

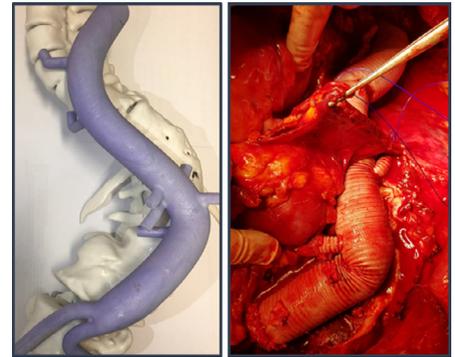


# 3D-Printing-Based Open Repair of Extensive Thoracoabdominal Aorta in Severe Scoliosis

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## CASE REPORT

A 58-year-old female with Marfan syndrome admitted for planned surgical repair of chronic type B aortic dissection. The patient had undergone David I procedure combined with prophylactic total-arch repair 6 months ago to treat severe aortic valve regurgitation associated with aortic root aneurysm in our institution. At the present admission, computed tomography (CT) images showed severely tortuous and dilated thoracoabdominal aorta (TAA) along with severe scoliosis (Fig. 1A). The origins of each visceral, renal and segmental arteries were markedly displaced in accordance with severe tortuosity of the aorta. In order to overcome these anatomical challenges, we decided to build up an anatomical model using 3D-printing technology. At first, virtual modeling was designed to mimic the native aorta and its major branches based on the patient's CT images (Fig. 1B). Based on these 3D-images, a referential virtual 3D-artificial graft respecting the tortuosity of the aorta fitted to the scoliosis was created. Finally, the 3D aortic model was printed using VisiJet PXL Core powder, VisiJet PXL clear binder, and Color bonds. Thereafter, actual aortic graft was constructed in accordance with 3D-printed aortic model before skin incision. During anesthetic induction, resected 10-mm-side branches were manually connected to commercialized aortic graft (Gelweave coselli thoracoabdominal graft 28 mm; Vascutek Ltd, Renfrewshire, UK) targeting intercostal branches. The planned surgical extent was from distal end of the



A final image of actual 3D aortic model (left) and an intraoperative finding (right).

## Central Message

3D-printing-based surgical repair of complex thoracoabdominal aortic disease may be a useful approach to enhance procedural efficiency.

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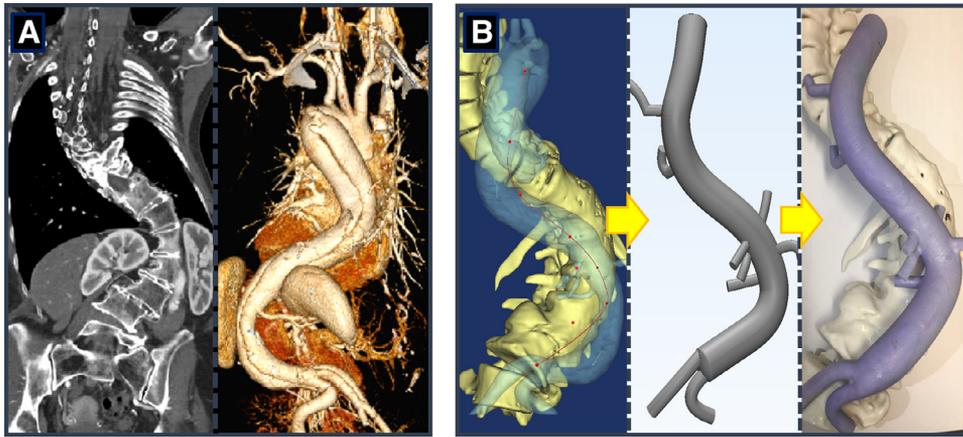
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prior graft in the distal arch to iliac bifurcation. For surgical procedures, we followed our previously reported methods.<sup>1</sup> In brief, cardiopulmonary bypass was established using the left femoral cannulations. For circulatory arrest during open proximal descending aorta repair, we used moderate hypothermia (26°C) and left ventricular venting catheter, which was followed by sequential aortic clamping technique for downstream aortic repairs during re-warming. After proximal anastomosis, we reattached intercostal arteries (thoracic 10th and 12th, and lumbar 1st levels) for spinal perfusion using preconstructed branch-grafts for spinal perfusion using preconstructed branch-grafts. And then, distal anastomosis was completed in a sequential segmental cross-clamping fashion. Sequential attachments of bilateral renal, superior mesenteric and celiac arteries were followed under the uses of direct visceral/renal perfusion techniques. Total procedural and cardiopulmonary bypass times were 6.8 hours and 184 minutes, respectively, including 11 minutes of circulatory arrest. Postoperative courses were uncomplicated without postoperative bleeding or neurologic events. Figure 2 depicts the final images of an interposed vascular graft of the TAA.

