Three-dimensional guidance for Endovascular Aortic Repair

Akademisk avhandling

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av
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Avhandlingen baseras på följande delarbeten:

I. Koutouzi G, Sandström C, Roos H, Henrikson O, Leonhardt H, Falkenberg M.
Orthogonal Rings, Fiducial Markers, and Overlay Accuracy When Image Fusion is Used for EVAR Guidance.
Eur J Vasc Endovasc Surg. 2016 Nov;52(5):604-611.

II. Koutouzi G, Henrikson O, Roos H, Zachrisson K, Falkenberg M.
EVAR Guided by 3D Image Fusion and CO_2 DSA: A New Imaging Combination for Patients with Renal Insufficiency.
J Endovasc Ther. 2015 Dec;22(6):912-7.

III. Koutouzi G, Sandström C, Skoog P, Roos H, Falkenberg M.
3D Image Fusion to Localise Intercostal Arteries during TEVAR.
EJVES Short Reports 2017 35, 7e10.

IV. Koutouzi G, Nasihatkton B, Danielak-Nowak M, Leonhardt H, Falkenberg M, Kahl F.
Performance of a Feature Based Algorithm for 3D-3D Registration of CT Angiography to Cone Beam CT for Endovascular Repair of Complex Abdominal Aortic Aneurysms.
Submitted 2017.

V. Koutouzi G, Pfister M, Breininger K, Hellström M, Roos H, Falkenberg M.
Deformation of the Iliac Artery during EVAR.
Manuscript.

SAHLGRENSKA AKADEMIN
INSTITUTIONEN FÖR KLINISKA VETENSKAPER

GÖTEBORGS UNIVERSITET

Three-dimensional guidance for Endovascular Aortic Repair

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ABSTRACT

Image fusion (IF) of preoperative computed tomography (CT) with intraoperative cone-beam CT (CBCT) is a potentially powerful tool for guidance during endovascular aortic repair (EVAR). It may improve intraoperative anatomic visualization and reduce doses of radiation and contrast medium. The technique is still new, however, and has not yet been standardized for routine use in all centers that have the facilities to perform it.

The main aims of this thesis were:

1. to describe the use of orthogonal rings for 3D guidance during EVAR and to investigate sources of registration and overlay error;
2. to investigate the feasibility of combining 3D fusion with carbon dioxide (CO_2) digital subtraction angiography (DSA) during EVAR, in order to reduce the dosage of iodinated contrast;
3. to determine whether 3D image fusion can be used to localize intercostal arteries during thoracic EVAR;
4. to evaluate the performance of a feature-based algorithm for 3D3D image registration; and
5. to assess iliac artery deformation due to stiff endovascular devices during EVAR.

In a prospective single-center study (I) involving 19 patients undergoing EVAR, we found that automatic intensity-based registration only was insufficient for guidance. Manual vertebrae-based registration was sufficient in only 37% of the patients. After aorta-based registration, the median overlay alignment error for the lowest renal artery at pre-deployment DSA was 2 mm (range 0–5 mm) sideways and 2 mm (range 0–9 mm) longitudinally.

Study II was a feasibility study showing that EVAR can be performed with 3D image fusion guidance combined with CO_2 DSA, instead of iodinated contrast medium DSA, which was only used for the completion angiography.

Study III was also a feasibility study showing that image fusion can facilitate thoracic EVAR (TEVAR) by visualization of intercostal arteries adjacent to the distal landing zones.

In study IV, a feature-based and an intensity-based registration algorithm were compared using datasets from 14 patients who underwent complex EVAR. The feature-based algorithm was more robust and accurate. The median 3D error for the feature-based algorithm was 2.3 mm (range 0.4–7.9 mm) as compared to 31.6 mm (range 0.5–112.2 mm) for the intensity-based algorithm ($p < 0.001$).

In study V, preoperative, postoperative, and intraoperative 3D image datasets were reviewed in order to assess iliac artery deformation by stiff endovascular devices during EVAR. The common iliac artery was shorter in both the intraoperative images ($p < 0.001$) and the postoperative images ($p = 0.015$) relative to the preoperative CTA. Furthermore, there was a dislocation of the aortic bifurcation in the cranial direction (93%) and a dislocation of the iliac bifurcation in the ventral direction (89%). The intraoperative C-arm angulation for optimal projection of the iliac bifurcation increased with 21 ± 43 degrees in the contralateral oblique direction relative to the angle predicted from the preoperative CTA.

In conclusion, 3D image fusion for EVAR guidance is a promising technique allowing improved intraoperative visualization of critical anatomical structures. However, limitations in registration accuracy and anatomy distortion compensation mandate further research.

Keywords:
Anatomy deformation, CBCT, EVAR, image fusion, image guidance, image registration.