Ultrasound-guided Vascular Navigation using Deep Learning

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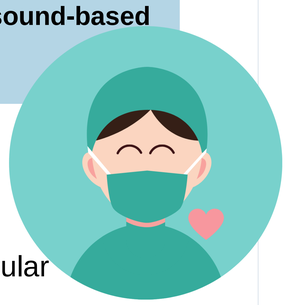
INTRODUCTION

During transcatheter cardiac and endovascular interventions, the guidewire navigate the vessels to reach the target area.

Current standards for vascular navigation include 2D fluoroscopic imaging & pre-operative CT mapping, which have some disadvantages:

- Radiation exposure to the patient and clinicians.
  "Interventionalist's disc diseases" i.e. back and neck pain due to wearing heavy led shielding.
- 2D projected views only
- Expensive, non-portable specialized room and equipment

PROPOSED SOLUTION – An ultrasound-based vessel navigation system

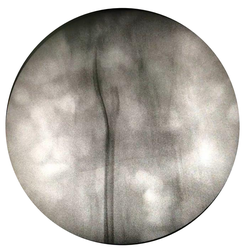


Proposed procedural workflow:

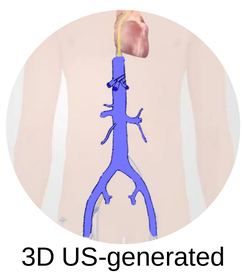
Generate in real-time a 3D vascular Roadmap, using a tracked intracardiac ultrasound (ICE) probe, which can then be employed as a GPS map to allow safe traversal by a tracked guidewire to reach the target organ or vessel.

OBJECTIVE

To reconstruct vascular access pathways using ICE imaging, tracking technology and deep learning based methods.



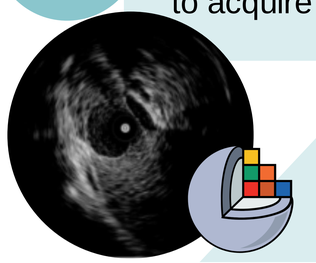
2D projected fluoroscopy



3D US-generated roadmap

METHODS

1 Magnetically tracked and calibrated end-firing 3D ICE probe scans a vessel via the pull-back method to acquire vascular lumen data for reconstruction.



2 Imaging & tracking data are recorded using a frame-grabber and PLUS[2] application

3 Vessel lumen is segmented from each 2D image via pre-trained U-net model[1]

Details of U-net model

Training: 70 images of animal vena cava

Ground truth label: manually annotated & verified by expert clinician

Pre-processing: crop to central 300x300 px

Data augmentation: random 90° rotation & elastic deformation

Post-processing: keeping largest connected island & hole filling

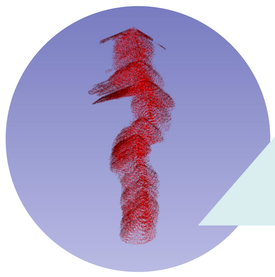
Validation: 9 images of animal vessels

Pre-processed image

U-net model generated label

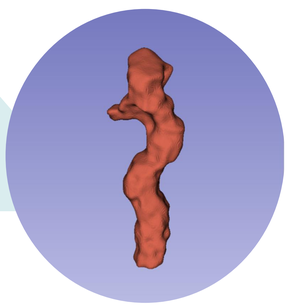
Post-processed label

Comparison with ground truth



4 Segmented vessel lumens are placed at their true locations in 3D space using the calibration and tracking information

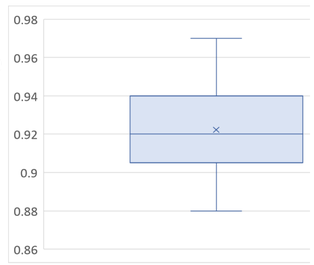
5 Vessel surface is reconstructed by applying binary morphological closing & Gaussian blur operations

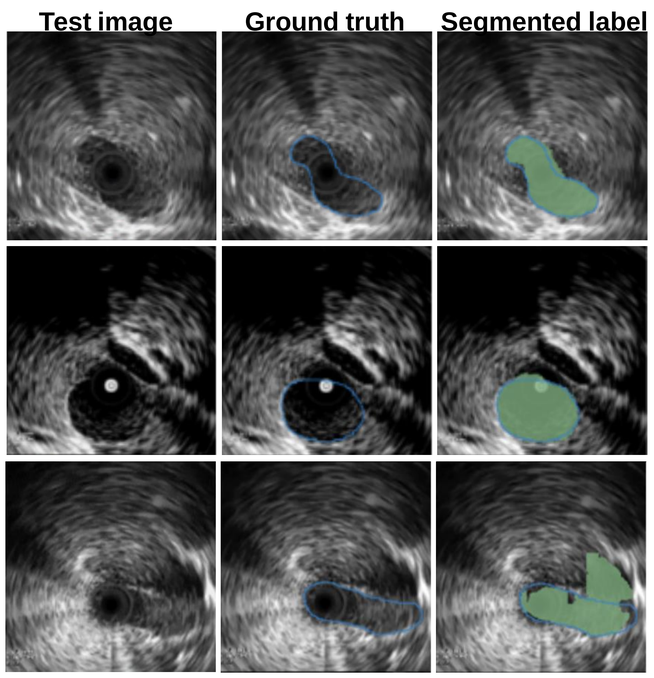


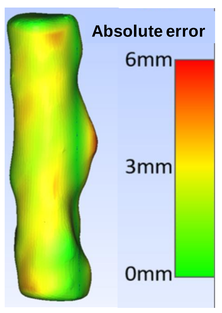
RESULTS

Testing: average Dice score 0.92

Distribution of Dice score across test dataset.
Worst-case segmentation can be seen in the last row below







To validate the reconstruction pipeline, a straight vessel phantom was reconstructed using tracked US imaging and compared to a CT-derived vessel in terms of absolute distance error

CONCLUSIONS

Reconstruction accuracy deemed clinically acceptable for navigation.

Limitation: Limited size and scope of training data

Tracked ICE ultrasound can generate a vascular path for guidewire navigation

REFERENCES

1. Ronneberger et al., U-Net: Convolutional Networks for Biomedical Image Segmentation, LNCS (2015)
2. Lasso et al., PLUS: Open-Source Toolkit for Ultrasound-Guided Intervention Systems, IEEE-TBME (2014)
3. Groves et al., Automatic segmentation of the carotid artery and internal jugular vein from 2D ultrasound images for 3D vascular reconstruction, IJCARS (2020)

Acknowledgment for animal data