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Automatic Comparative Imaging in CTPA for Quantifying Treatment Effect of Balloon Pulmonary Angioplasty in CTEPH

Introduction

- Chronic thromboembolic pulmonary hypertension (CTEPH) is caused by persistent obstruction of pulmonary arteries. Without treatment, CTEPH patients have poor prognoses: 2-years survival rate is less than 50% in patients with mean pulmonary artery pressure (PAP) > 30 mmHg. For patients with inoperable CTEPH, Balloon Pulmonary Angioplasty (BPA) can improve the clinical status and hemodynamics with a low mortality [1].
- Evaluation of disease severity and assessment of treatment effects play an important role in the therapy of CTEPH. The invasive right-heart catheterization (RHC) serves as the gold standard and CT pulmonary angiography (CTPA) can be used in the evaluation of severity of CTEPH.
- The BPA treatment can improve the hemodynamics of pulmonary vascular systems and may contribute to the improvements of pulmonary vascular and parenchymal perfusion. We hypothesized that the perfusional changes achieved by BPA can be quantified by density changes in CTPA.

Methods

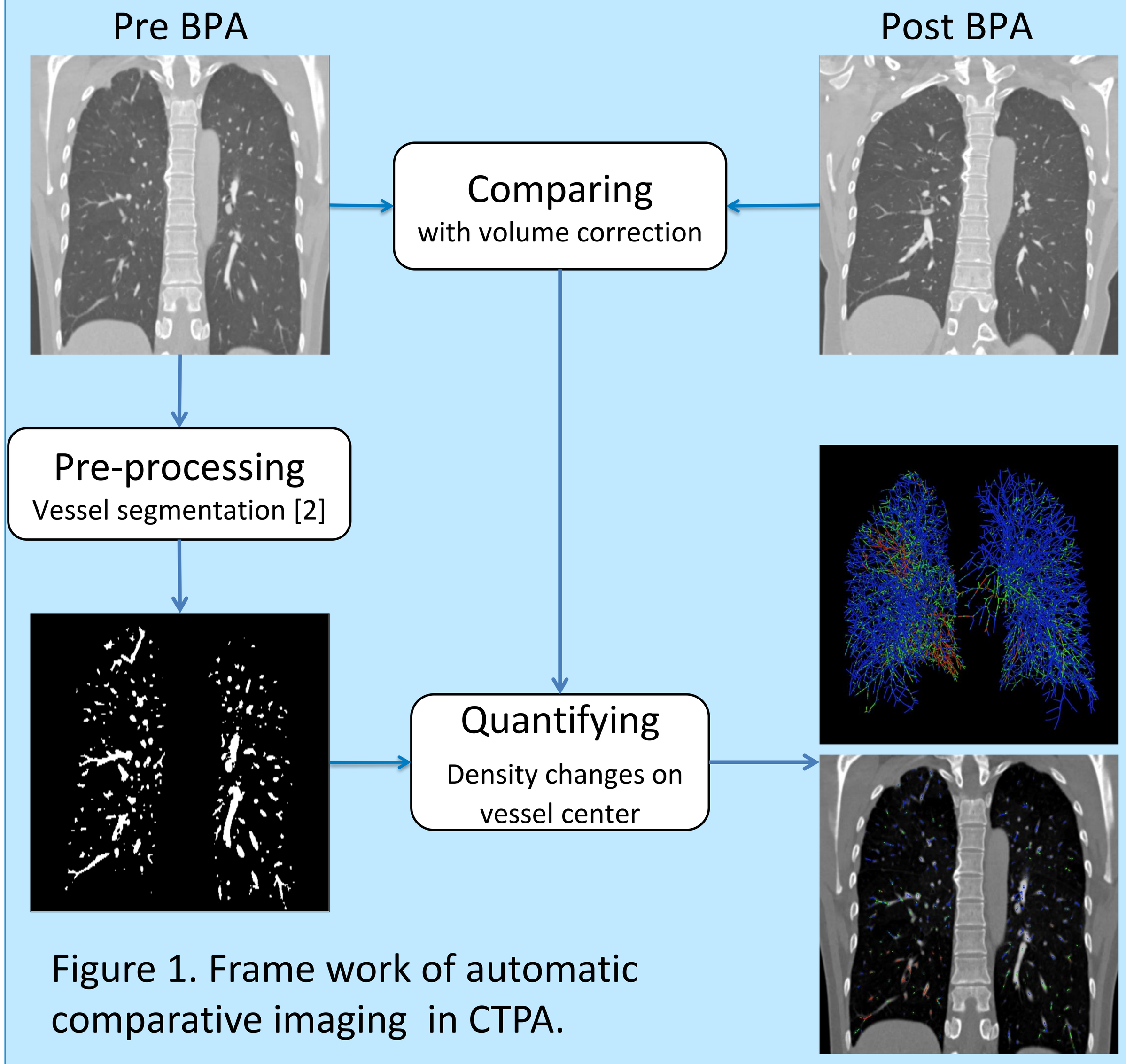

Figure 1. Frame work of automatic comparative imaging in CTPA.

Density changes with volume correction [3]:

