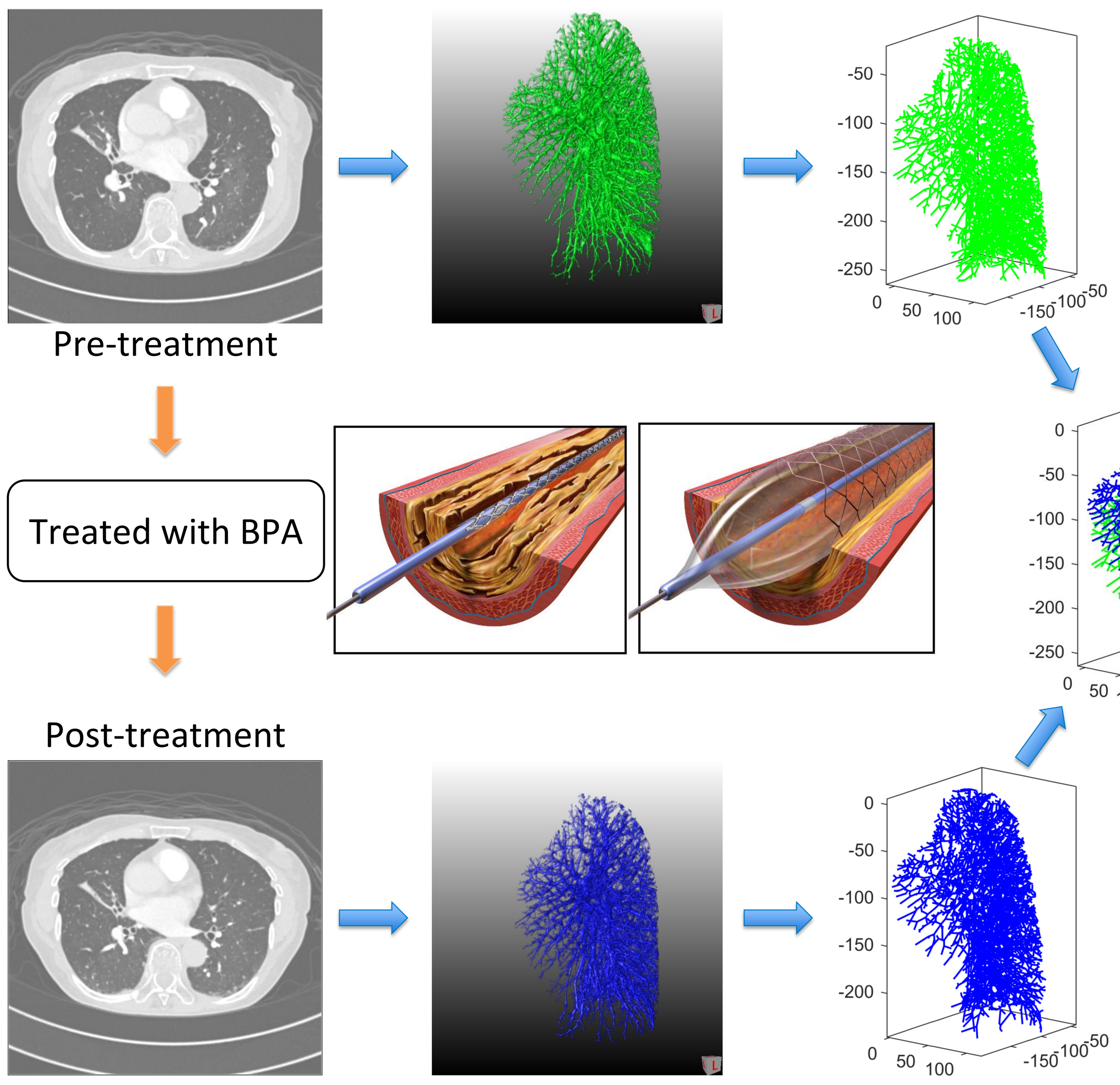
Leiden University Medical Center

Z. Zhai[1], M. Staring[1], H. Ota[2], and B. C. Stoel[1]
[1] Division of Image Processing, Department of Radiology, Leiden University Medical Center, Leiden, The Netherlands
[2] Department of Diagnostic Radiology, Tohoku University Hospital, Japan

