Automatic coronary centreline tracking from coronary MRI

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INTRODUCTION

- Detecting coronary artery abnormalities is crucial in the management of coronary artery disease
- Acquisition and image quality of coronary MR angiography (CMRA) has improved considerably over the past years[1,2,3,4]
- For time-efficient analysis automatic centerline tracking is required. This has extensively been investigated in CTA[5], but only before recent improvements in acquisition were made in CMRA[6]

Therefore our aim was to:

Perform automatic coronary artery centerline tracking on state-of-the-art CMRA data, in a clinically relevant population

METHODS

Data

- Thirty patients with suspected coronary artery disease were included
- CMRA images were acquired as described in[4] (free-breathing, image-based respiratory motion navigation, acquired resolution 1.3 mm isotropic, reconstructed ~0.74x0.74x0.65 mm) .
- Clinical records indicated that 9 patients had single or multi-vessel disease based on previous CTA or X-ray imaging.

Centreline tracking

- For reference manual centerlines were annotated on the three main coronary artery branches: right coronary artery (RCA), left anterior descending (LAD) and left circumflex (LCX). Occluded (3) and stented (2) arteries were excluded.
- Automatic centerline extraction:

1. *Vesselness computation*: The Hessian matrix was computed at 0.5, 1 and 1.5 mm. The parameters α and β were used to balance between tube- and plane-like structures and the deviation from blob-like structures, and were optimized on a random selection of three patients (9 arteries). Combinations for α and β of 0.3, 0.5, 0.7 and 0.9 were evaluated.
2. *Fast marching:* Centrelines were traced between the start and end point of each manually annotated centerline using a fast marching algorithm.

- The settings that yielded the smallest average centerline distance between the automatic and manual centerlines were used to analyse the arteries of the remaining 27 patients. All implementations were done in Matlab.
- If errors were detected a second automatic tracing was performed using one additional point on the manual centerline in the area where the tracing went wrong.

