Type A aortic dissection model to improve endovascular research and technologies

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Disclosures

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Objectives and Project aims

• Endovascular treatment of the ascending aorta remains challenging due to anatomical structures e.g. aortic root, coronary arteries and supra-aortic vessels. ¹,²

• First clinical trials are limited to anatomically suitability with the entry tear above the sinotubular junction and proximal to the innominate artery and no severe aortic valve insufficiency. ³

• Nevertheless, endovascular aortic repair carries enormous potential and holds great promise for future treatment options in selected patients.

• To improve technologies and facilitate preoperative training, a Type A dissection model is needed to understand device specifications related to tissue-device interaction.

• Project Aim: Ascending aortic dissection model with additional endovascular treatment.


Methods - Dissection model

- Human aortas (n=5) preserved with formalin and stored in 75% ethanol, were anatomically prepared from the aortic root to the iliac arteries (Figure 1.A).

- Ascending aortas were opened semi-circularly and intimal-media dissection was produced by separating the media layer from the intima (Figure 1.B).

- Intimal tube was adapted by using monofilament (6-0 Prolene, Ethicon®) sutures in running fashion, followed by closure of the aortotomy (Figure 1C).

- Suitability of formalin fixed human aortic tissue for experimental evaluation has been successfully described elsewhere. ⁴

* Studies were approved by ethics committee (D 434/04).

Figure 1. A: Isolated human aorta. B: Surgical aortic dissection. Intimal and medial-adventitial layer separated. C: Intimal tube (*) was re-adapted using monofilament-suture. Medial-adventitial incision closed with monofilament sutures. D: Reconstruction of CT scan showing the dissection membrane in the ascending aorta (*).  

Methods – CT-Evaluation

• Evaluation of the specimens was done by a 128-slice computer-tomography-scanner (SOMATOM Sensation, Siemens, PA, USA).

• DICOM (Digital Imaging and Communications in Medicine) data were analyzed using the open source software OSIRIX (Pixmeo SARL).

• The CT-measurements were taken from the aortic wall to the endothelial intimal flap at the sinotubular junction (STJ), ascending aorta and the aortic arch.

• The parameters were defined as pre-stent-implantation (PRSI) and post-stent-implantation (POSI).

![Figure 2. The curved-path of the dissection membrane in CT reconstruction](image)
Methods - Stent Implantation

- Four of the created aortic dissection models (n=4/5) were used for the implantation of endovascular stents (Endovascular I-IV). One aorta was kept as a control.

- Bare metal stents (n=4) used for thoracic endovascular aortic repair (TEVAR) in type B dissection (E®-XL Endoluminal Aortic Stent, Jotec®).

- In addition, endoscopic imaging (Olympus® BF-Q® 180) for the analysis of the intraluminal position.
Methods - Stent Implantation

Figure 5. TEVAR stent implantation performed under fluoroscopy. A. TEVAR-stent in the ascending aorta; B. Guide-wire; C. 14-gauge needle placed in the left coronary ostia for improved orientation
Results - Dissection Model

- Modelling of ascending aortic dissection could be sufficiently performed in all aortic models (n=5).

- In the CT evaluation air provided sufficient contrast for clear identification of the dissection membrane.

- The dissection started on average 3.9±1.4 cm proximally from the aortic root with an average length of 4.6±0.9 cm towards the aortic arch.

- In the control group, CT-measurements of the intimal flap distance at the sinotubular junction (STJ), ascending aorta and aortic arch were at 0.19 cm, 0.49 cm and 0.89 cm (Control).
Results – Stent Implantation

- The TEVAR stents were successfully deployed (Endovascular I-IV).

- The pre-stent-implantation (PRSI) measurement of the intimal flap distance was documented with an overall mean of 0.34±0.09 cm at the STJ, 0.63±0.163 cm in the ascending aorta and in the aortic arch 0.38±0.12 cm.

- Post-stent-implantation (POSI) it was decreased to 0.15±0.05 cm at the site of the STJ, to 0.26±0.13 cm for the ascending aorta and in the aortic arch to 0.26±0.09 cm.