Pulmonary vessel tree matching for quantifying changes in vascular morphology

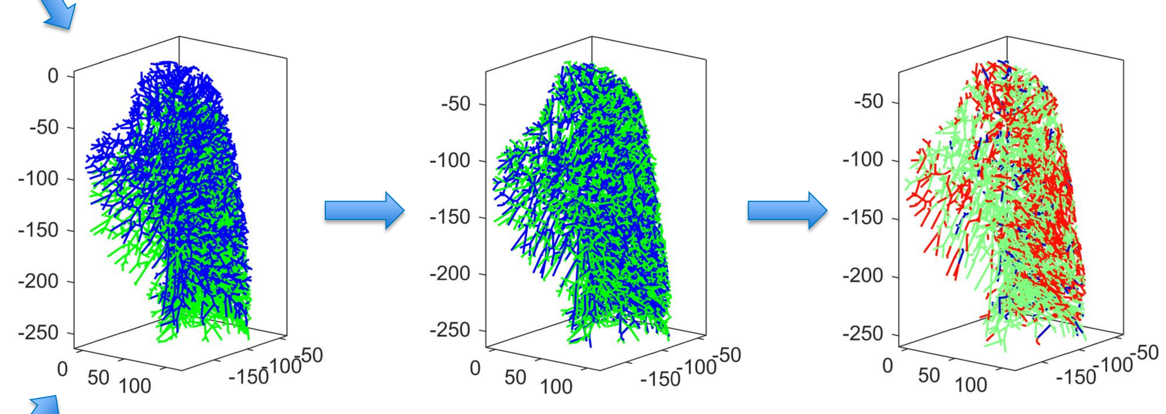
Introduction

- Computed tomography pulmonary angiography (CTPA) is an important modality for assessing the severity and treatment effects of pulmonary vascular diseases, such as chronic thromboembolic pulmonary hypertension (CTEPH).
- However, the invasive right-heart catheterization (RHC) serves as the gold standard. Quantifying density changes in pulmonary vessels, by automatically comparing CTPA scans of pre- and post-treatment with image registration, can assess treatment effects of CTEPH [1].
- We hypothesized that quantifying morphological changes by matching vascular trees may provide a non-invasive assessment of treatment effects. The vascular tree matching can be treated as a point set registration task.



Frame work of processing:

1) Constructing vascular trees;
2) Vascular tree matching with geodesic preservation;



3) Quantitatively analyzing vascular morphology changes.

Poiseuille's law: $\Delta P/F = \frac{8\eta L}{\pi r4}$

Data set

- Synthetic data set: 10 synthetic trees T^i, i=1, ..., 10, were generated by randomly removing 30*i leaf nodes from initial tree T^0 (with 3176 nodes) and deformed with non-rigid transformation parameters.
- CTEPH data set: 14 CTEPH patients, who were treated with balloon pulmonary angioplasty (BPA), underwent CTPA scans and RHC examinations, pre- and post-BPA treatment. The invasive RHC examinations, including pulmonary artery pressure (PAP, systolic, diastolic and mean; sPAP, dPAP and mPAP) and pulmonary vascular resistance (PVR). [1]

