In vivo validations of 3D tubular NURBS fitting model applied on severe stenotic and high curvature MRA of carotid arteries

e-Poster: 262

Congress: ESMRMB 2009

Type: Scientific Paper

Topic: Angiography

Authors: A. Suinesiaputra[1], P.J.H. de Koning[1], E. Zudilova-Seinstra[2], J.H.C. Reiber[1], R.J. van der Geest[1]; [1]Leiden/NL, [2]Amsterdam/NL

MeSH:

Carotid Arteries [A07.231.114.186]

Carotid Stenosis [C14.907.137.230]

Magnetic Resonance Angiography [E01.370.350.500.500]

Keywords: Segmentation, Non-Uniform Rational B-Splines

1. Purpose

To validate a fully automated segmentation method based on 3D Non-Uniform Rational B-Splines (NURBS) fitting model for severe stenotic and high curvature carotid artery structures. We have developed a deformable tubular NURBS model to automatically fit onto luminal areas of carotid arteries from MRA images with minimal interactions. The model was designed to delineate severe stenoses and high curvature vessels structure.

2. Material and Methods

Contrast-enhanced MRA from 11 patients suffering atherosclerotic disease were selected. Eight stenotic and five complex vessel segments were defined for the validation. Ground truth was manual contours on image slices perpendicular to the vessel.

Fast marching level set method [1] was used to detect luminal pathline automatically from minimum of two seed points, placed manually by a user. One or more intermediate points may be additionally placed if necessary to guide the pathline detection. A gradient-based surface fitting was performed to segment the lumen [2].

3. Results

In total, 308 normal and 432 stenotic vessel slices were analyzed. Some of the automated segmentation results are given in [Five examples of the automated segmentation results.] Fig. 1. Correlation coefficients of cross-sectional area were 0.97 (P<1E-16) and 0.92 (P<1E-16) for complex vessel and stenoses, respectively (see [Linear regression plots.] Fig. 2). The mean difference for complex structure was 0.5 mm^2 (SD 1.8 mm^2), while for stenoses it was 1.6 mm^2 (SD 5.5 mm^2). Bland-Altman plots in [Bland-Altmann plots.] Fig. 3 show high agreement between automatically and manually derived cross-sectional areas.

[Distributions of percentage area overlap for each cases (11 patients).] Figure 4 shows the distributions of percentage area overlap and the mean was 86.1% (SD 8.2%) for complex vessel, 73.4% (SD 18.1%) for stenoses. The degree of stenosis was quantified (see Table 1). The mean difference for degree of stenosis was 18.5% (SD 13.8%). Table 1 also shows percentage area overlap for each segment.

Table 1: Validation results.

	patient	pct. area overlap			automated		expert	
		min	mean	max	dmin	dos	dmin	dos
complex	P1	48.26%	86.36%	94.87%	2.71		3.75	
	P2	60.00%	89.83%	100.00%	3.78		4.02	
	P3	72.18%	87.02%	95.11%	3.28		3.63	
	P4	70.81%	86.81%	94.87%	3.15		3.85	
	P5	61.19%	74.51%	85.07%	1.78		2.55	
stenoses	P6	32.44%	72.97%	90.45%	1.75	66.91%	2.43	49.30%
	P7	36.97%	76.54%	95.13%	1.06	82.32%	1.68	71.07%
	P8	25.09%	73.42%	92.76%	0.33	92.66%	2.53	52.19%
	P9	39.48%	84.15%	95.49%	1.79	63.73%	2.37	56.55%
	P10	9.45%	64.34%	93.01%	0.54	84.98%	1.10	71.60%
	P11	46.30%	78.44%	93.99%	1.27	65.03%	3.02	25.09%
	P12	35.72%	71.34%	91.75%	1.29	67.84%	1.95	59.46%
	P13	29.08%	75.64%	96.65%	1.06	85.15%	1.84	75.67%
dmin = minimum diameter (mm), dos = degree of stenosis								

4. Conclusion

There is an excellent correlation of cross-sectional area between the automated method with expert. Strong agreement for area overlap was achieved, particularly for complex vessels. Disagreement occurs for the degree of stenosis, due to poor resolution and low signal intensity. In all stenotic cases, the degree of stenosis from the automated method is higher than the observer derived measurement.

The current method is designed to fit into a single artery branch, which is suboptimal for bifurcation area. Extension of the method for bifurcation areas is still an ongoing research process.

