How accurate is intraoperative overlay imaging?

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Accuracy

- The quality or state of being correct or precise

- Technical: the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard
Vessel deformation

Prediction of deformations during endovascular aortic aneurysm repair using finite element simulation.

Kaladji A Comput Med Imaging Graph. 2013 Mar

(EVAR), the introduction of medical devices deforms the arteries

The aortoiliac structure was extracted from the preoperative CT angiography of fourteen patients underwent EVAR. The simulation consists in modeling the deformation induced by the stiff wire used during EVAR. The results of the simulation were projected onto the intraoperative images, using a 3D/2D registration. The mean distance between the real and simulated guidewire was $2.3 \pm 1.1 \text{mm}$. Our results demonstrate that finite element simulation is feasible and appear to be reproducible in modeling device/tissue interactions and quantifying anatomic deformations during EVAR.
Feasibility

- Evaluation of automated 2D-3D image overlay system utilizing subtraction of bone marrow image for EVAR: feasibility study.

  Fukuda T. Eur J Vasc Endovasc Surg. 2013 Jul

- To evaluate the automated 2D-3D image overlay system ("3D Roadmap") for use during endovascular aneurysm repair (EVAR).

- Preoperative CT images were modified to subtract dense bone marrow to improve the visualization of vasculature on the overlaid image, and allow for accurate navigation of the endovascular devices. The 3D-CT overlay image was registered on the 2D fluoroscopy image to mark the iliac crest and lumbar vertebrae on both images as landmarks. Arteriography was performed only twice to confirm the precision of the position of renal artery and the final evaluation. Twenty patients underwent EVAR with Medtronic Endurant, Gore Excluder, or COOK Zenith using "3D Roadmap". The origin of the renal artery and iliac bifurcation were registered with complete accuracy in 10 patients (50%). The lower renal artery deviated toward the cranial side less than 3 mm in six patients. In all cases, EVAR was successful, and completed with the volume of contrast material limited to 43.8 ± 3.1 mL.
Dynamic 3D Roadmap
Basics

- Overlay of live fluoroscopy onto 3D-RA or CBCT volumetric projection
- Synchronized with FPD magnification, C-arc angulations and Table movements

registration precision < 0.2 mm
MR/CT roadmap

Basics

- Registration of 3D-RA or CBCT with previously acquired CT/MR datasets
- Same technical principles (inverse perspective) and synchronization as in dynamic 3D roadmap
- Precision of 3D–3D registration < 0.55 mm
Image overlay?

- CBCT
- Superimposed with CTA
- Overlay to fluoroscopy
- 3D CTA Road mapping
- Combined to table movements and to the C-arm
Calcifications

Thick-slab MIP rendering of diagnostic CTA

Sagittal slice of blanco XperCT
Results

XperCT showing complete stent-graft deployment

Control CTA confirms complete aneurysm coverage and no endoleaks
Results

Virtual stent position

Post-interventional CTA
Comparison of Two-dimensional (2D) Angiography, Three-dimensional Rotational Angiography, and Preprocedural CT Image Fusion with 2D Fluoroscopy for Endovascular Repair of Thoracoabdominal Aortic Aneurysm

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**Volume de PDC**

Contrast (ml)

<table>
<thead>
<tr>
<th>Group</th>
<th>Volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>235ml</td>
</tr>
<tr>
<td>Group 2</td>
<td>223ml</td>
</tr>
<tr>
<td>Group 3</td>
<td>65ml</td>
</tr>
</tbody>
</table>

\[ p(g_1/g_3) \text{ and } p(g_2/g_3) : S \]
### Intervention Data

<table>
<thead>
<tr>
<th>Parameters (n ± SD or %)</th>
<th>2DA Group</th>
<th>3DA Group</th>
<th>IF Group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success of procedure</td>
<td>8(89%)</td>
<td>14(100%)</td>
<td>14(100%)</td>
<td>0.24</td>
</tr>
<tr>
<td>Duration of Intervention (minute)</td>
<td>233(±123)</td>
<td>181(±53)</td>
<td>189(±60)</td>
<td>0.59</td>
</tr>
<tr>
<td>DAP (Gy×cm²)</td>
<td>1188(±1067)</td>
<td>984(±581)</td>
<td>656(±457)</td>
<td>0.18</td>
</tr>
<tr>
<td>Contrast (ml)</td>
<td>235(±145)</td>
<td>225(±119)</td>
<td>65(±28)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

### Endoleaks

#### Endoleak on the first CT control

<table>
<thead>
<tr>
<th>Endoleak</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoleak</td>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Type 1</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Type 2</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Type 3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
4 Fenestrations
No Angio KT
Neck deformation
KT in the 4 target vessels
After stentgraft deployment
No correction
Vessel deformation and shift
Origine of Errors

- **Vessels shifts:**
  - central<<peripheral
  - Straight <<< tortuosity and angulation
  - Floppy<<<stiff

- **Patients movements:**
  - General anesthesia<<local anesthesia
  - Pain, and patient shifts
  - Respiratory and heart movements

- **Errors of overlay:**
  - 2D/3D<3D/3D
  - Time between diagnostic and treatment
Stentgraft with MRA overlay
Zero contrast

Sever Allergy
Fusion with MRA Technique
Application:
AAA symptomatic: 56 mm
MRA No rupture but wall enhancement
Anaphylactic Choc during 2 coronarography «15 stents »
Symptomatic AAA

Anaphylactic choc to CM: 2 episodes

MRA overlay

Intervention: 70 Min

Fluoro: 15 Min

Graphic acquisition: 0

CM: 0cc
Magellan system:
KT in the CT
Splenic aneurysm embolization
Conclusions

- All aortic parts and vessels are not equal to deformations
- Technology is accurate but we induce errors
- 3D/3D seems to be > to 2D/3D (my opinion)
- Several origin of errors: +/- easy to avoid
- Clinical applications for today technology is enough
- Futur (robotics and automatic navigation) need more accuracy???