Ascending aortic rupture after zone 2 endovascular repair: a multiparametric computational analysis

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Abstract

A 74-year-old woman expired from ascending aortic rupture 3 months following branched zone 2 endovascular aortic repair. Multiparametric image-based computational evaluation of this case suggested that the stiffness mismatch between the endograft and the native aorta increased haemodynamic loads and likely led to the rupture of the ascending aorta. This under-recognized phenomenon should be considered in preoperative planning and presents suggestions for endograft development.

Keywords: Thoracic endovascular aortic repair • Computational fluid dynamics • Aortic aneurysm • Aortic rupture

INTRODUCTION

Branched endografts obviate the need for extra-anatomical bypass surgery when performing thoracic endovascular aortic repair (TEVAR) in the arch. Early results are promising \cite{1}, but significant complications have been reported that warrant further investigation. In this article, we examine the case of an ascending aortic rupture following branched zone 2 TEVAR \cite{2}.

This study was approved by the institutional review board (HUM00112350), with a waiver of informed consent.

CASE REPORT

A 74-year-old woman presented with an asymptomatic mid ascending aortic aneurysm (49 mm) and an proximal descending aneurysm (63 mm). Her medical history included hypertension, hypercholesterolemia and smoking. She had a family history of aortic aneurysms. An additional medical history is reported in the Supplementary Material. Annual imaging follow-up with computed tomography angiography (CTA) examinations showed rapid enlargement of the descending aortic diameter to 73 mm and a modest increase in the ascending aorta to 53 mm in 2 years (Fig. 1A). We elected to treat the larger aneurysm first with branched zone 2 TEVAR, anticipating a second stage repair of the ascending aorta 2 months thereafter.

The diameters of the proximal and distal landing zones for the descending aneurysm were 34 mm and 42 mm, respectively. The diameters and lengths of the proximal Gore TBE and distal Conformable Gore TAG endoprosthesis were $37 \times 100$ mm and $45 \times 150$ mm, respectively, resulting in 9\% proximal and 7\% distal oversizing. Controlled hypotension (systolic pressure of 80 mmHg) was used to reduce the risk of malpositioning. The deployment of the branched proximal component, using the Gore TBE delivery system, resulted in 5-mm distal dislocation resulting in type Ia endoleak. Two proximal extension devices were deployed. After balloon dilation of these devices, proximal infolding and bird beaking were observed (Fig. 1B). As angiography showed brisk filling of the LSA and no pressure gradient was detected in the aortic arch, no additional procedures were performed. The patient recovered well and was discharged 10 days after the procedure. Blood pressure measurements and antihypertensive medication during follow-up are reported in the Supplementary Material, Table S1.

Thirty days post-TEVAR, CTA demonstrated stable position of the endograft without endoleak and an increase in the ascending aortic diameter by 1 mm (Fig. 1A). The patient suddenly expired 3 months post-TEVAR. Autopsy determined the cause of death to be hemothorax due to a 4.0-cm longitudinal tear without associated dissection in the lesser curvature of the ascending aorta (Fig. 1B).

Computational analysis

FSI techniques were used to examine haemodynamic alterations attributable to the presence of the endograft. First, a pre-TEVAR model was created and validated \cite{3}. Then, 2 additional models...
were constructed: (i) post-TEVAR and (ii) virtual uncomplicated endograft deployment (i.e. without infolding and bird beak) [4].

Vascular deformation mapping was used to calculate the normalized index of distensibility (NID) from the pre-TEVAR and 30-day post-TEVAR image data. Increased NID indicates higher aortic wall stresses.

The details of the methods and limitations of the FSI and vascular deformation mapping analyses are reported in the Supplementary Material.

Computational results

The ascending aortic pulse pressure increased by 35% post-TEVAR (Fig. 2A). Virtual uncomplicated endograft deployment decreased the ascending aortic pulse pressure by only 2 mmHg compared to post-TEVAR. This finding is consistent with the intraoperative pressure measurements and indicates that the increased pulse pressure was not caused by the infolded proximal extension device.

Haemodynamic wall shear stresses in the ascending aorta were higher in both the post-TEVAR and the virtual uncomplicated endograft deployment model compared to pre-TEVAR (Supplementary Material, Fig. S3).

Figure 2B depicts the pre-TEVAR and 30-day post-TEVAR NID maps. NID increased in the unstented segments of the aorta post-TEVAR. NID increased by 173% in the location corresponding to the site of rupture, suggesting that this region experienced higher stresses post-TEVAR.

COMMENT

A stiffness mismatch between the endograft and the native proximal aorta increases the pulse pressure in the ascending aorta, resulting in higher regional wall stresses that may contribute to rupture. This under-recognized phenomenon should be considered in preoperative planning. Patients presenting with a proximal descending and concomitant ascending aortic aneurysm should be counselled to undergo ascending aortic repair.
with a frozen elephant trunk procedure and early completion TEVAR.

Another potential aetiology (albeit not confirmed during autopsy or imaging studies) that could have contributed to aortic rupture in this patient is guidewire or device-induced ascending aortic injury during deployment.

SUPPLEMENTARY MATERIAL

Supplementary material is available at EJCTS online.

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studied in this research. The VDM technology has been licensed to Imbio, LLC. All other authors declared no conflict of interest.

REFERENCES


