Leiden University Medical Center

Treatment Effect of Balloon Pulmonary Angioplasty in CTEPH, Quantified by Automatic Comparative Imaging in CTPA

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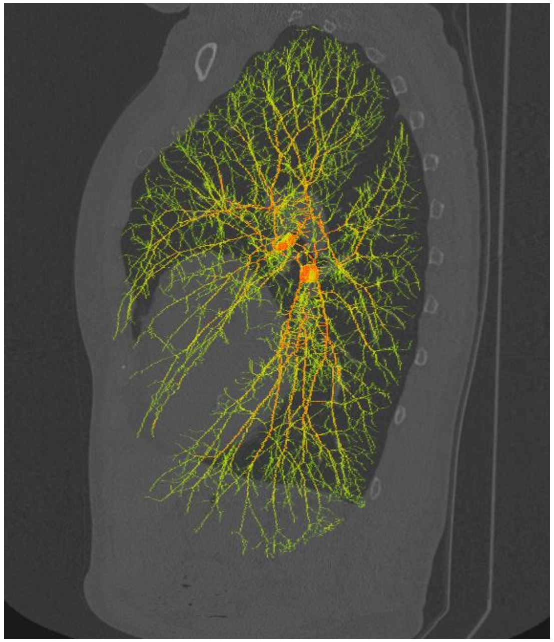
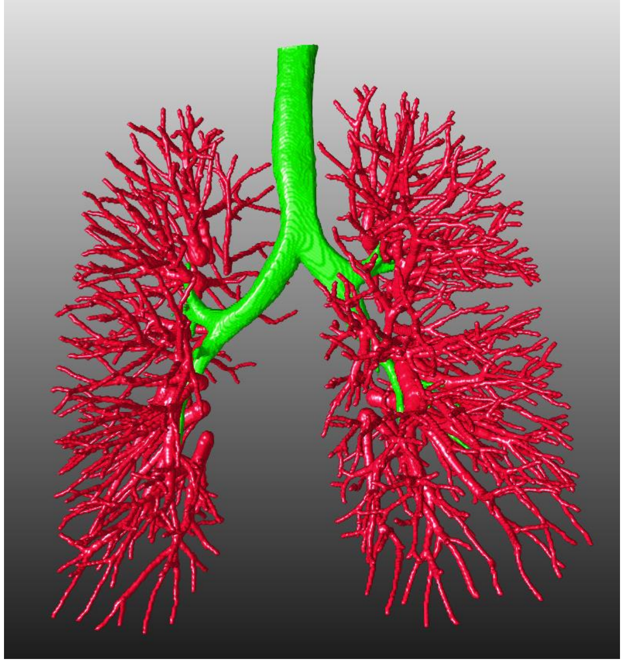