5. References

1. de Koning, P.J.H., Schaap, J.A., Janssen, J.P., Westenberg, J.J.M., van der Geest, R.J., Reiber, J.H.C.: "Automated segmentation and analysis of vascular structures in magnetic resonance angiographic images". Magn Reson Med, 50(6), 1189-1198, 2003.
2. Makowski, P., de Koning, P., Angelie, E.,Westenberg, J., van der Geest, R., Reiber, J.: "3D cylindrical B-Spline segmentation of carotid arteries from MRI images". Biomedical Simulation, 188-196, 2006.

6. Personal Information

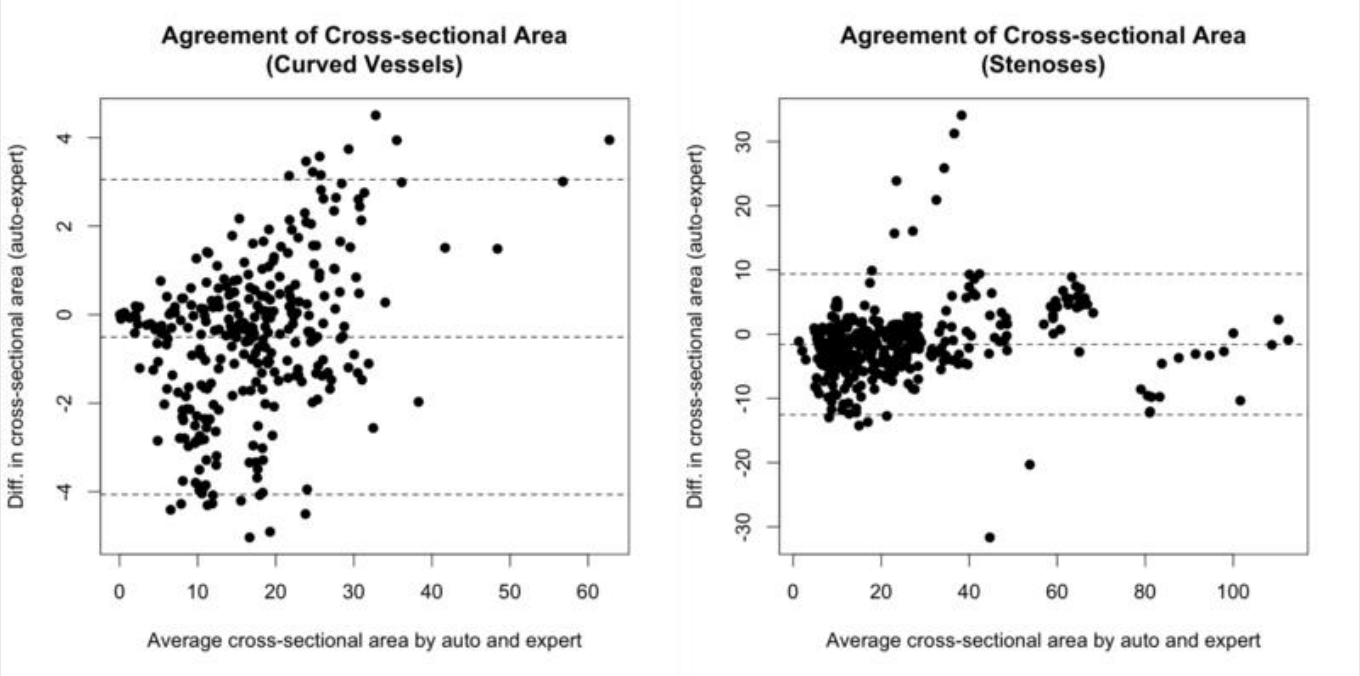
A. Suinesiaputra, P.J.H. de Koning, R.J. van der Geest and J.H.C. Reiber are with the Division of Image Processing, Department of Radiology, Leiden University Medical Center, Leiden, the Netherlands.

