3D Guidance including Shape Sensing of a Stentgraft System

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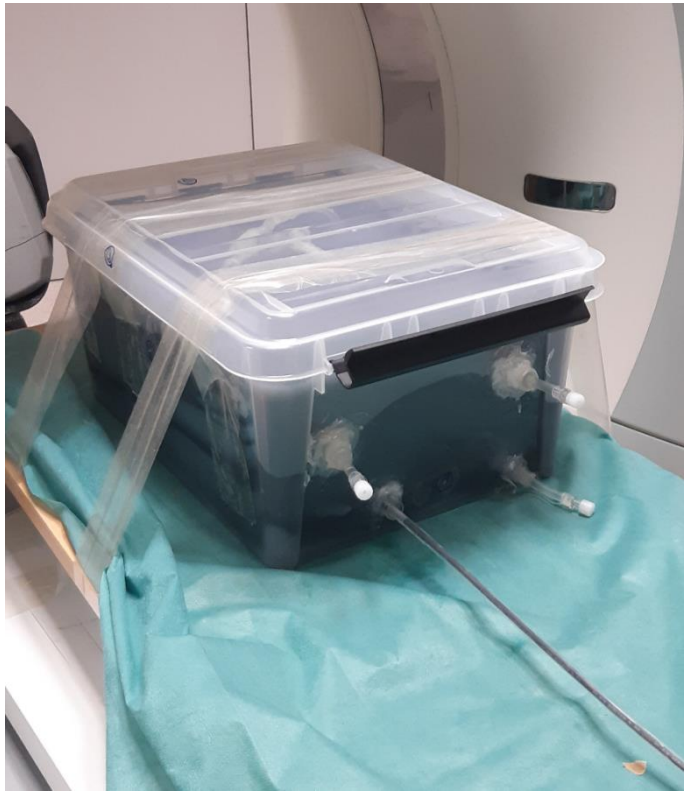
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Motivation – What is guidance?