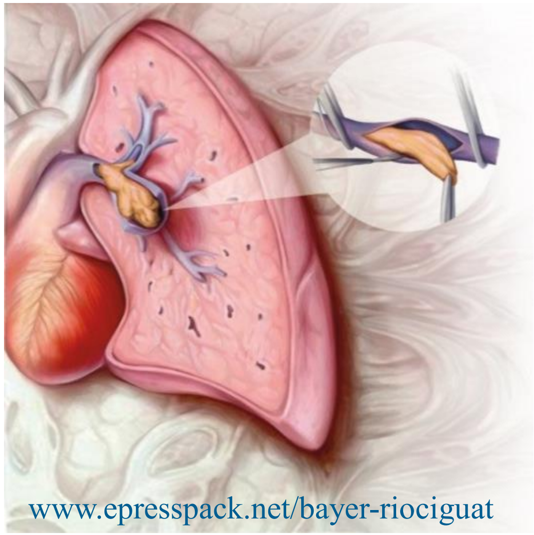
Contents

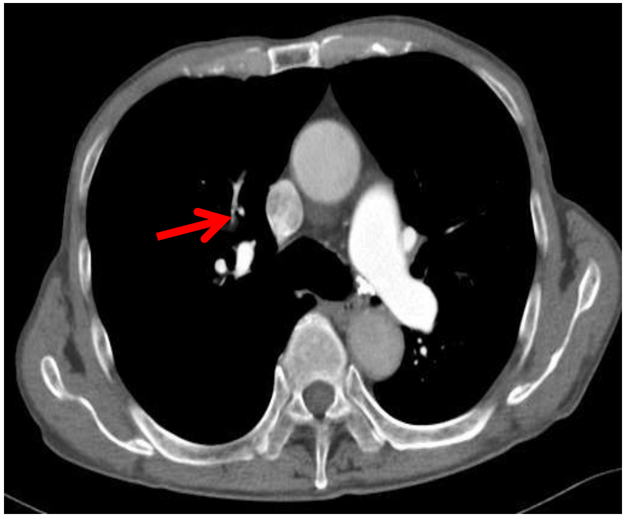
- **Introduction to CTEPH**
- Study population treated with BPA
- Methods of quantification
- Results & Discussion

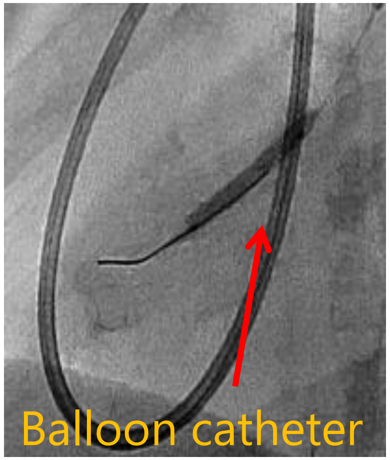


Introduction

- **Chronic thromboembolic pulmonary hypertension (CTEPH)**
  - Caused by persistent obstruction of pulmonary arteries
  - Surgical treatment: pulmonary endarterectomy
  - Inoperable CTEPH: Balloon Pulmonary Angioplasty (BPA) is an alternative treatment



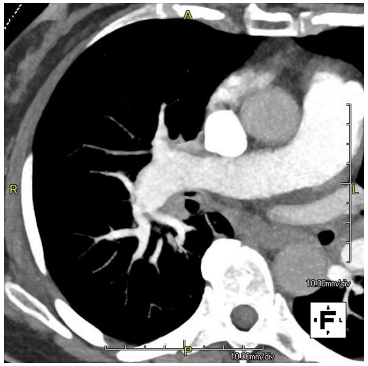




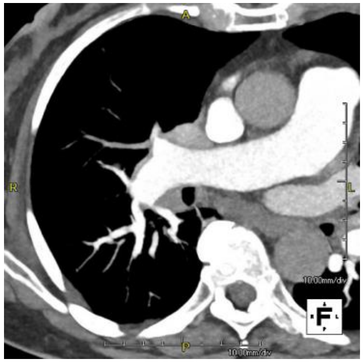
Introduction

- **Assessment of treatment effects**
  - Noninvasively: 6-min walk distance; brain natriuretic peptide (BNP) level; (dual-energy) CT pulmonary angiography (CTPA)
  - Invasively: right heart catheterization (RHC) (gold standard)

- **Purpose of this study**
  - Automatic comparison of pre- and post-treatment CTPA, to provide a non-invasive assessment of BPA treatment



Pre BPA



Post BPA

ESC-ERS Guidelines, European heart journal. 2015:ehv317
H Takagi et al., European Journal of Radiology. 2016;85(9):1574-80
JA Feinstein et al., Circulation 2001;103:10-13.