## DISCUSSION

Risks of mortality and disabling complication after Crawford extent II TAA repair have been reported at rates of around 10.0%

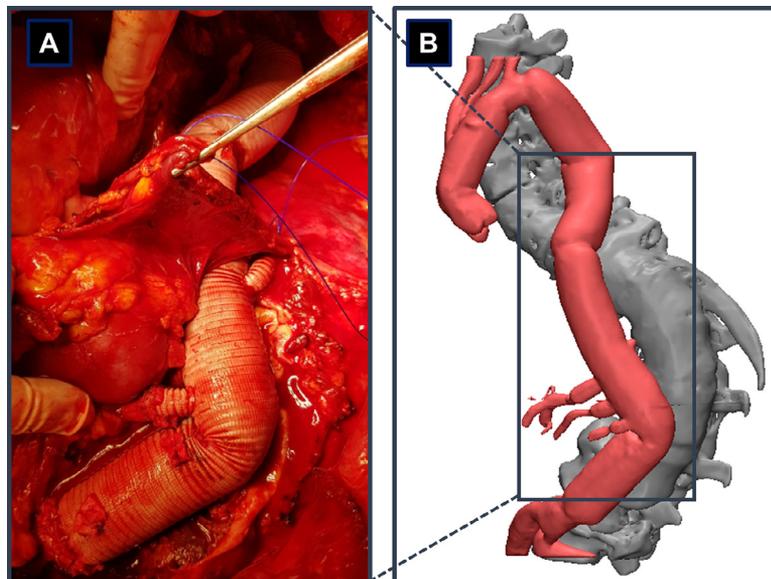


**Figure 1.** Processes of 3D-printed sculpture mimicking the patient's native aorta. (A) A preoperative computed tomography (CT) scan showing tortuous descending aorta along with severe scoliosis. (B) A serial process of the 3D-printing technique from a virtual modeling to a referential printed model.

and 7.5%, respectively, even in expert groups.<sup>2,3</sup> These high surgical risks are partly attributed to difficulty in addressing vital branch arteries in proper positions during constructing the new aortic graft in addition to the complexity of the entire surgical procedures.<sup>4</sup> To overcome these challenges, island anastomosis technique has been used to simply reconstruct the branch arteries in open repair of extensive TAA. This technique may be helpful for reducing procedural time by saving several anastomoses of the individual vital arteries, however, high incidence of patch aneurysm formation has been reported as a late complication.<sup>5</sup> The island technique is particularly regarded not feasible for those with connective tissue disorder or young individuals. Markedly

displaced origins of visceral vessels also are a hindering factor to utilize the island technique.

In surgical planning for the TAA repair, a high degree of understanding and a comprehensive awareness on individualized anatomic variations are essential. In addition, straightforward and efficient execution of surgical procedures is probably one of the most important factors to shorten cardiopulmonary and operative times, which in turn is believed to improve surgical outcomes. In the present case with severe scoliosis, highly displaced configurations in visceral, segmental arteries as well as the extremely tortuous main stem aorta were challenging requiring high level of surgical planning and performance. To address



**Figure 2.** Final image and photograph of the replaced actual hand-sewn graft. (A) An intraoperative photograph of replaced graft. (B) A reconstructed postoperative CT scan image.

these anatomical hurdles, 3D-printing method was used based on the 3D-CT image to understand detailed anatomies on-hands. For constructing the final virtual 3D neo-aorta imaging, smoothing process on sharp-angled course of the native aorta and extremely deviated branching arteries was taken carefully by discussion among clinicians and technicians. Finally, an actual vascular graft was constructed resembling the final 3D-printed aortic model. These preincisional processes have contributed to reducing operational time and have promoted straightforward processes of serial anastomosis with easier identification of target intercostal arteries. The results of this case indicate that the preconstructed graft based on 3D-printing technique may be helpful to improve surgical outcomes in TAA extent II repairs presenting with challenging anatomy.

### Acknowledgment

All individuals with involvement in the study were included in authorship.

### SUPPLEMENTARY MATERIAL

The following is the supplementary data to this article:



**Video 1.** A videoclip of surgical repair for the patient with chronic thoracoabdominal aortic dissection and severe scoliosis.

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