Fluoro-free, Ultrasound-based Navigation System for Cardiac Interventions

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INTRODUCTION

INTRACARDIAC INTERVENTIONS

- Image guidance is critical for minimally invasive cardiac procedures because of absence of direct line of sight.
- Two major stages of any percutaneous intervention:
  - Navigation of tools through vasculature.
  - Positioning of tools at the target site.

STANDARD OF CARE

Navigation

- Fluoroscopy

Positioning

- Fluoroscopy
- Ultrasound – Transesophageal (TEE) and intracardiac echocardiography (ICE)

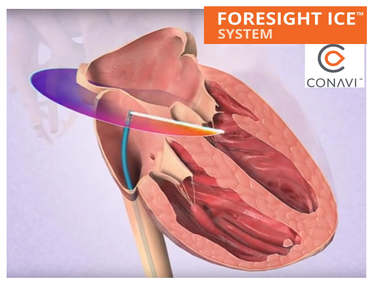


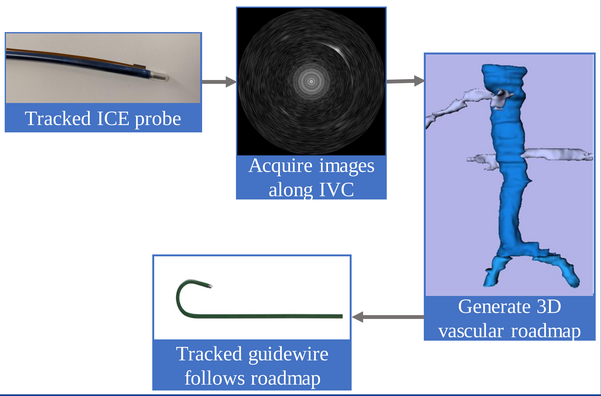
IMAGE GUIDANCE SYSTEMS

- Combine imaging modalities with tracking technology in a user-friendly virtual environment, to assist surgical interventions in real-time.

MOTIVATION

- To reduce fluoroscopy during navigation phase of cardiac interventions because:
  - Exposure to harmful radiation.
  - Lack of visualization for the anatomy.
  - Risk of puncturing vessels.
  - Specialized equipment required.
- An ultrasound-based image guidance system can allow for a safe and radiation-free navigation through inferior vena-cava (IVC).

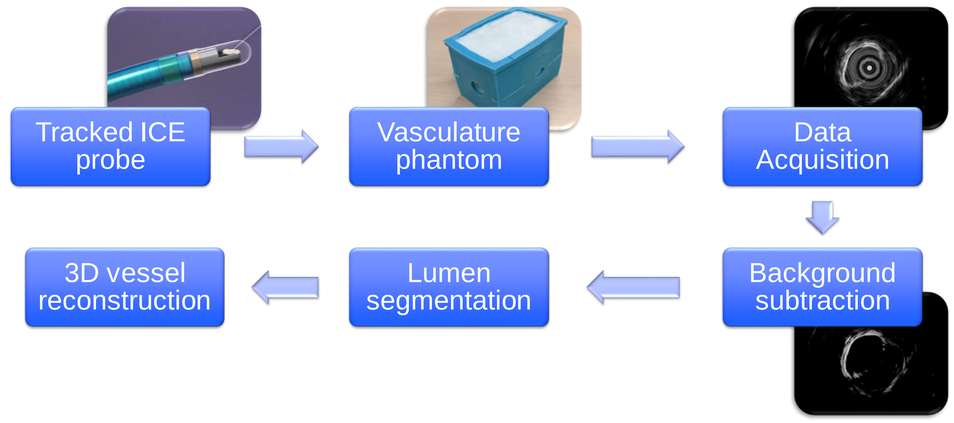
PROPOSED SURGICAL WORKFLOW



OBJECTIVE

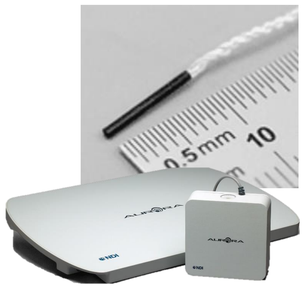
To generate a navigation roadmap of a vascular phantom using tracked Conavi Foresight™ ICE probe to facilitate tool navigation during intracardiac interventions

