medical simulation, such as patient-specific virtual-reality rehearsal with the PROcedure Rehearsal Studio (PRS) software (Simbionix USA Corp, Cleveland, OH), enable the endovascular team to practice and treat the aortic pathology on a virtual platform before treating the actual patient. These rehearsals may increase the procedural comfort, influence the selection of landing zones and devices, and optimize device deployment, resulting in improved technical success.

We describe 2 patients in whom PRS was performed before TEVAR and the results of a multicenter retrospective study evaluating the feasibility and realism of patient-specific TEVAR simulations.

Technology

The PRS software was used to generate 3D reconstructions of the patient's relevant anatomy (aorta, supraaortic branches, celiac trunk, superior mesenteric artery, renal arteries, and iliac arteries) from patient-specific uploaded computed tomography angiography (CTA) data.

Dr Van Herzeele discloses a financial relationship with Medtronic, Academia, and Silkroad Medical; Drs Rancic and Vermassen with Medtronic and Academia; Dr Bicknell with Medtronic; and Dr Rundback with Simbionix.

Accepted for publication Sept 19, 2016.

Address correspondence to Dr Desender, Department of Thoracic and Vascular Surgery, Ghent University Hospital, 2K12D, De Pintelaan 185, 9000 Ghent, Belgium; email: liesbeth.desender@ugent.be.

Published by Elsevier Inc.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2016.09.066

Acronyms and abbreviations

3D = three-dimensional
ATAI = acute traumatic aortic injury
CTA = computed tomography angiography
IQR = interquartile range
LSA = left subclavian artery
PAU = penetrating aortic ulcer
PRS = PROcedure Rehearsal Studio
TAA = thoracic aortic aneurysm
TEVAR = thoracic endovascular aortic repair

Technique

The 3D reconstruction of this data is achieved by the level set method of segmentation and is a partially automated step. Manual enhancement of aortic side branches (eg, carotid artery) may be required. Next, bony landmarks are assigned to the arterial reconstruction as fiducial references to indicate the correct location of the vasculature with respect to the virtual fluoroscopy imagery of the spine and pelvis. Calculation of the vessel centerline is done automatically for the aorta and iliac arteries, but should be performed manually for the supraaortic branches. The end result is a 3D reconstruction with a centerline that can be uploaded to form the scaffold for the virtual reality simulation (Fig 1). The ANGIO Mentor Express Dual Access Simulation System (Simbionix) was used to conduct the patient-specific simulations. Technical details have previously been described [5].

Clinical Experience

Patient 1

A 71-year-old man with a chronic type B aortic dissection extending from the left subclavian artery (LSA) to the celiac trunk, initially managed medically, presented with aneurysmal dilatation of the distal aortic arch and proximal descending thoracic aorta to a maximal diameter of 60 mm. The treatment plan was to cover the origin of the LSA with a stent graft to obtain a good proximal landing zone and to successfully exclude the aneurysm.

Preemptive revascularization of the LSA was performed by a transposition to the left common carotid artery. The CTA data were used to create a 3D reconstruction of the patient's relevant anatomy (Fig 2). Immediately before the TEVAR, the endovascular team (lead implanter, assistant, and scrub nurse) performed the patient-specific rehearsal. The simulation was completed in 16 minutes. From the rehearsal they identified a 55-degree left anterior oblique angle as the optimal C-arm angulation for visualization of the proximal and distal landing zone, which was confirmed by angiographic images in real life.

In the simulated and actual TEVAR, the thoracic aneurysm was successfully excluded using 2 Valiant Thoracic stent grafts (Medtronic Vascular, Santa Rosa,

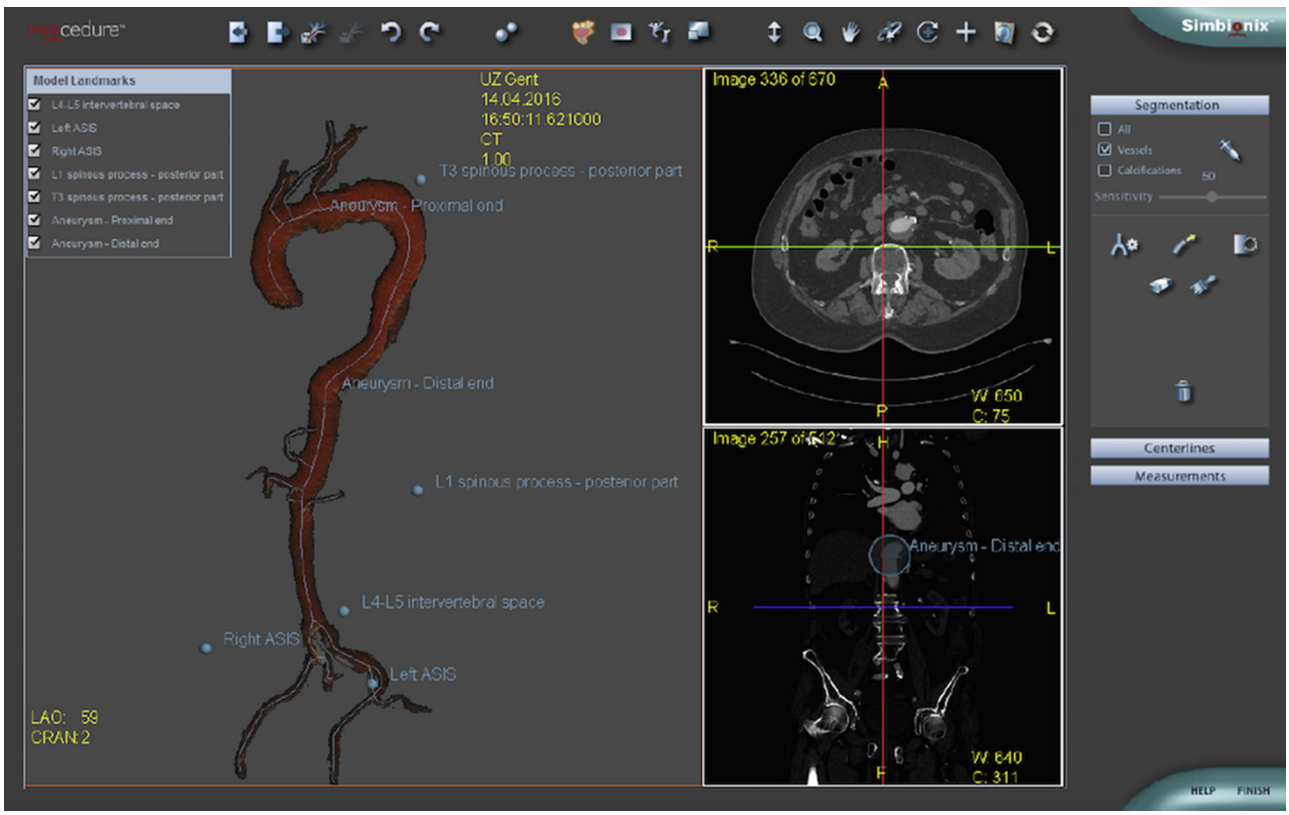

Fig 1. Construction of a virtual three-dimensional model with the PROcedure Rehearsal Studio (Simbionix USA Corp, Cleveland, OH) software. (ASIS = anterior superior iliac spine; CRAN = cranial; CT = computed tomography; LAO = left anterior oblique.)