$$\Delta D(\boldsymbol{x}) = I_{post}\left(\boldsymbol{T}(\boldsymbol{x})\right) - I_{pre}(\boldsymbol{x}) \cdot \boldsymbol{C}(\boldsymbol{x})^{-1}$$

$$\boldsymbol{C}(\boldsymbol{x}) = max\{\theta_{min}\left(I_{pre}(\boldsymbol{x})\right), min\{\theta_{max}\left(I_{pre}(\boldsymbol{x})\right), det\boldsymbol{J_T}(\boldsymbol{x})\}\}$$

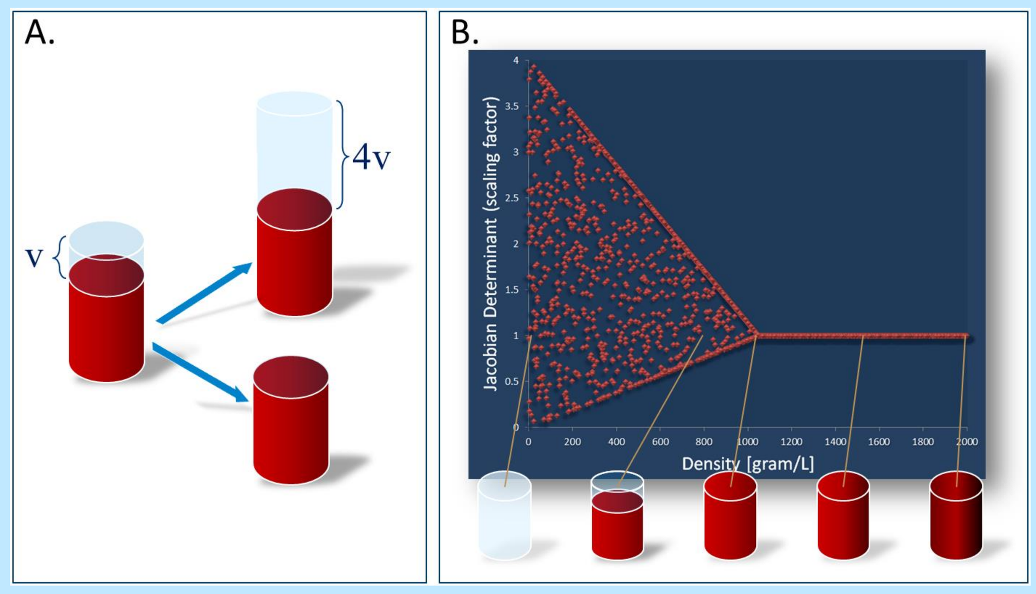

Figure 2. A) Two-component model: a voxel is composed of an air and blood compartment. B) The scaling factor from the determinant of the Jacobian is thus restricted by an upper and lower limit depending on the density of a voxel.

Results

Table 1. One-sample t-test analysis for hemodynamic changes and image-derived quantifications

RHC parameters changes	Pre-BPA	Change	p-value
sPAP (mmHg)	63.9 ±16.4	-24.1 ± 19.8	0.001
dPAP (mmHg)	21.9 ± 7.34	-7.07 ± 8.45	0.008
mPAP (mmHg)	36.7 ± 9.62	-12.6 ± 12.8	0.003
PVR (dyne·s/cm^5)	554 ± 230	-242 ± 259	0.004
Perfusional changes (HU)			
Median of ΔVD	-	-48.2 ± 18.4	<0.001
IQR of ΔVD	-	186 ± 42.8	<0.001
Median of ΔPD	-	-0.429 ± 19.3	0.935
IQR of ΔPD	-	47.4 ± 12.3	<0.001

sPAP, systolic pulmonary artery pressure; dPAP, diastolic pulmonary pressure; mPAP, mean pulmonary artery pressure; PVR, pulmonary vascular resistance; IQR, inter-quartile range; ΔVD, change of vascular density; ΔPD, change of parenchymal density.