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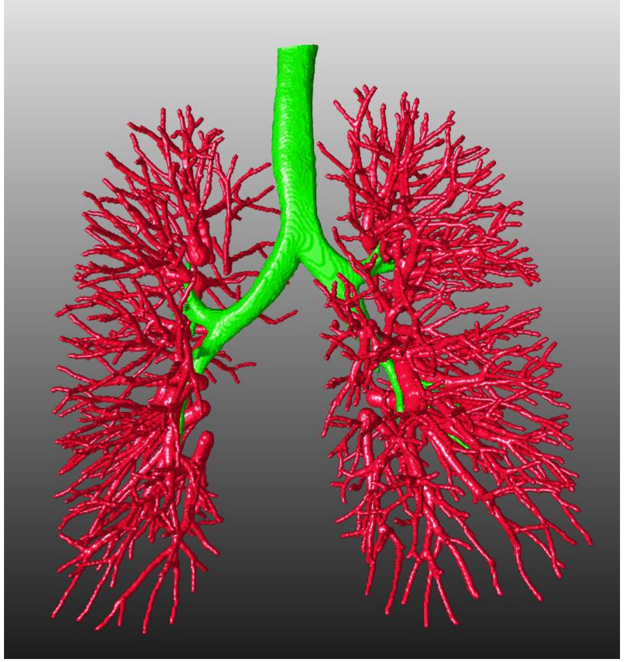

Patient group

- **14 CTEPH patients treated with BPA**
  - Mean age 70.5 ± 24 years, 12 females (86%)
  - Right heart catheterization (RHC) performed pre- and post-BPA:
    - Pulmonary artery pressure (PAP: mean, systolic and diastolic)
    - Pulmonary vascular resistance (PVR)
  - CTPA of pre- and post-BPA were performed with iodine contrast
  - Interval between CTPA and RHC was 0 - 37 days (median 2 days)
  - All patient data were collected from Tohoku University Hospital (Japan)

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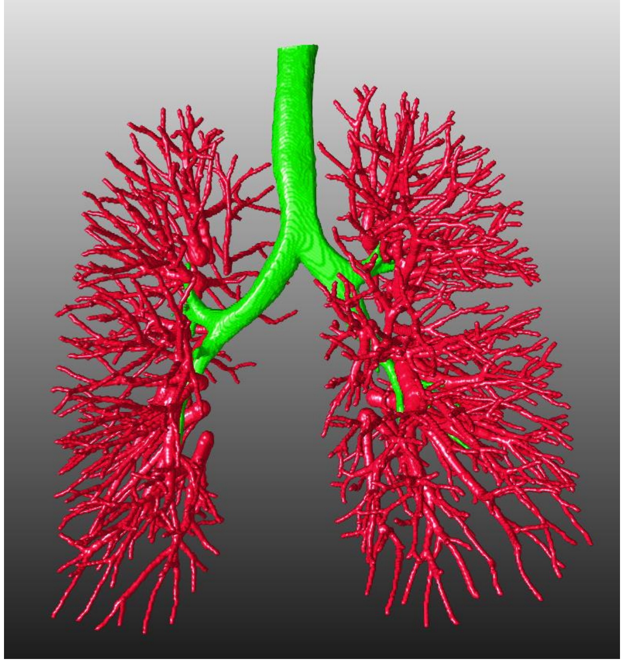
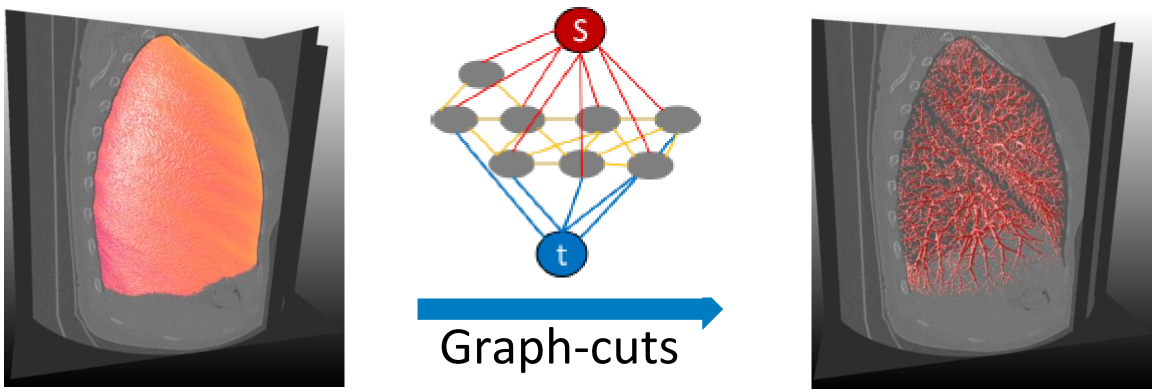