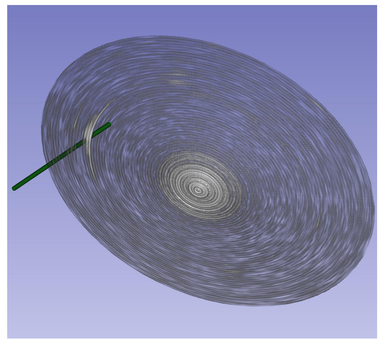
METHODS



ULTRASOUND TRACKING & CALIBRATION

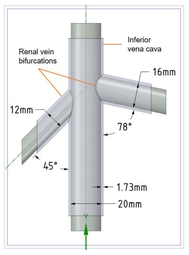
- Electromagnetic tracking device – NDI Aurora.
- Mini 6 degree of freedom tracking sensor (0.8 mm x 9 mm).
- Point to line calibration leads to correct spatial alignment of tracked tools and tracked ultrasound image in a virtual environment.



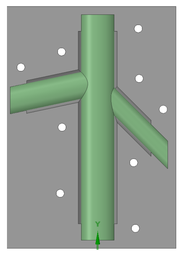


VASCULAR PHANTOM

- Realistic under ultrasound, hollow, with vessel wall and surrounding tissue mimicking layer
- Similar geometry as IVC and renal veins.
- Material: Polyvinyl alcohol cryogel (PVAC) mixed with talc as scattering agent.



CAD model of vessel geometry



CAD model of mould and inserts

PVAC + 2.5% talc (1 freeze-thaw cycle)

Ready to add outer layer material

PVAC + 0.05% talc (2 freeze-thaw cycle)

DATA ACQUISITION AND POST-PROCESSING

Background subtraction

- Background modelling – using a sector of artefacts, rotated along 360 degrees and combined.

Vessel lumen segmentation

- Active contour algorithms to be used to segment the vessel lumen in each image.

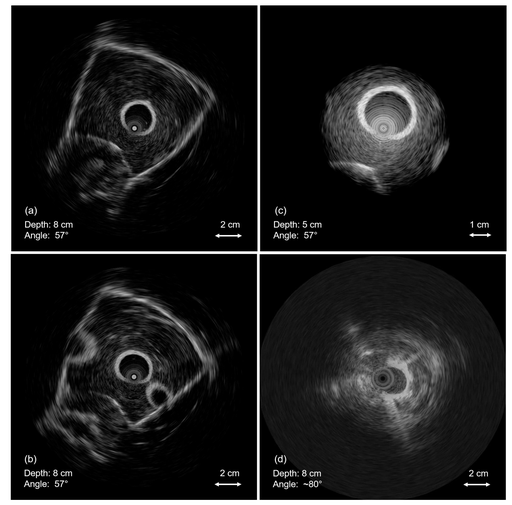
3D vessel reconstruction

- Possibly 'joint smoothing' and/or 'model fitting' algorithms to be used.

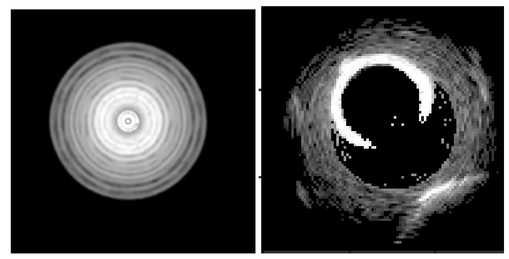
RESULTS

- Vascular phantom was successfully created with desired geometries.
- Average error in lumen diameter = 0.9 mm

Foresight™ ultrasound imaging (ICE) of the phantom (a) showing main vessels, (b) bifurcations, and (c) at a smaller depth. Comparison with (d) Swine IVC



Background model and subtracted image extracted from image (c) above



DISCUSSION

- This is an on-going preliminary phantom study which focuses on the design on an image guidance system for navigation through IVC.
- Background noise artefacts i.e. concentric circles are additive in nature and background removal often results in the loss of anatomical information.
- We are currently working on the post-processing of our phantom images. Region growing or active contour algorithms are favorable for image segmentation.
- Future work involves doing animal studies and designing a robust algorithm to take care of varying appearances of veins in ultrasound.

ACKNOWLEDGEMENTS

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