A Modular Approach for an Endovascular Training Environment using 3D-Rapid-Prototyping as Part of the Nav EVAR Project

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Speaker name: Mark Kaschwich

I have the following potential conflicts of interest to report:

- Consulting
- Employment in industry
- Stockholder of a healthcare company
- Owner of a healthcare company
- Other(s)

I do not have any potential conflict of interest
Disclosure

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FKZ: 13GW0228A

Project Time: October 1\textsuperscript{st} 2017 – September 31\textsuperscript{th} 2020

Funding 4.2 Mio €
Why do we need Simulators for Endovascular Training?
In aviation, simulator training has become a key component to learn basic skills and to be prepared for challenging situations!
Development of Endovascular Surgery

Endovascular interventions are highly specialized procedures

OR 1914

Hybrid-OR 2018
What do we expect from an endovascular simulator?

- **Realistic Shape of Vascular Walls** (*incl. Wall adherent thrombus*)
- **Different Vascular Morphologies** (*AAA, TAAA*)
- **Surrounding anatomical landmarks** (*e.g. spine*)
- **Access to different Vascular Regions** (*femoral, brachial*)
- Transportable
- Perfusion
McKinsey Report 2013
Potentially Economically Disruptive Technologies

- Mobile Internet
- Automation of knowledge work
- The Internet of Things
- Cloud technology
- Advanced robotics
- Autonomous and near-autonomous vehicles
- Next-generation genomics
- Energy storage
- 3D printing
- Advanced materials
- Advanced oil and gas exploration and recovery
- Renewable energy
Application of 3D-Rapid-Prototyping in Medicine

Three-dimensional (3D) printing and its applications for aortic diseases

Patrick Hangge, Yash Pershad, Avery A. Witting, Hassan Albadawi, Rahmi Oklu


3D printing and its applications in orthopaedic surgery

A technological marvel

Hitesh Lal, Mohit Kumar Patralekh

Central Institute of Orthopaedics, Safdarjang Hospital and VMMC, New Delhi, 110029, India
What are the advantages of 3D-rapid-prototyping in vascular training?
3D-Vascular-Models for Endovascular Training

Eur J Vasc Endovasc Surg (2017) 54, 247—253

A simulator for training in endovascular aneurysm repair: The use of three dimensional printers

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Methods

- prospective, controlled, single centre study
- control group (five residents and 30 patients in 2014) without simulator training
- training group (five residents and 25 patients in 2015) with simulator training
3D-Vascular-Models for Endovascular Training

Results:

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control group</th>
<th>Training group</th>
<th>( p )</th>
<th>Control group</th>
<th>Training group</th>
<th>( p )</th>
<th>Results from ANCOVA model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopy time (min)</td>
<td>36.5 (25.7–65.2)</td>
<td>23 (17–30)</td>
<td>&lt;.01</td>
<td>48.2 (39.7–58.4)</td>
<td>33.3 (26.1–42.3)</td>
<td>&lt;.01</td>
<td>30%</td>
</tr>
<tr>
<td>Total procedure time (min)</td>
<td>272.5 (198.7–327.5)</td>
<td>187.5 (148.7–217.5)</td>
<td>&lt;.01</td>
<td>291.6 (253.4–335.5)</td>
<td>206.5 (172.7–246.8)</td>
<td>&lt;.01</td>
<td>29%</td>
</tr>
<tr>
<td>Contrast volume (mL)</td>
<td>75 (62.5–110)</td>
<td>55 (45–72.5)</td>
<td>&lt;.01</td>
<td>86.6 (72.8–103.1)</td>
<td>64.9 (51.8–81.3)</td>
<td>.02</td>
<td>25%</td>
</tr>
<tr>
<td>Time to gate cannulation (min)</td>
<td>7 (4.5–12.5)</td>
<td>2 (1.5–5)</td>
<td>&lt;.01</td>
<td>6.5 (4.1–10.2)</td>
<td>3.1 (1.7–5.5)</td>
<td>.03</td>
<td></td>
</tr>
</tbody>
</table>

Note. IQR = interquartile range; CI = confidence interval.

\( ^{a} \) Adjusted for internal iliac embolisation.

Torres and De Luccia, 2017
Results
The residents considered the training **useful and realistic**, and reported that it **increased their self confidence**.
3D-Rapid-Prototyping of the Aorta

Post processing – patient specific model

Final Model – ready for application
How accurate are 3D-Vascular-Models?
Validation of Accuracy – Results

Comparison of original CT-scan with CT-scan of 3D-printed model
# Variety of Materials for 3D-Rapid-Prototyping

<table>
<thead>
<tr>
<th>Material</th>
<th>Tango Plus</th>
<th>Vero Clear</th>
<th>ABS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image</strong></td>
<td><img src="image1.png" alt="Tango Plus" /></td>
<td><img src="image2.png" alt="Vero Clear" /></td>
<td><img src="image3.png" alt="ABS" /></td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Elasticity</strong></td>
<td>✓</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Perfusion</strong></td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td><strong>Surface</strong></td>
<td>smooth</td>
<td>smooth</td>
<td>rough edges</td>
</tr>
<tr>
<td><strong>Segmentation</strong></td>
<td>Materialise Mimics &amp; 3-matic</td>
<td>Materialise Mimics &amp; 3-matic</td>
<td>Materialise Mimics &amp; 3-matic</td>
</tr>
<tr>
<td><strong>3D-Printer</strong></td>
<td>Connex500 (Objet)</td>
<td>Connex500 (Objet)</td>
<td>Delta-Kinematik (Robotics Univ. Lübeck)</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>700€</td>
<td>890€</td>
<td>5-10€</td>
</tr>
<tr>
<td><strong>Printing time</strong></td>
<td>Ca. 20h</td>
<td>Ca. 20h</td>
<td>Ca. 10h</td>
</tr>
<tr>
<td><strong>Deviation</strong></td>
<td>5.23% (3.42%)</td>
<td>5.38% (3.6%)</td>
<td>5.26% (3.41%)</td>
</tr>
</tbody>
</table>

*From left to right (Material VeroClear und Tango+): Shore A27, Shore A40, Shore A50, Shore A60, Shore A70 and VeroBlue*
Development of an Endovascular Simulator with Exchangeable Vascular Pathologies
Endovascular Simulator with Exchangeable Vacular Pathologies
Endovascular Simulator with Exchangeable Pathologies – Study Set Up
Use of Simulators for Endovascular Training
Using Authentic Simulators for New Endovascular Approaches
Avoidance of Animal Experiments using Authentic Endovascular Simulators

Three „R“ rule (according to German Animal Protect Act):

- Replace
- Reduce
- Refine

- concept of 3R has become the accepted standard in Europe and the US
- German Animal Protection Act (Section 7)
- EU guidelines for the protection of animals (2 and 3 86/609 / EEC)
- Directive obliges EU Member States to the development and promotion of alternative methods.
Reasons for using 3D-Rapid-Prototyping-Models for Endovascular Training

Summary

- Better pre-operative planning of complicated procedural steps
- Different pathologies with different skills levels can be trained
- Limits the use of animals
traditional mantra of
‘see one, do one, teach one’
should be replaced by
‘see one, sim many, do one, teach one’
Future Purposes – Universal Vascular Training System
Thank you for your attention!