- Methods
  - Lung segmentation & lung vessel extraction
    - Atlas-based lung segmentation & graph-cuts based vessel extraction



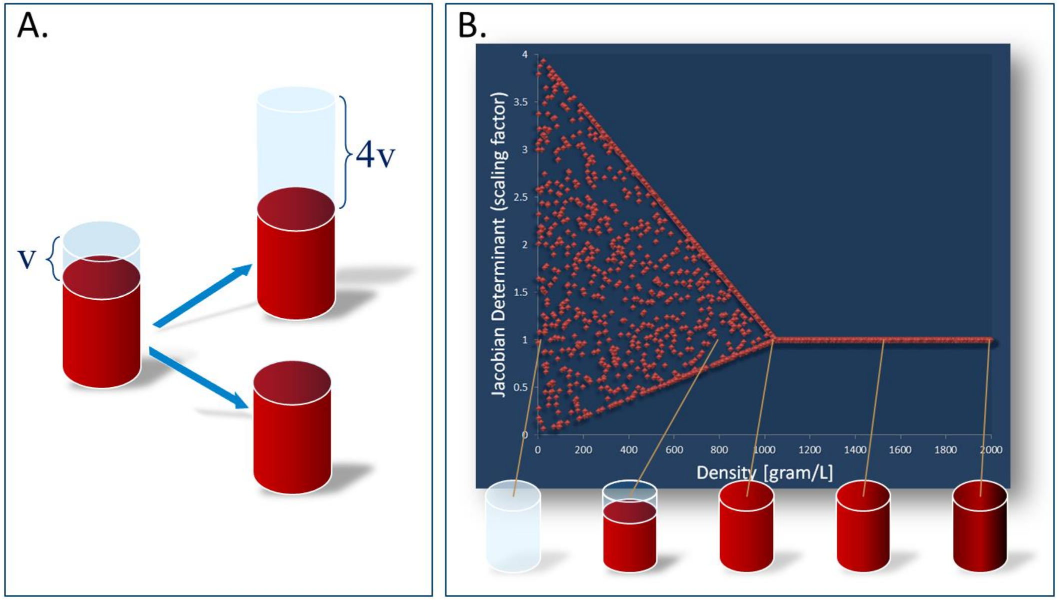
Total lung   Vessel tree

  - Automatic comparison of CTPAs of pre- and post-treatment
    - Pairwise image registration with volume correction
  - Quantification of changes in perfusion using densitometry

Z Zhai, et al., SPIE Medical Imaging 2016 (pp. 97842K-97842K)

Methods

- Comparative imaging in CTPAs of pre- and post-treatment
  - Image registration of post-BPA and pre-BPA scans using Elastix
  - Volume correction using two-component model:



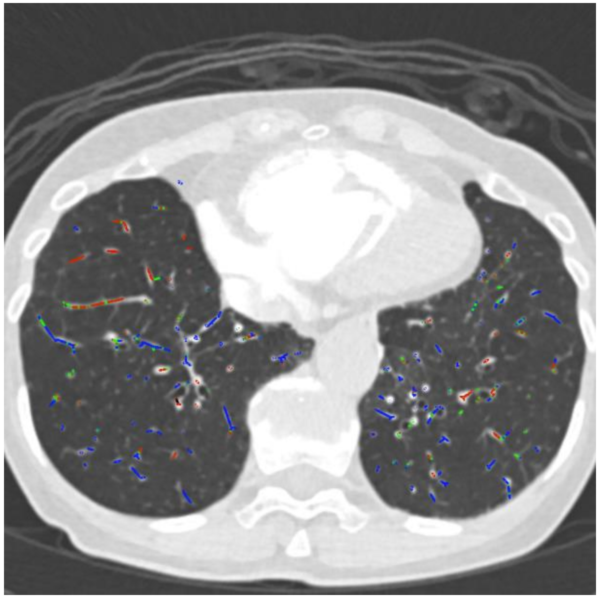
  - $Progression(x) =$

$$I_1(T(x)) - I_0(x) \cdot Max\{\theta_{min}(I_0(x)), Min\{\theta_{max}(I_0(x)), detJ_T(x)\}\}^{-1}$$