Table 2. Correlation (R, p-value) analysis between RHC parameters and image-derived perfusional changes

	ΔsPAP	ΔdPAP	ΔmPAP	ΔPVR
Median of ΔVD	(0.53, 0.054)	(0.18, 0.536)	(0.46, 0.095)	(0.28, 0.325)
IQR of ΔVD	(-0.58, 0.031)	(-0.71, 0.005)	(-0.71, 0.005)	(-0.77, 0.001)
Median of ΔPD	(-0.32, 0.263)	(-0.58, 0.030)	(-0.59, 0.025)	(-0.43, 0.121)
IQR of ΔPD	(-0.18, 0.529)	(-0.40, 0.152)	(-0.37, 0.190)	(-0.36, 0.201)

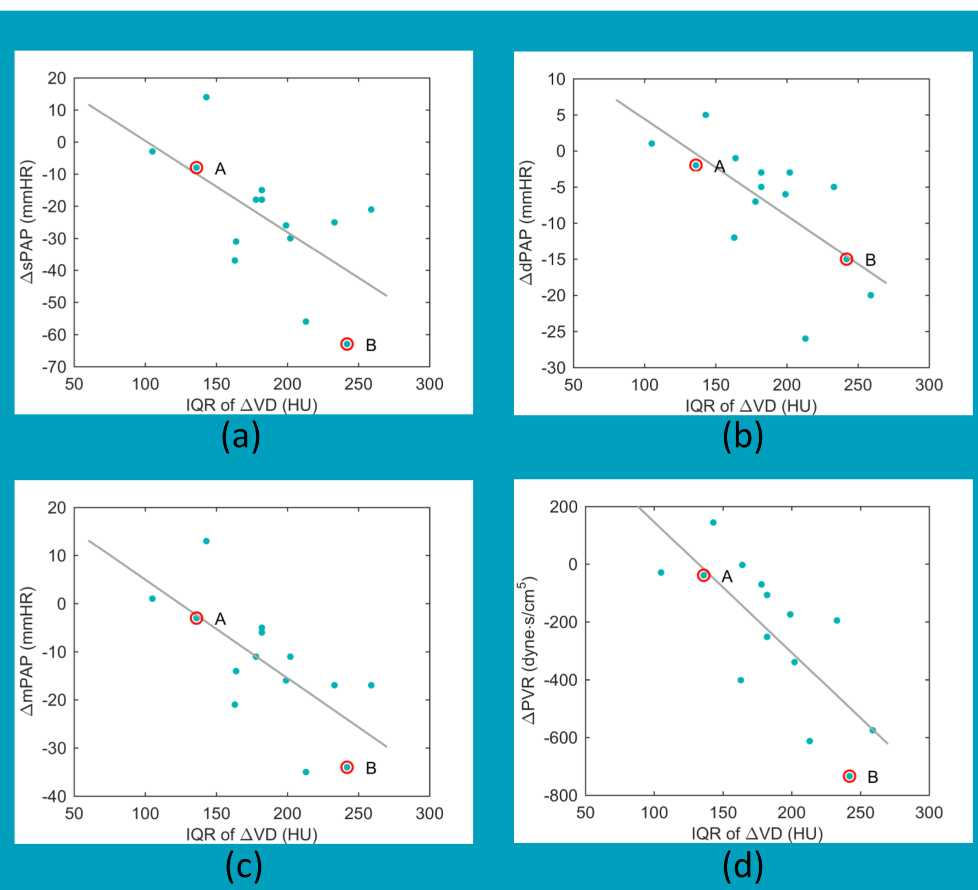

Figure 3. Correlation between IQR of ΔVD and RHC parameters (A and B correspond to patient A and B in Figure 4).