View in real world



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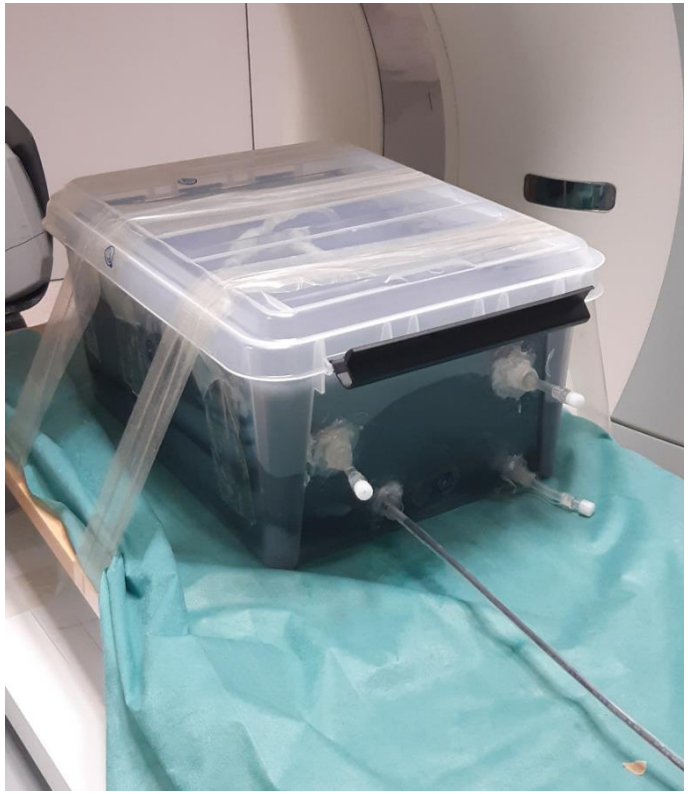
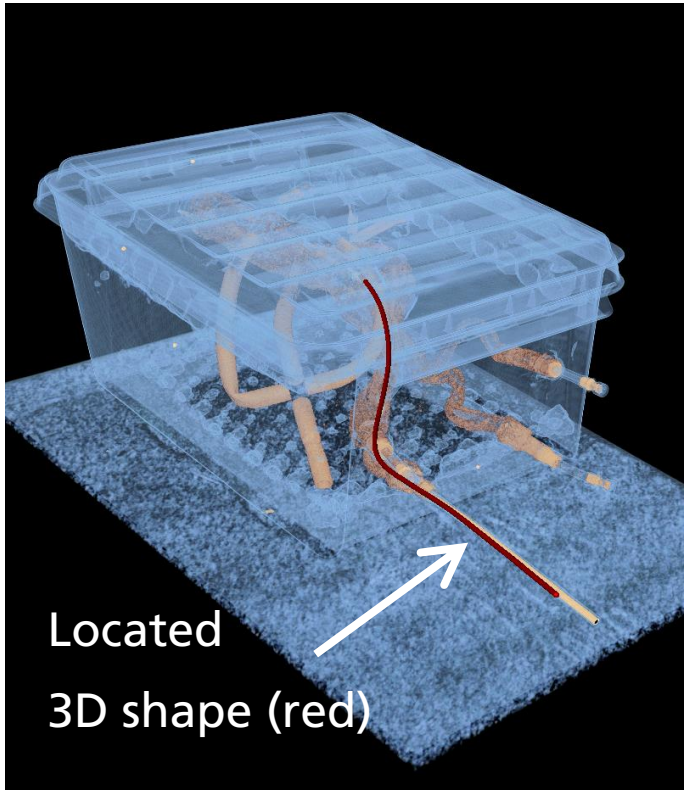
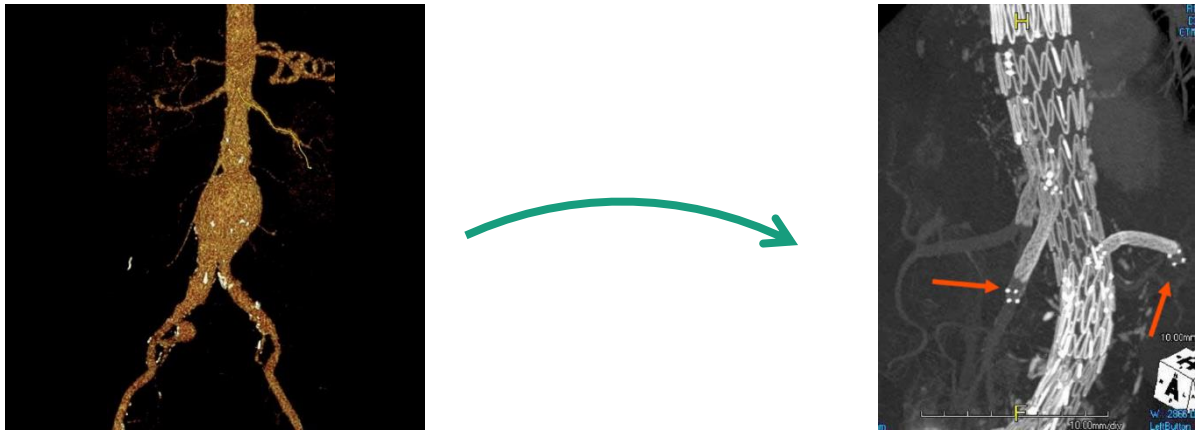