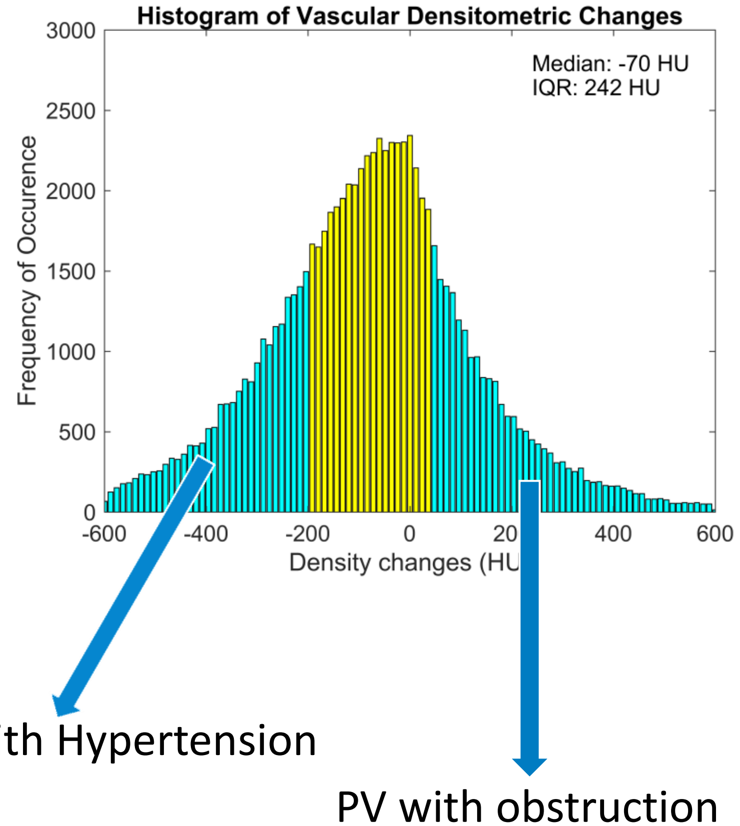
S Klein et al. IEEE transactions on medical imaging 29.1 (2010): 196-205.
M Staring et al. Medical Physics. 2014;41(2).

Methods

- Quantification of changes in perfusion
  - Vascular densitometry:
    median and IQR of vascular densitometric changes (ΔVD)



(red: increase, blue: decrease)



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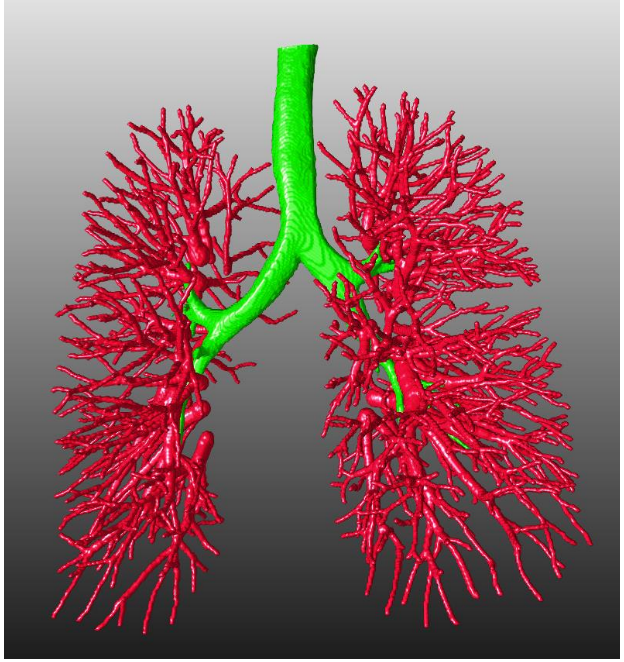