Figure 7. Example of CT guided measurement in the ascending aorta for Endovascular IV. (A) In the pre-stent-implantation (PRSI) the distance of the intimal flap to the aortic wall is at 0.59 cm. (B) The distance was reduced to 0.15 cm after TEVAR stent implantation (POSI: post-stent-implantation)
Results – Intimal Alignment

Table 1. Computed tomography measurements of the distance of the intimal flap to the aortic wall.

<table>
<thead>
<tr>
<th>Site</th>
<th>Control</th>
<th>Specimen no. 1</th>
<th>Specimen no. 2</th>
<th>Specimen no. 3</th>
<th>Specimen no. 4</th>
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<tr>
<td></td>
<td></td>
<td>PRSI</td>
<td>POSI</td>
<td>PRSI</td>
<td>POSI</td>
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<tr>
<td>Sinotubular junction</td>
<td>0.19</td>
<td>0.24</td>
<td>0.13</td>
<td>0.40</td>
<td>0.20</td>
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<td>(cm)</td>
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<tr>
<td>Ascending aorta</td>
<td>0.49</td>
<td>0.63</td>
<td>0.25</td>
<td>0.47</td>
<td>0.21</td>
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<tr>
<td>(cm)</td>
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<tr>
<td>Aortic arch</td>
<td>0.89</td>
<td>0.22</td>
<td>0.15</td>
<td>0.51</td>
<td>0.32</td>
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<tr>
<td>(cm)</td>
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<tr>
<td>Mean</td>
<td>0.52</td>
<td>0.36</td>
<td>0.18</td>
<td>0.46</td>
<td>0.24</td>
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<tr>
<td>Standard deviation</td>
<td>0.35</td>
<td>0.23</td>
<td>0.06</td>
<td>0.06</td>
<td>0.07</td>
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<td>0.39</td>
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<td></td>
<td></td>
<td>0.11</td>
<td>0.05</td>
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n/a: not applicable; POSI: post-stent implantation; PRSI: pre-stent implantation.
Results – Position

- Examination revealed a partial over-stenting (<50%) of the aortic valve for Endovascular I with complete over-stenting of the coronary arteries and supra-aortic vessels.

- Endovascular II and III the over-stenting was <50% of the coronary arteries, however there was a complete over-stenting of the supra-aortic vessels in Endovascular II.

- The analyses of Endovascular IV showed <50% over-stenting of the coronary arteries without any interference with the aortic valve or supra-aortic vessels.

Figure 8. (A) The endoscopic imaging with an over-stenting of the left coronary artery in Endovascular I. (B) CT-imaging showed complete over-stenting of the supra-aortic vessels in Endovascular II.
Conclusion

• The artificial dissection of the ascending human aorta was reproducible and identification was possible using standard CT imaging.

• Endovascular stent implantation in the aortic dissection model decreased the intimal-flap distance and resulted in improved alignment of the intima.

• However the post-implantation analysis exposed an increased rate of interference with the aortic side branches e.g. coronary arteries (Table 2).

• The result was dependent on ideal anatomical conditions to achieve a favourable result (Endovascular IV).

• Further investigation is necessary for the examination of stent grafts in a perfused aortic model.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Specimen no. 1</th>
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<th>Specimen no. 3</th>
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<tr>
<td>Aortic valve</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Left coronary</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Right coronary</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Truncus brachiocephalicus</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Left carotid artery</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Left subclavian artery</td>
<td>Yes</td>
<td>Yes</td>
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</table>

Table 2. Partial (<50%) or complete (>50%) over-stenting of anatomical structures
Outlook

• Development of an animal based (e.g. porcine) or artificial (e.g. silicone) model ideally perfused could offer better reproducibility and easier availability.

• Considering the participation of the aortic root with type A dissection, an “Endovascular-Bentall” could be a potential technical but challenging future option.  

Figure 9. Ultrasound based measurement POSI of intimal flap distance in the ascending aorta under perfusion with 3 l/min (A) Horizontal-distance of intimal flap with 0.05 cm (B) Longitudinal-distance of intimal flap with 0.09 cm

Future investigation

- Including the aortic root in the experimental set-up could assist in the research towards new stent graft design.

- Development of fenestrated stent-graft technology for aortic root and arch therapy. 5, 6

- The presented model serves as a basic technology for the development of a compliant artificial pressurized aortic root model. 7, 8

References:
Current developments


Thank you for your attention

“One must merely sew. And when one knows where to sew, there is no problem.”

Åke Senning