CT scan view



Motivation – clinical problem

Use case: vessel repair by implanting a stentgraft



Current guidance method: 2D fluoroscopy with contrast agent

Motivation – clinical problem

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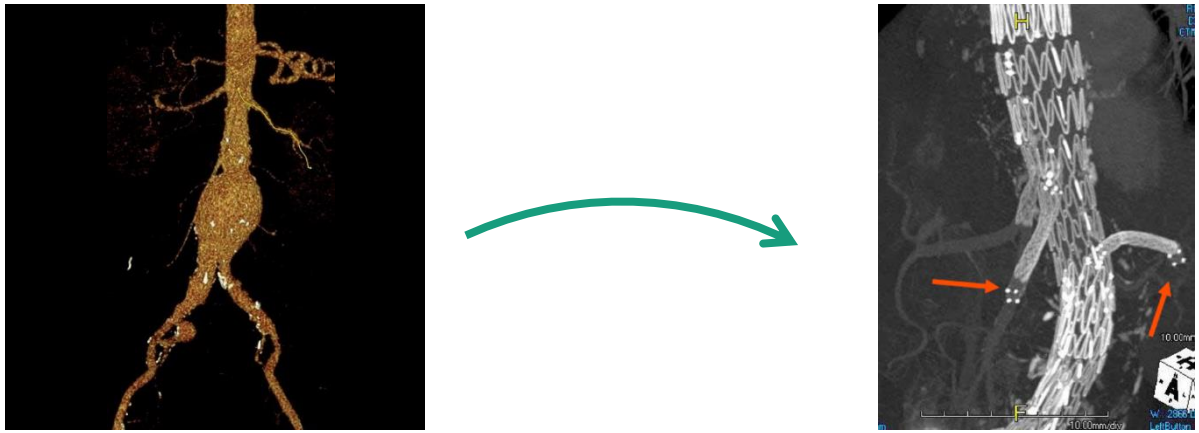


Current guidance method: 2D fluoroscopy with contrast agent

- Drawbacks:
  - Missing depth information
  - Radiation exposure of surgical team and patient (Rehani et al. 2006)
  - Kidney damaging contrast agent (Saratzis et al. 2015)

Motivation – goal and idea

- Goal: 3D guidance without the use of X-rays and contrast agents
- Idea:

Fiber optical shape sensing

✓ Shape

X Location

Khan et al. 2019,

Roesthuis et al. 2014

+

Electromagnetic (EM) tracking

X Shape

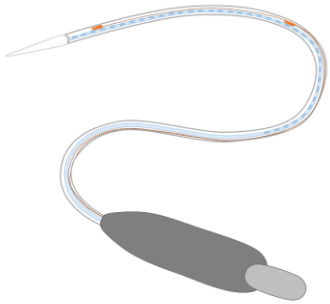
✓ Location

Condino et al. 2012,

Lambert et al. 2012

=

3D guidance

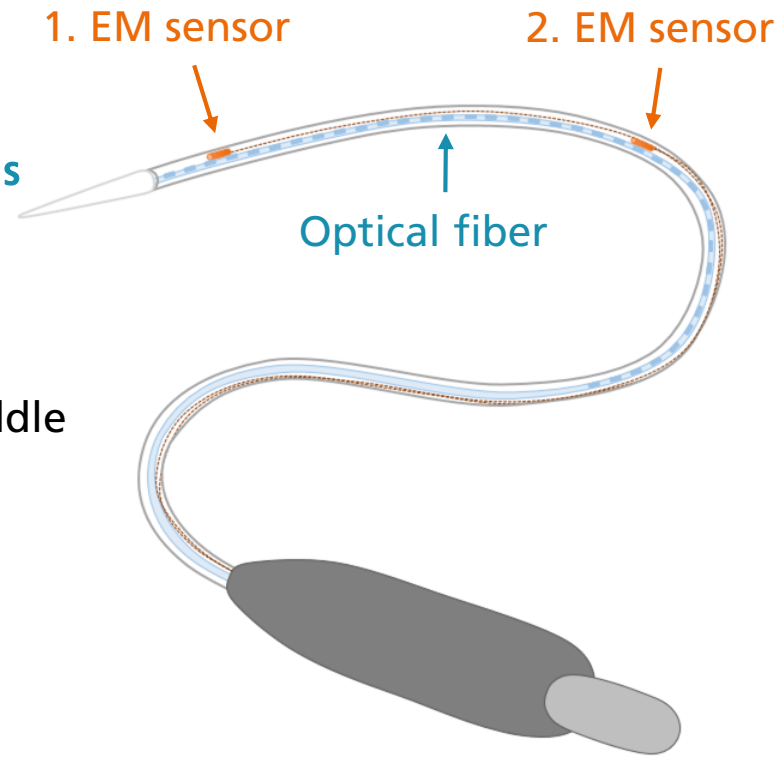


✓ Shape

✓ Location

Stentgraft system

- Contains tracking system:
  - 1 Optical fiber
    → **Reconstructed shape of 38 cm as shape point list**
  - 2 EM sensors near the tip and the middle of the shape sensing region
    → **Position and orientation information**