Result

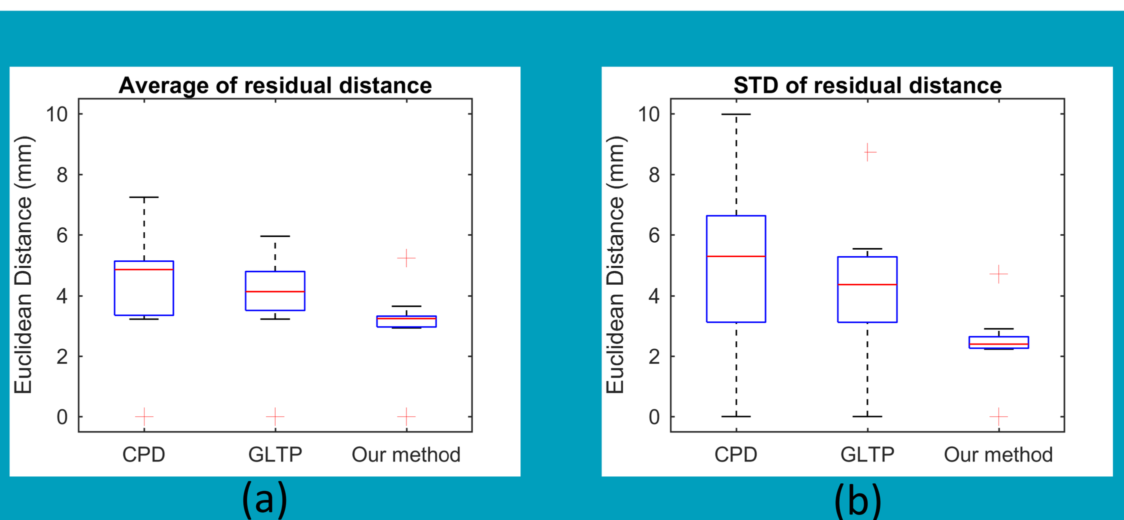


Fig 1. Evaluation for vascular tree matching, average and STD of distance, of three methods: CPD [2], GLTP [3] and our method.

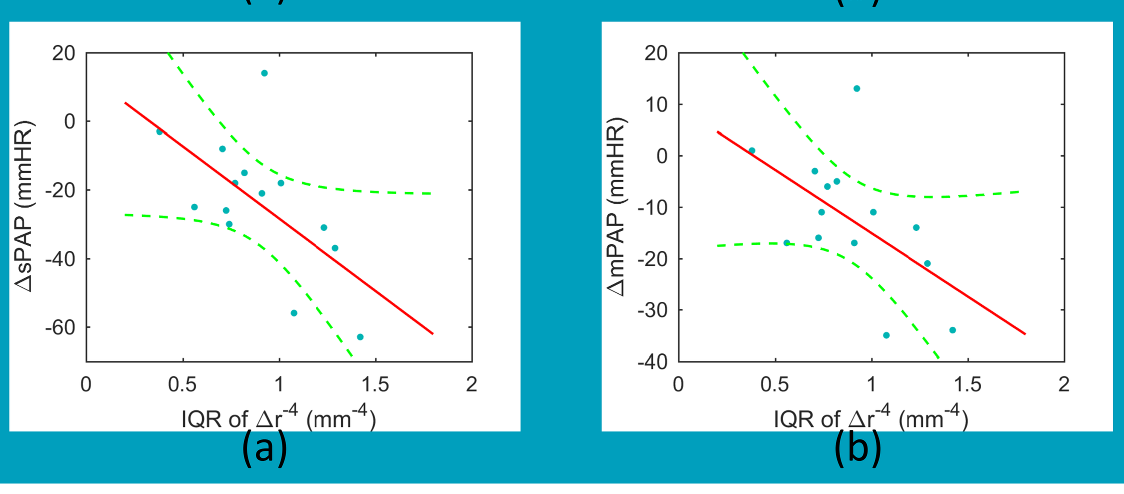
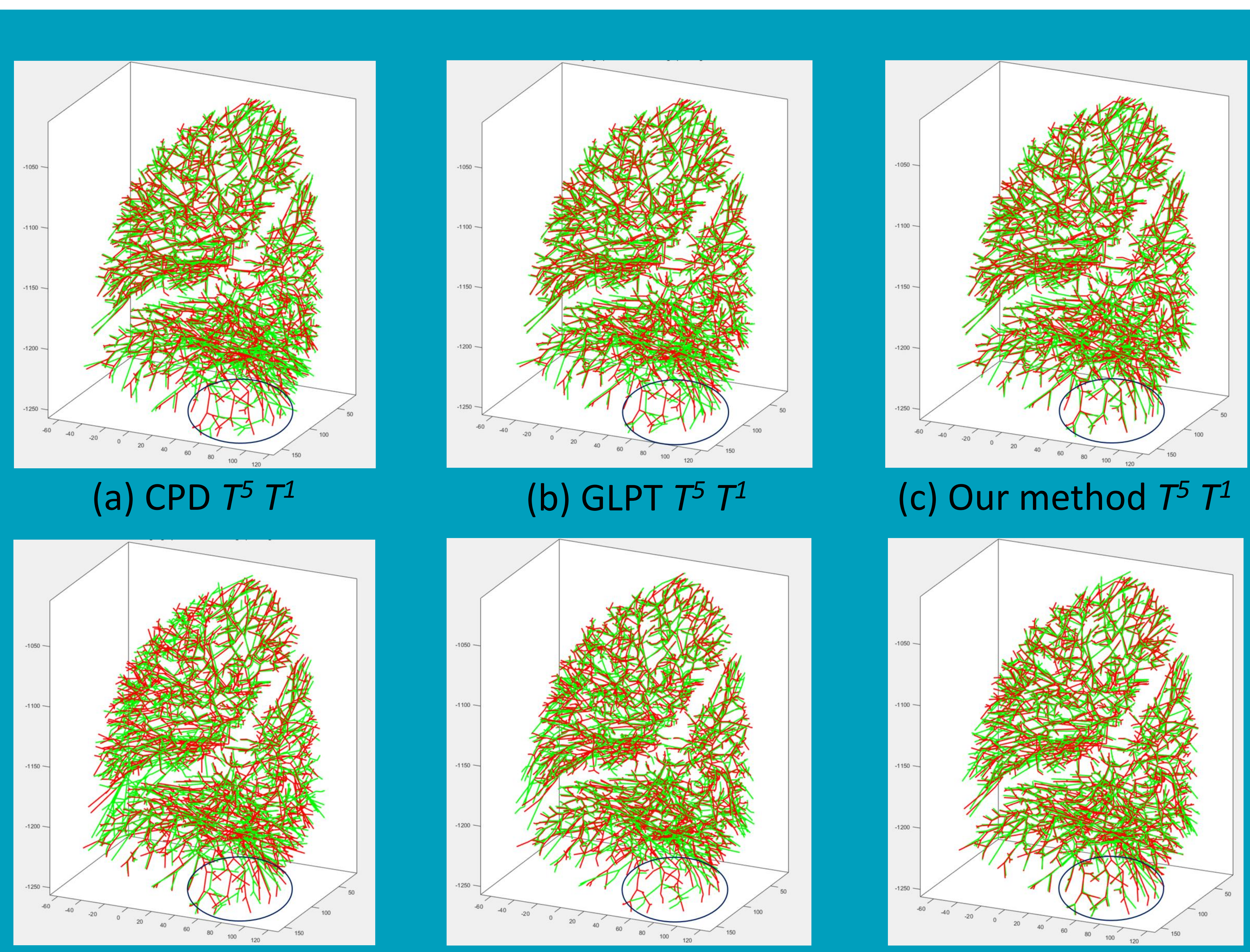