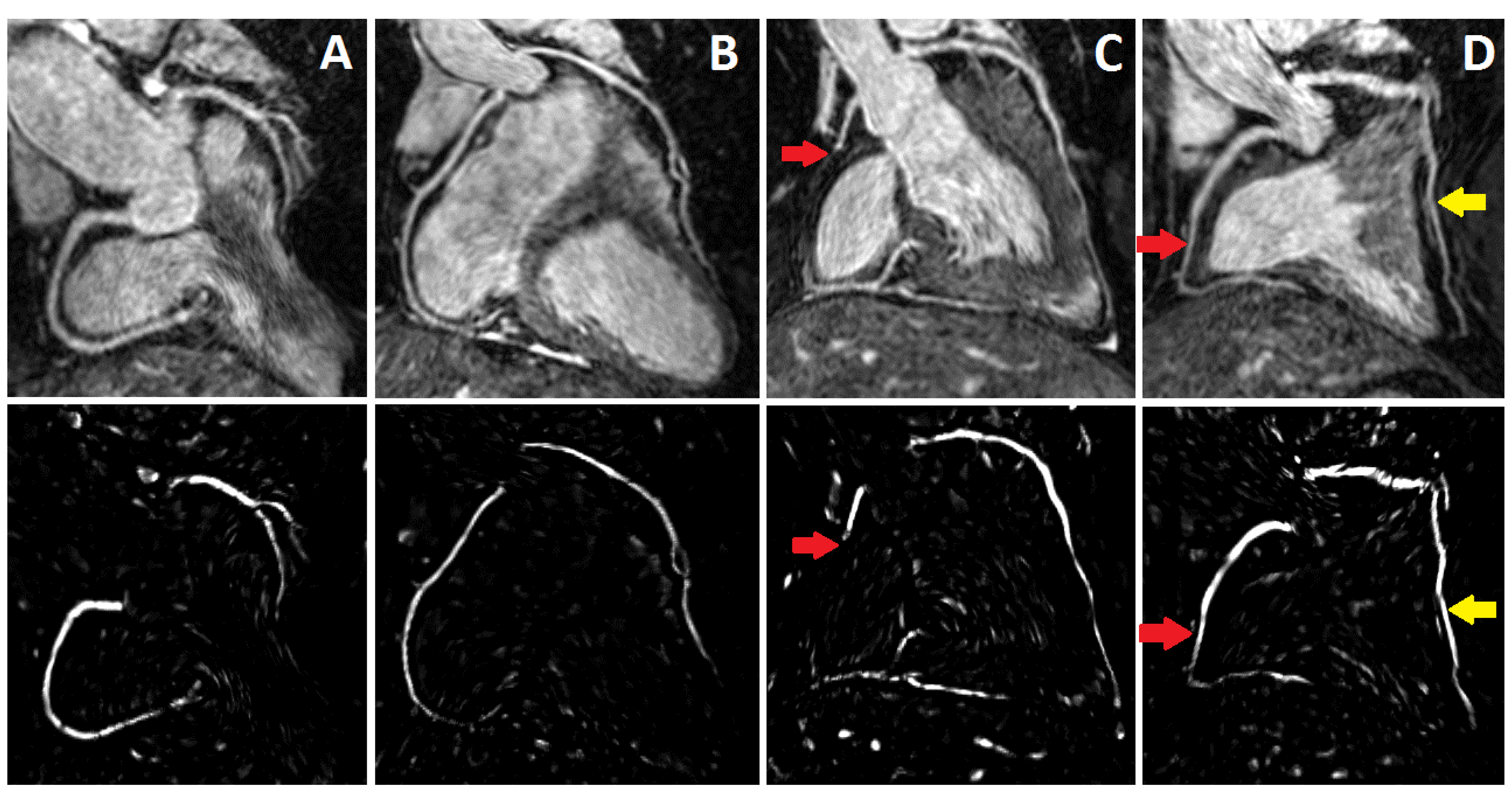

Figure 1: Reformatted images of original CMRA (top) and corresponding vesselness images (bottom). Two healthy subjects (A, B), one patient with a normal LAD and occluded RCA (C, red arrow, excluded from study) and one patient with diffuse CAD in both RCA (red arrow) and LAD (yellow arrow) (D).

RESULTS

- The optimized parameters for vesselness computation were α=0.9 and β=0.3. Four examples of obtained vesselness images are shown in Figure 1.
- All (quantitative) results are provided in Table 1. Examples of automatically traced centerlines are shown in Figures 2 and 3.

Table1: Evaluation measures: Success of tracking, centerline distance between manual and automatic tracing, and the centerline length (all results given as median [IQR])

	RCA	LAD	LCX
Success rate: direct tracing start-end	22/24 (92%)	19/26 (73%)	15/26 (58%)
Success rate: including one extra point	22/24 (92%)	23/26 (88%)	17/26 (65%)
Median centreline distance (mm)	1.0 [0.9-1.1]	1.0 [0.9-1.2]	0.9 [0.7-1.3]
Maximum centreline distance (mm)	2.3 [1.9-2.5]	2.6 [2.2-4.6]	3.2 [2.1-7.3]
Max distance using extra point (mm)	2.3 [1.9-2.5]	2.4 [1.9-2.7]	2.5 [2.0-5.8]
Manually traced length (cm)	15.5 [14.5-17.3]	15.8 [11.8-17.2]	11.3 [8.5-13.1]
Traceable length (cm)	15.4 [14.0-17.1]	13.1 [9.7-16.9]	10.8 [7.0-12.3]

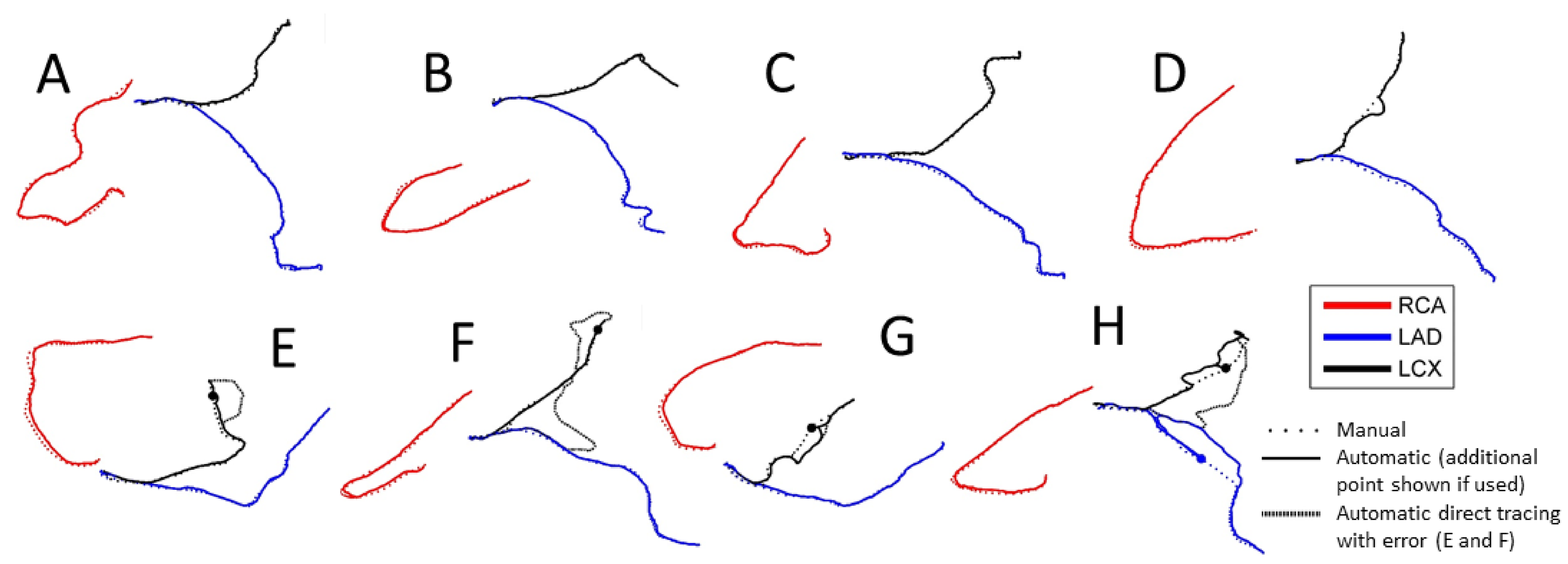

Figure 2: Resulting automatically traced centerlines. A-C: correct centerlines, D: small error in LCX, E-F: wrong tracing in LCX that was corrected by adding one additional point (shown as black dot), G-H: wrong tracing of LCX (G) and both LCX and LAD (H) that was not corrected by adding an additional point.