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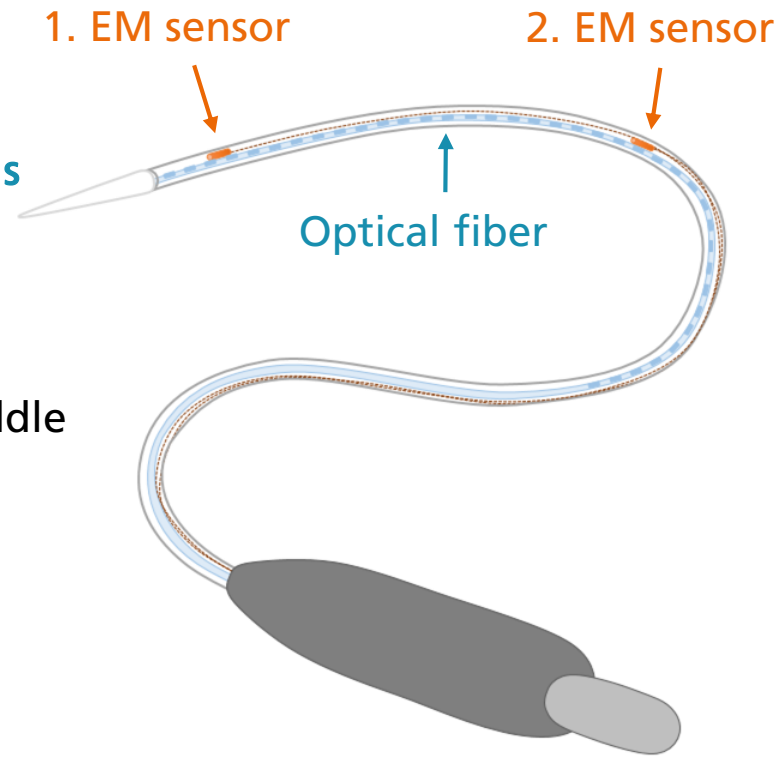

→ **Accurate localization at the front part of the stentgraft system**

Guidance method – shape localization

- Given: Calibrated positions and direction vectors of tracking systems

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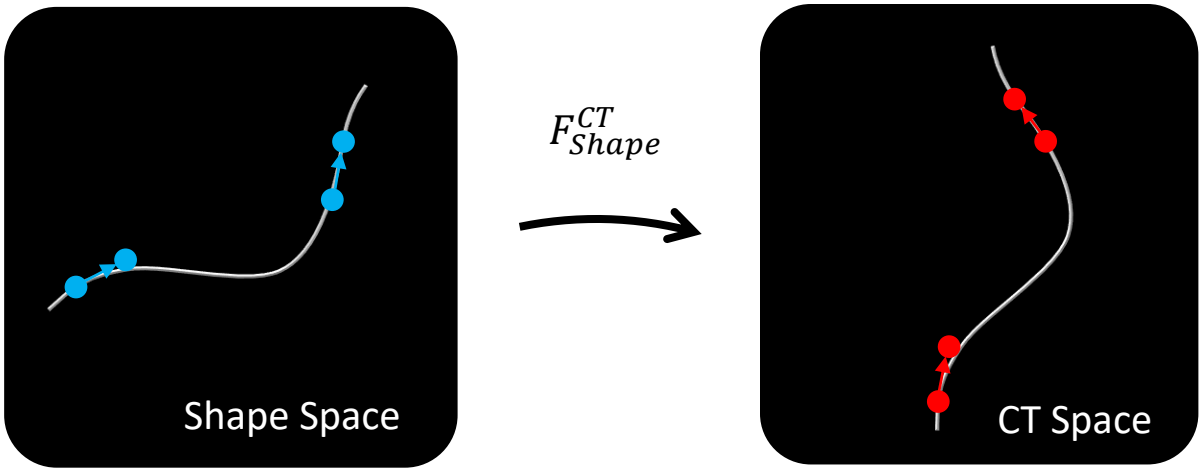