Fig 2. Scatter plot for IQR of Δr^{-4} against ΔsPAP and ΔmPAP.

Table 1: Pearson's correlation R (p-value) between morphological changes and hemodynamic changes.

	ΔsPAP	ΔdPAP	ΔmPAP	ΔPVR
median of Δr^{-4}	0.19 (0.506)	0.04 (0.901)	0.16 (0.576)	0.07 (0.815)
IQR of Δr^{-4}	-0.62 (0.019)	-0.46 (0.097)	-0.56 (0.038)	-0.47 (0.088)



(a) CPD T^5 T^1 (b) GLPT T^5 T^1 (c) Our method T^5 T^1

(d) CPD T^5 T^7 (e) GLPT T^5 T^7 (f) Our method T^5 T^7

Fig 3. 3D visualization of vascular tree matching for two cases, first row is for a good case: matching T^5 and T^1, CPD 5.26±6.85 mm, GLTP 4.01±4.13 mm and our method 3.17±2.64 mm; second row is for a bad case: matching T^5 and T^7, CPD 7.25±9.98 mm, GLTP 5.96±8.74 mm and our method 2.97±2.41 mm.

Conclusions

- The vascular tree matching method with geodesic paths for local topology preservation showed a better performance, in comparison with methods of CPD [2] and GLTP [3].
- Morphological changes can reflect hemodynamic changes, and quantifying morphological changes by matching vascular trees can provide a non-invasive assessment of treatment effects in CTEPH patients.

References

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[3] S. Ge, G. Fan, and M. Ding. "Non-rigid point set registration with global-local topology preservation." Proceedings of the IEEE Conference on CVPR Workshops. pp. 245-251. 2014.

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