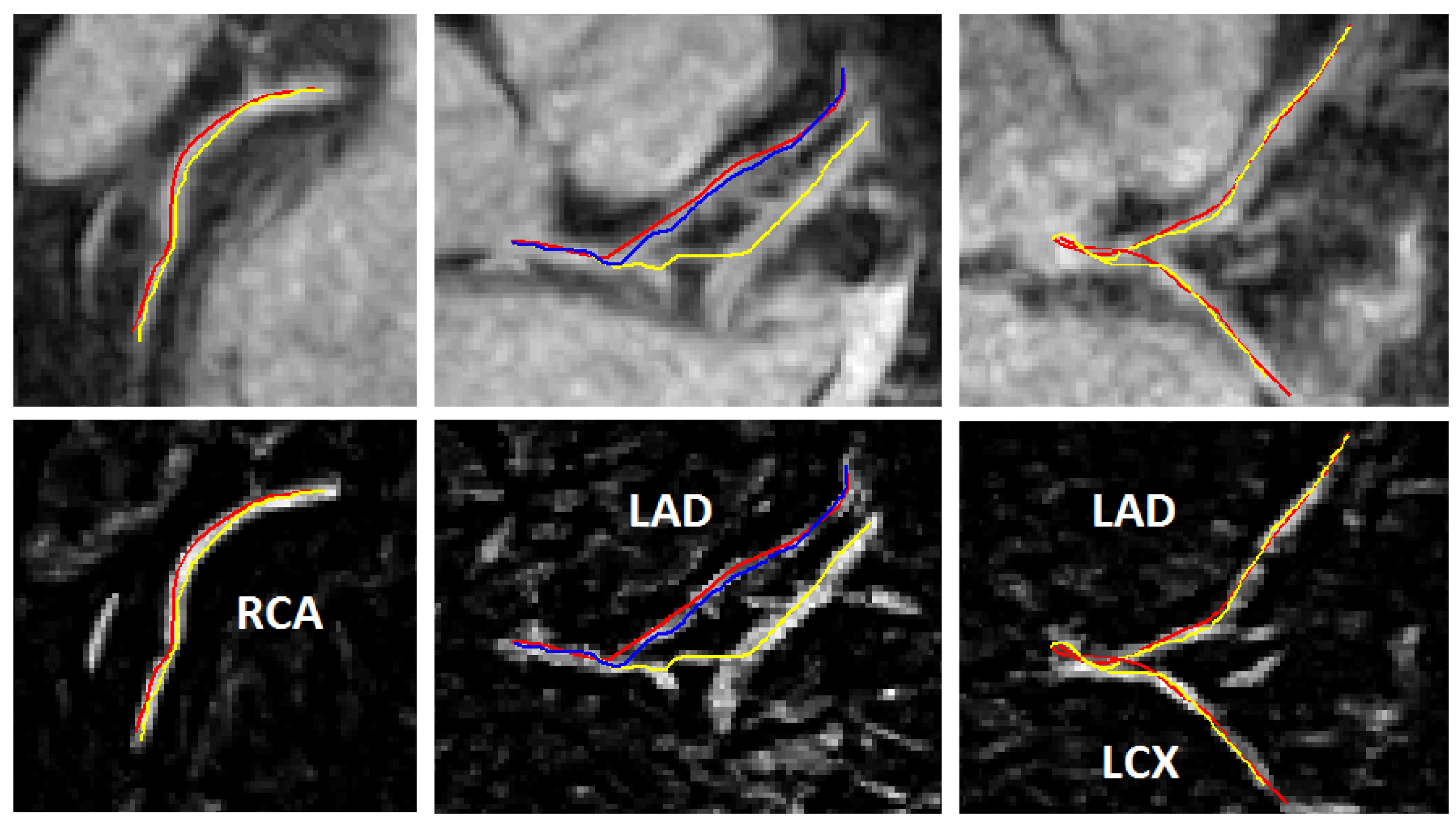

Figure 3: Centerlines projected onto a MIP of a few slices of the original images (top row) and vesselness images (bottom row). Manual centerlines in red, automatic in yellow, and, when measured, the automatic centerline by using one extra point in blue.

DISCUSSION & CONCLUSION

- Automatic centerline extraction from CMRA is possible in 74% of arteries in clinically relevant patients, increasing to 82% when one additional point on the centerline could be used.
- Lowest accuracy was found for LCX, which was mainly caused by wrong tracing through neighboring veins.
- Generally, these results show promise for automatic coronary artery analysis on CMRA.
- Future work should focus on automated stenosis detection.

References

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Acknowledgements

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