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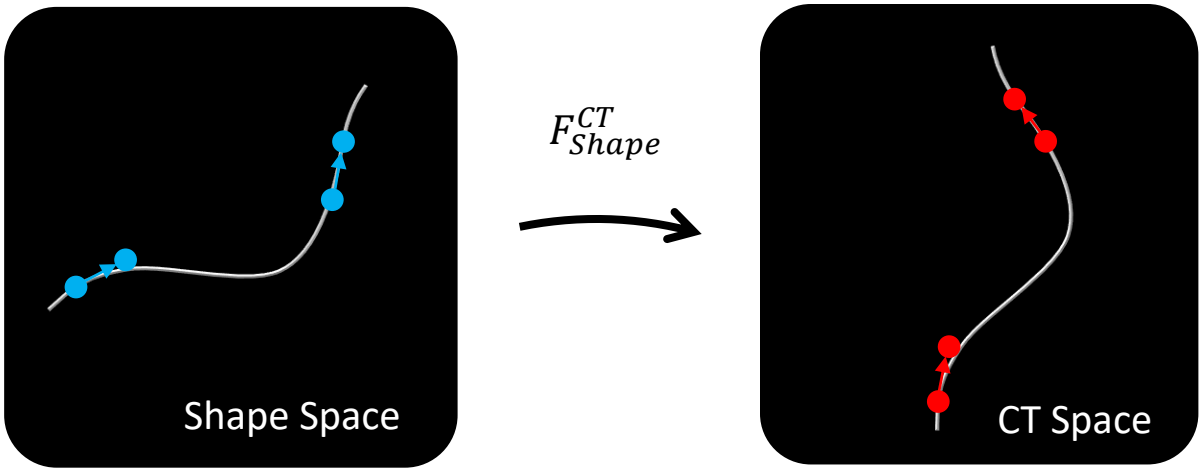


- Computation of rigid transformation F_{Shape}^{CT} from shape space in CT space by means of point based registration.
  (Arun et al. 1987)

Experiments – vessel phantom

- Insertion of the stentgraft system into a vessel phantom:

without agar-agar

with agar-agar

Experiments – setup

- Evaluation at three different insertion depths of the stentgraft system
- CT acquisition and the segmentations are used as ground truth
- Measures:

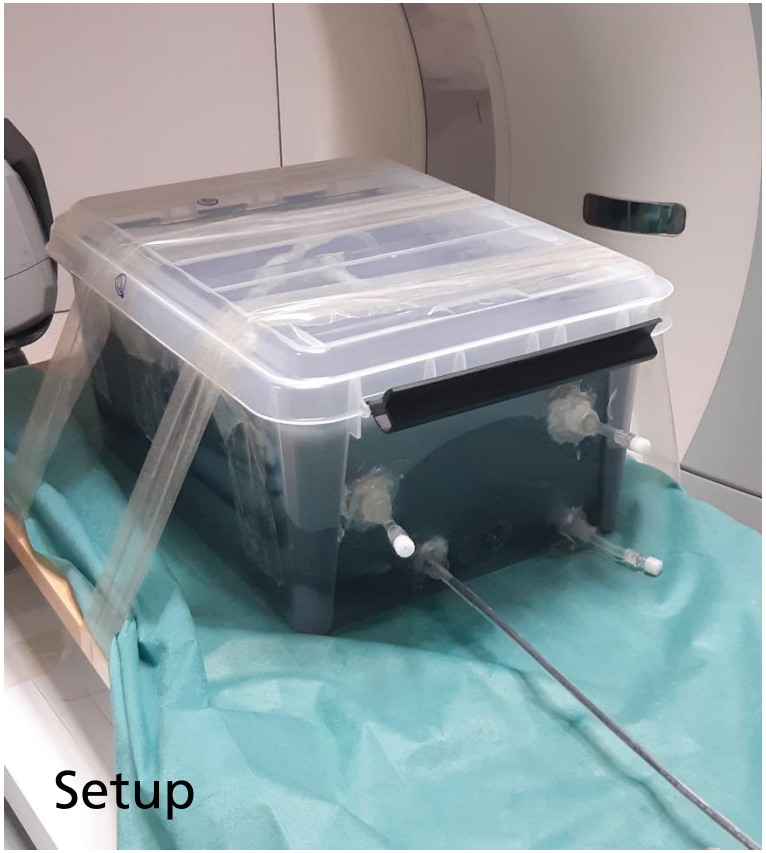
  average error: $e_{avg} = \frac{1}{m}\sum_{i=1}^{m}\left\|x_i - x_i^{gt}\right\|_2$