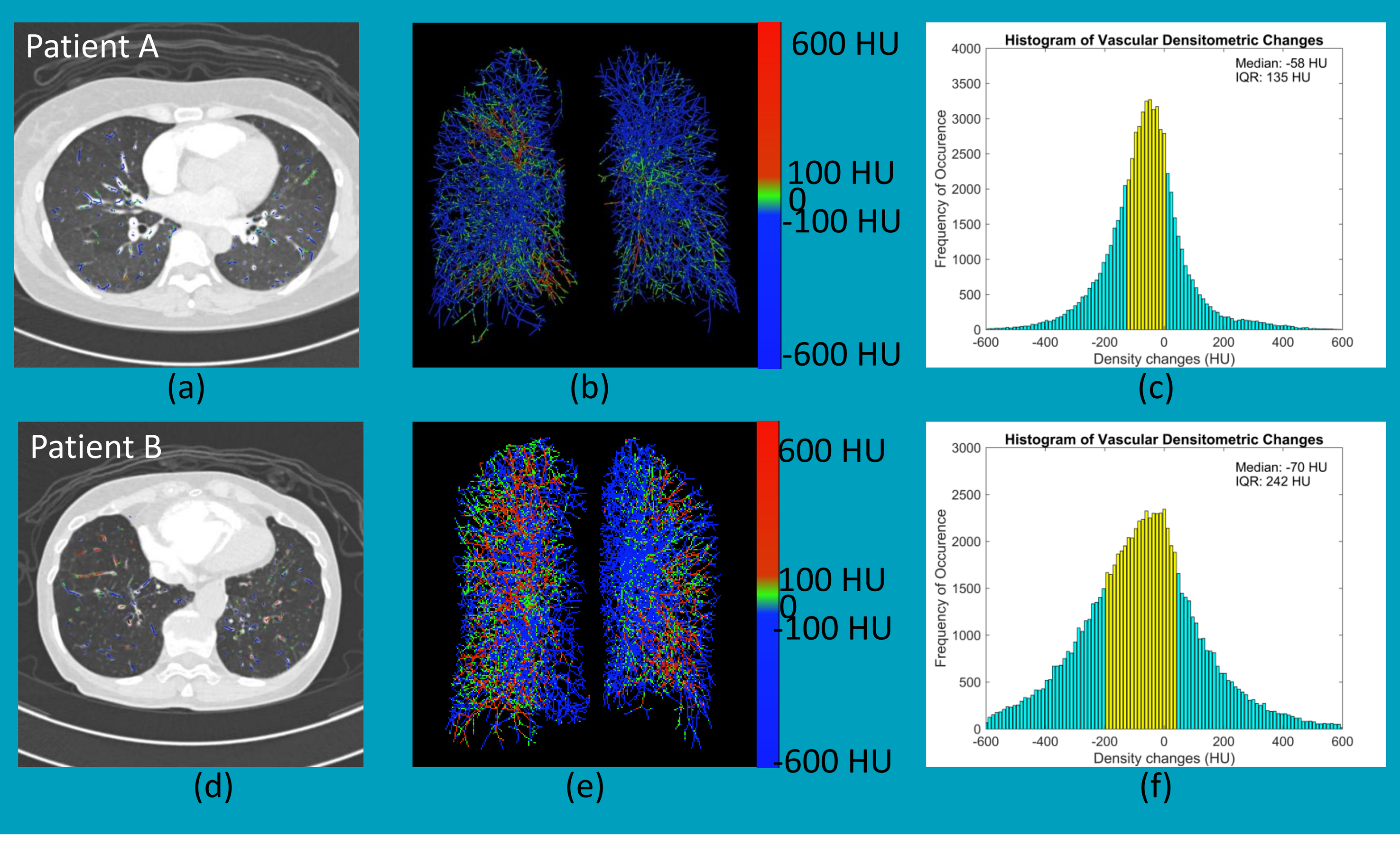

Figure 4. Vascular densitometric changes quantifications of two patients.

Conclusions

- The hemodynamics were significantly improved after BPA, in the studied patient group with inoperable CTEPH.
- The perfusional changes in pulmonary vasculature achieved by BPA was assessed, using an automatic comparison of CTPAs acquired pre- and post-treatment.
- The IQR of ΔVD is associated with hemodynamic changes and can be used as a non-invasive measurement for assessing BPA treatment effects.

References

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