# Fully Automatic 3D Whole Atria Segmentation and Reconstruction from Gadolinium-Enhanced MRIs Using Convolutional Neural Networks

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## Introduction

Atrial Fibrillation (AF) is the most common cardiac arrhythmia and catheter ablation is a promising approach for treating AF. Accurate representation of the atrial anatomy and its underlying structure for patients with AF undergoing the ablation procedure provides an effective patient-specific approach for targeted diagnostics and treatment [1].

## Aim

To develop robust, fully automatic algorithms to segment the atrial structure from clinical image data.

## Methods

- 3D late gadolinium enhanced (LGE)-MRI data (N = 20) with a spatial resolution of $0.625 \times 0.625 \times 1.25$ mm$^3$ from patients with AF was provided by The University of Utah [2] and contained the left atrial (LA) wall and cavity segmentations.
- Manually segment the right atrium (RA) with protocols consistent with The University of Utah:
  1. Delineate the RA epicardium and extend this inwards with a constant thickness towards the endocardium to obtain the RA wall.
  2. Fill the volume enclosed by the wall to obtain the RA cavity. The tricuspid valve region is defined by a linear cut to be consistent with the Utah LA mitral valve.
- Split dataset and labels into training (N=14) and validation (N=6) sets.
- Develop convolutional neural network (CNN) for atrial segmentation (**Fig 1**) on the training set.
- Evaluate the algorithm using the DICE score on the validation set.

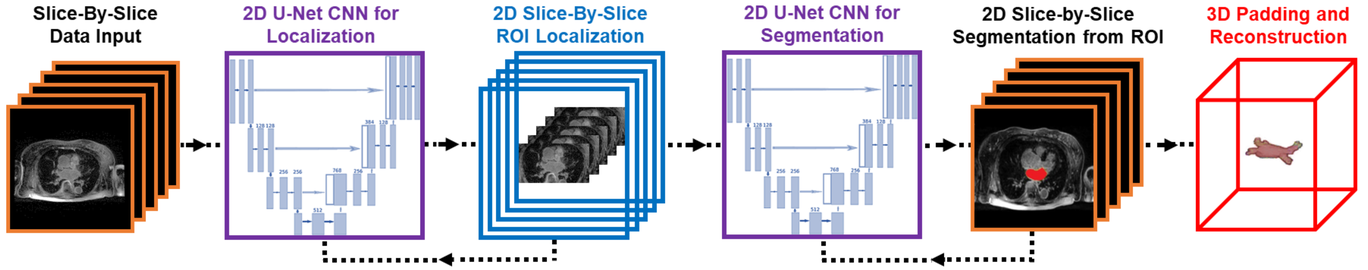


**Fig 1.** The workflow of the proposed pipeline. The late gadolinium enhanced (LGE)-MRI is inputted into a 2D convolutional neural network (CNN). The first CNN performs slice-by-slice localization to determine the region of interest (ROI) containing the atria. The ROIs were then inputted into a second CNN for slice-by-slice segmentation of the atria. The 2D segmentations were stacked together and padded to the original dimensions to obtain the final 3D reconstruction.

## Results

The proposed method achieved a DICE score of 93% for the atrial cavity and 94% for the atrial wall + cavity segmentations. The CNN segments each 3D LGE-MRI within 2.5 seconds on an NVidia Titan V GPU. Visualizations of a reconstructed atria are shown in **Figs 2&3.**

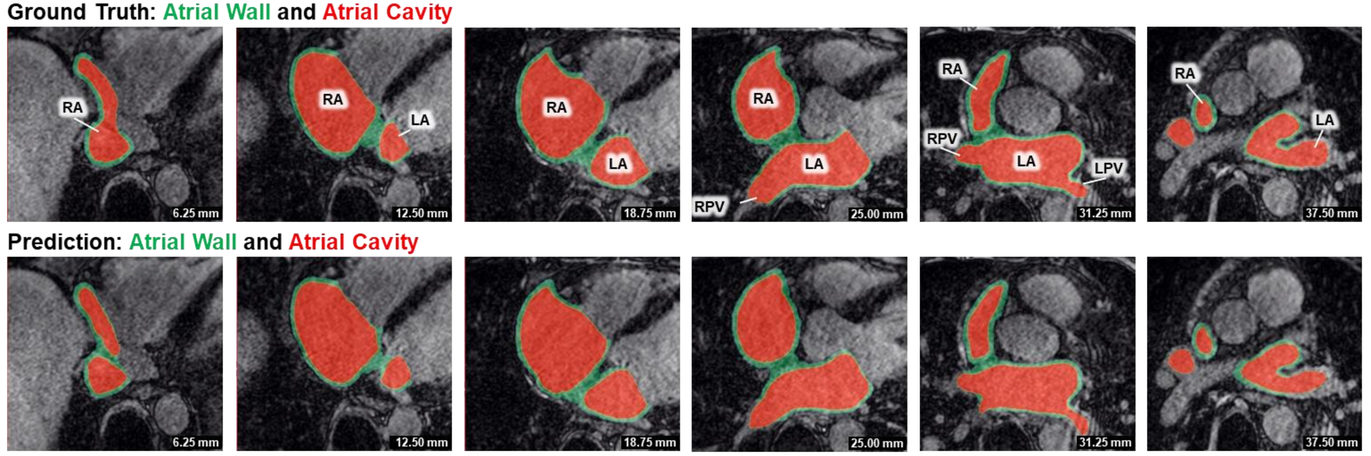


**Fig 2.** Side-by-side comparison between manual (1st row) and automated (2nd row) segmentations in typical 2D late gadolinium enhanced (LGE)-MRI slices. The depth of the LGE-MRI for each slice is shown in mm. The bi-atrial wall is shown in green, while the cavity is shown in red. RA, right atrium; LA, left atrium; RPV, right pulmonary vein; LPV, left pulmonary vein.

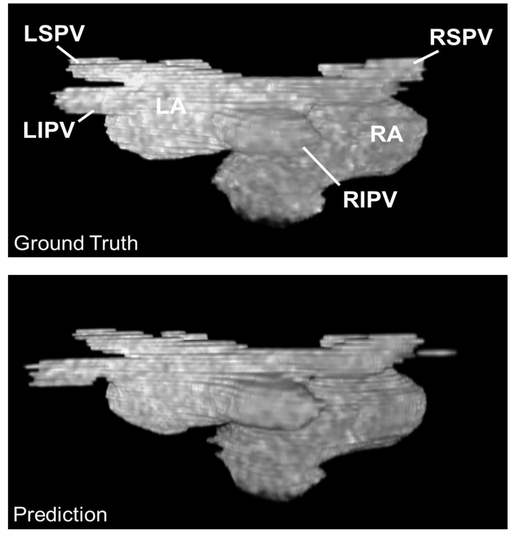


**Fig 3.** Comparisons of the 3D reconstructed bi-atrial chambers from manual (top) and automated (bottom) segmentation. LA/RA, left/right atrium; LIPV/LSPV/RIPV/RSPV, left/right inferior/superior pulmonary veins.

## Conclusion

We have proposed and validated an effective framework for robust bi-atrial chamber segmentation from clinical LGE-MRIs. Our study potentially be used for improved clinical diagnosis, patient stratification and clinical guidance during ablation treatment for patients with AF.

## References

[1] Xiong et al. (2019). *IEEE Transactions on Medical Imaging.*

[2] McGann et al. (2014). *Circulation: Arrhythmia and Electrophysiology.*