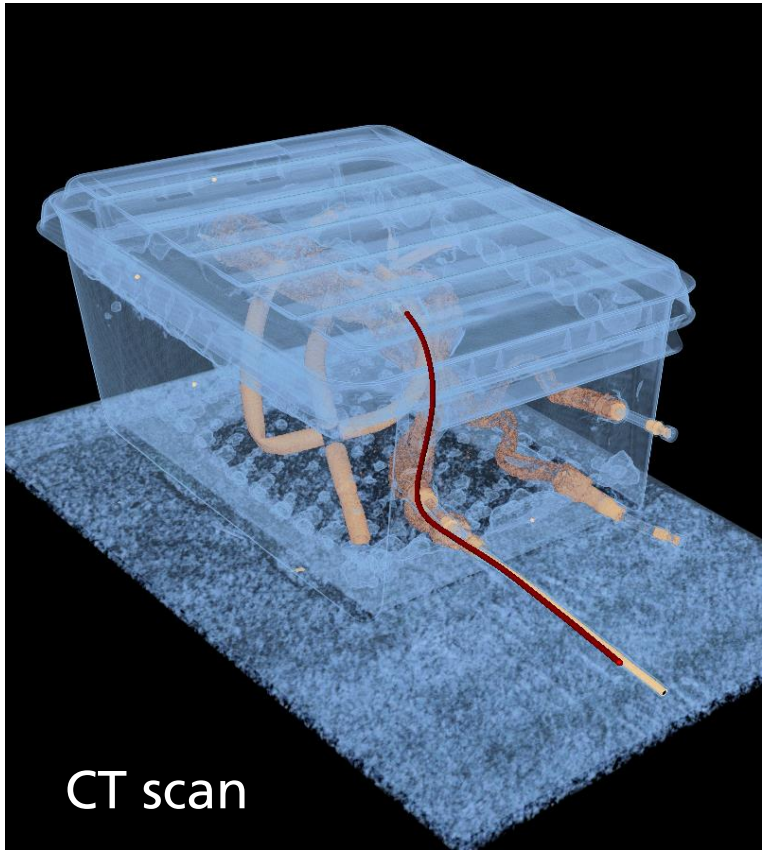
  maximum error: $e_{max} = \max\left(\left\|x_1 - x_1^{gt}\right\|_2, \ldots, \left\|x_n - x_n^{gt}\right\|_2\right)$

- A continuous measurement of tracking systems during insertion the stentgraft system

Results

Phantom with inserted stentgraft system (22cm insertion depth)





Results

- Measured errors (in mm) for different insertion depths:

	Whole 38 cm		Shape inside vessel	
Shape \ Error	e_{avg}	e_{max}	e_{avg}	e_{max}
22 cm inside	2.39	2.80	2.47	2.80
17 cm inside	1.28	2.94	1.00	1.39
12 cm inside	2.24	5.76	2.10	3.24