E. Zudilova-Seinstra is with the Section of Computational Science, University of Amsterdam, Amsterdam, the Netherlands.

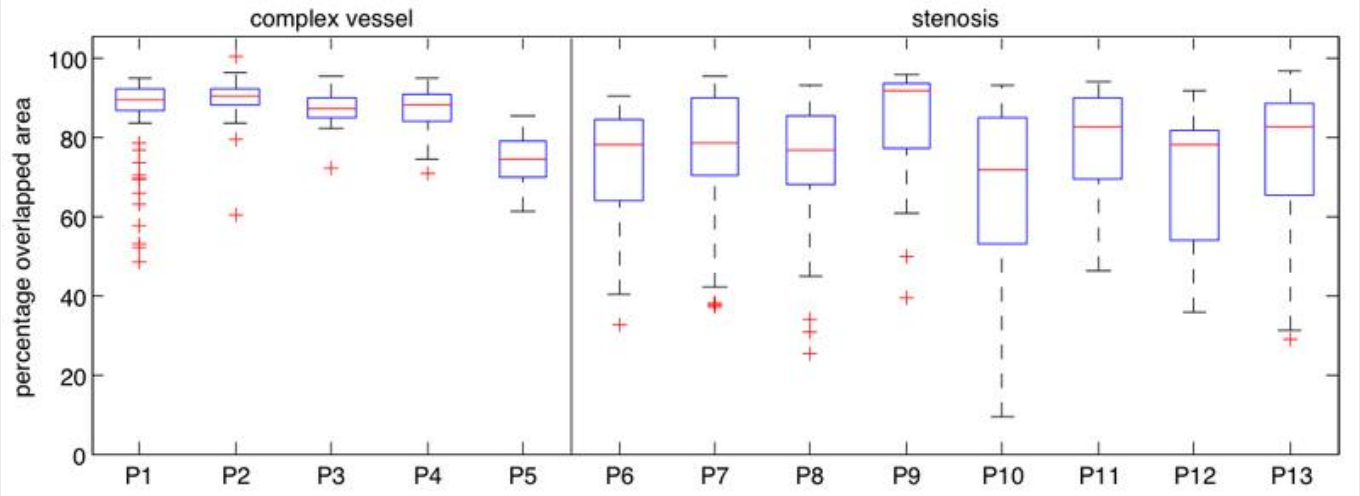
This work is supported by the Dutch Science Foundation (NWO) under the Multimodal Visualization Environment for Interactive Analysis of Medical Data (Multi-Vis) grant number N 643.100.602.

7. Mediafiles

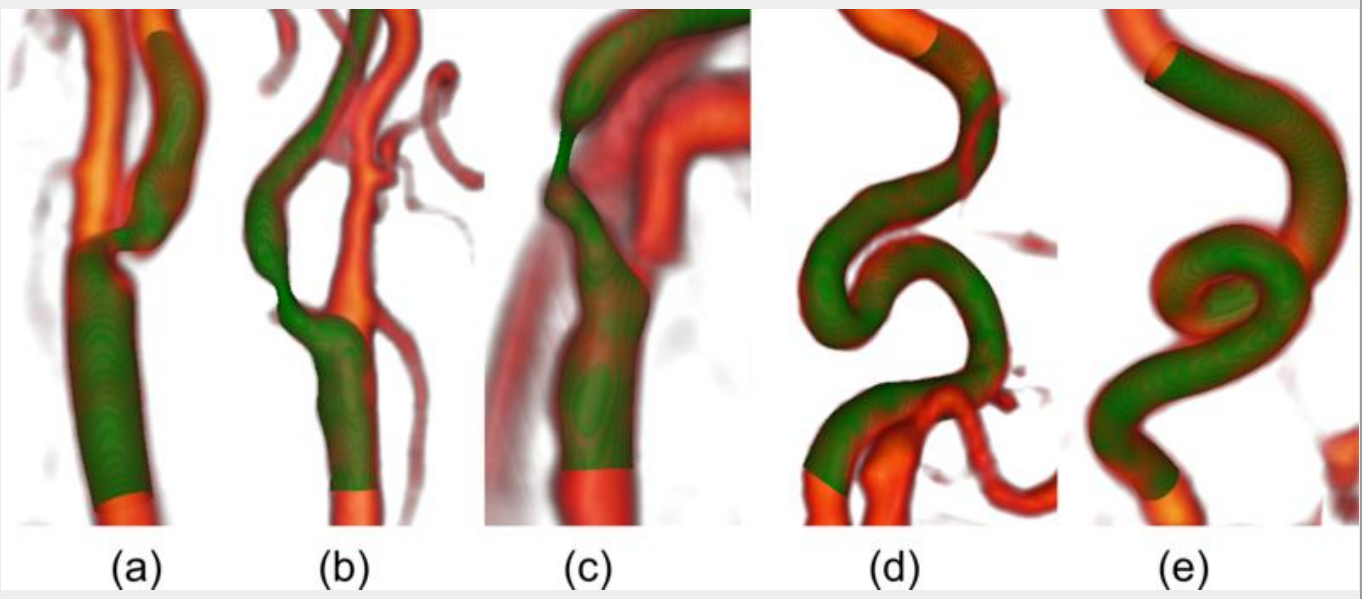
Bland-Altmann plots.



Distributions of percentage area overlap for each cases (11 patients).



Five examples of the automated segmentation results.



Segmentation results on severe stenotic cases (a-c) and complex vasculature (d-e).

Linear regression plots.