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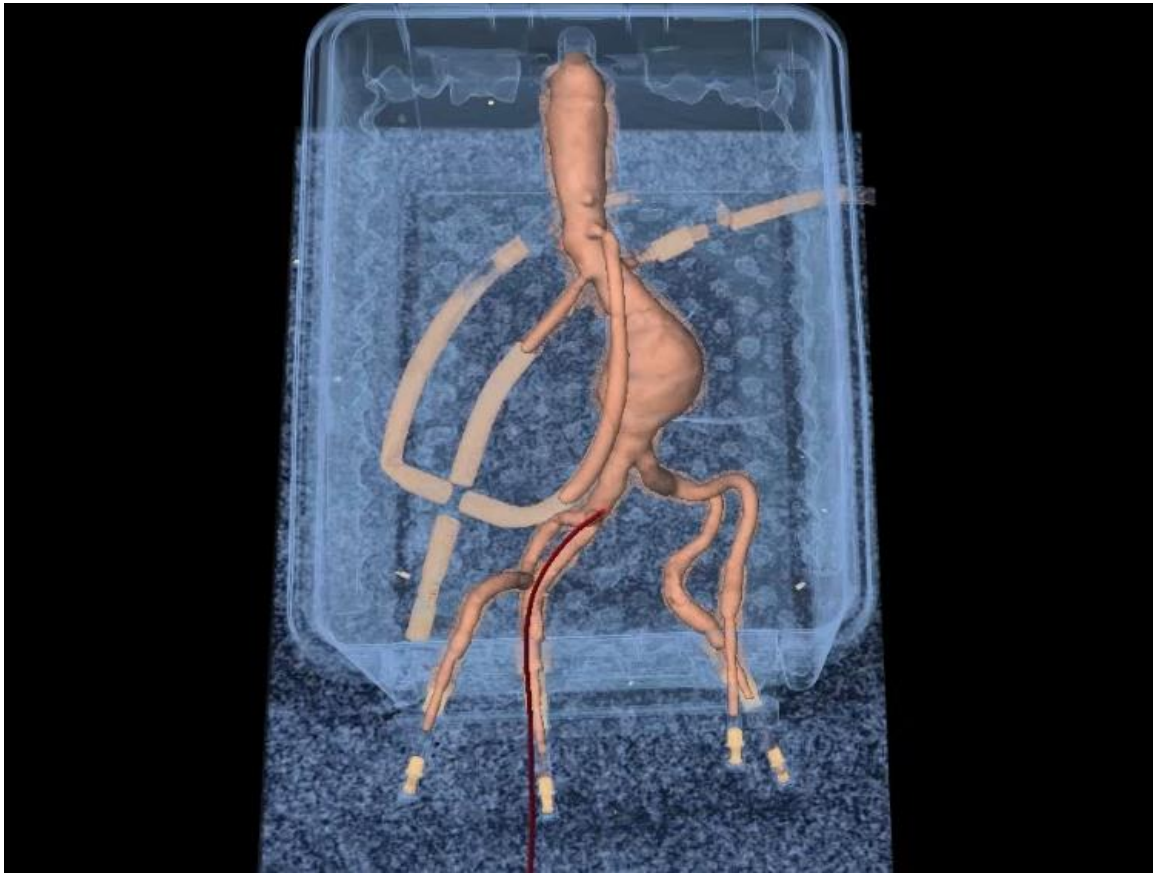
- Clinical requirement: errors ≤ 5mm

  → Promising results for clinical usage

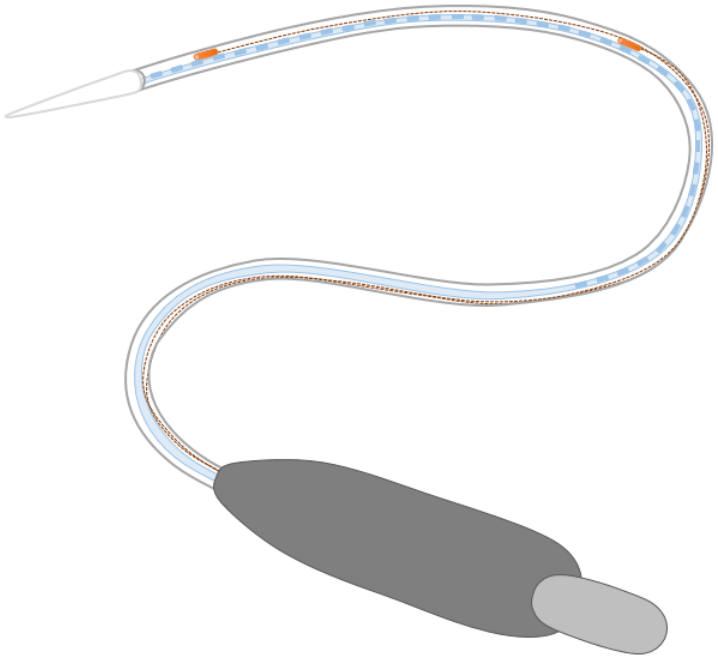
Results

- Continuous measurement:



Conclusion

- A first stentgraft system with a multicore fiber and two EM sensors



- **A novel 3D guidance method**
  → Promising for clinical usage

- Future work:
  - Evaluation in real-time
  - Development of a stentgraft guidance

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