Results

Changes in hemodynamic parameters and densitometry measurements

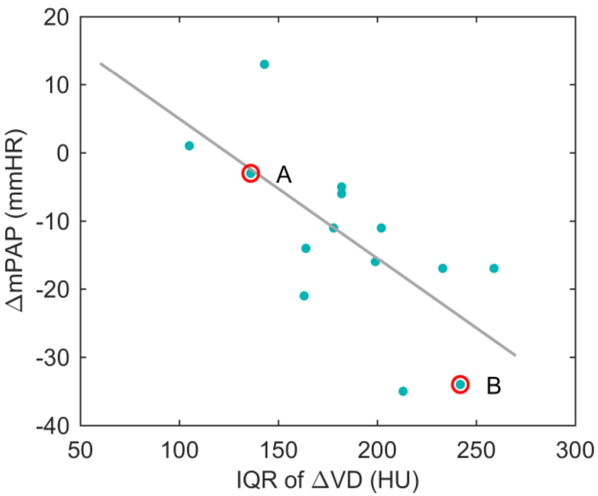
	Pre-BPA	Post-BPA	Change	p-value
RHC parameters				
sPAP (mmHg)	60.5 ± 33	36 ± 19	-23 ± 19	0.002
dPAP (mmHg)	20 ± 16	12.5 ± 11	-5 ± 11	0.006
mPAP (mmHg)	34.5 ± 17	21.5 ± 15	-12.5 ± 14	0.003
PVR (dyne·s/cm^5)	496 ± 396	246 ± 185	-185 ± 409	0.004
Density measurements (HU)				
Median VD	-415 ± 101	-433 ± 114	-51.5 ± 20.8	<0.001
IQR of VD	437± 73	475 ± 67	182 ± 60	<0.001

Changes in RHC parameters and density measurements between pre- and post-BPA were tested using paired t-tests or Wilcoxon signed-rank tests, as appropriate.

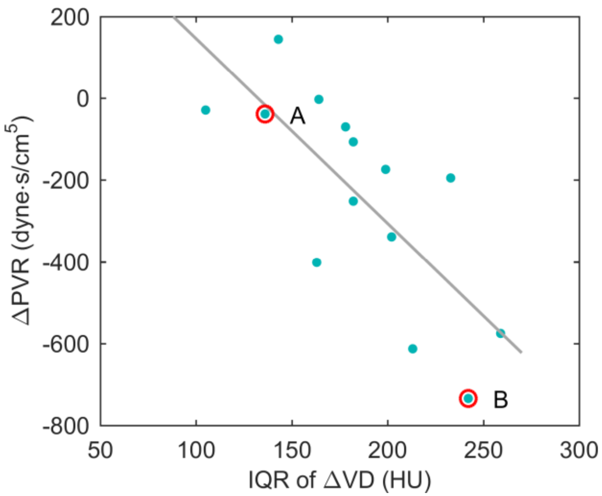
Results

Spearman's correlation (R, p-value) between RHC changes and density 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)



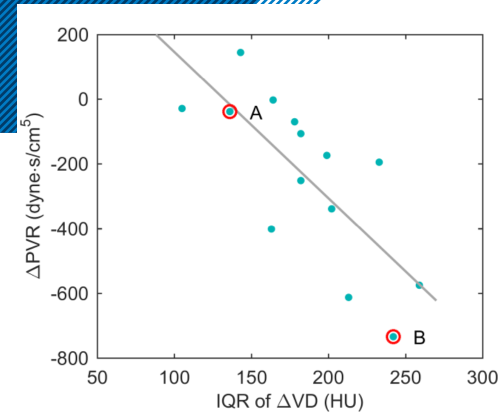
(a)

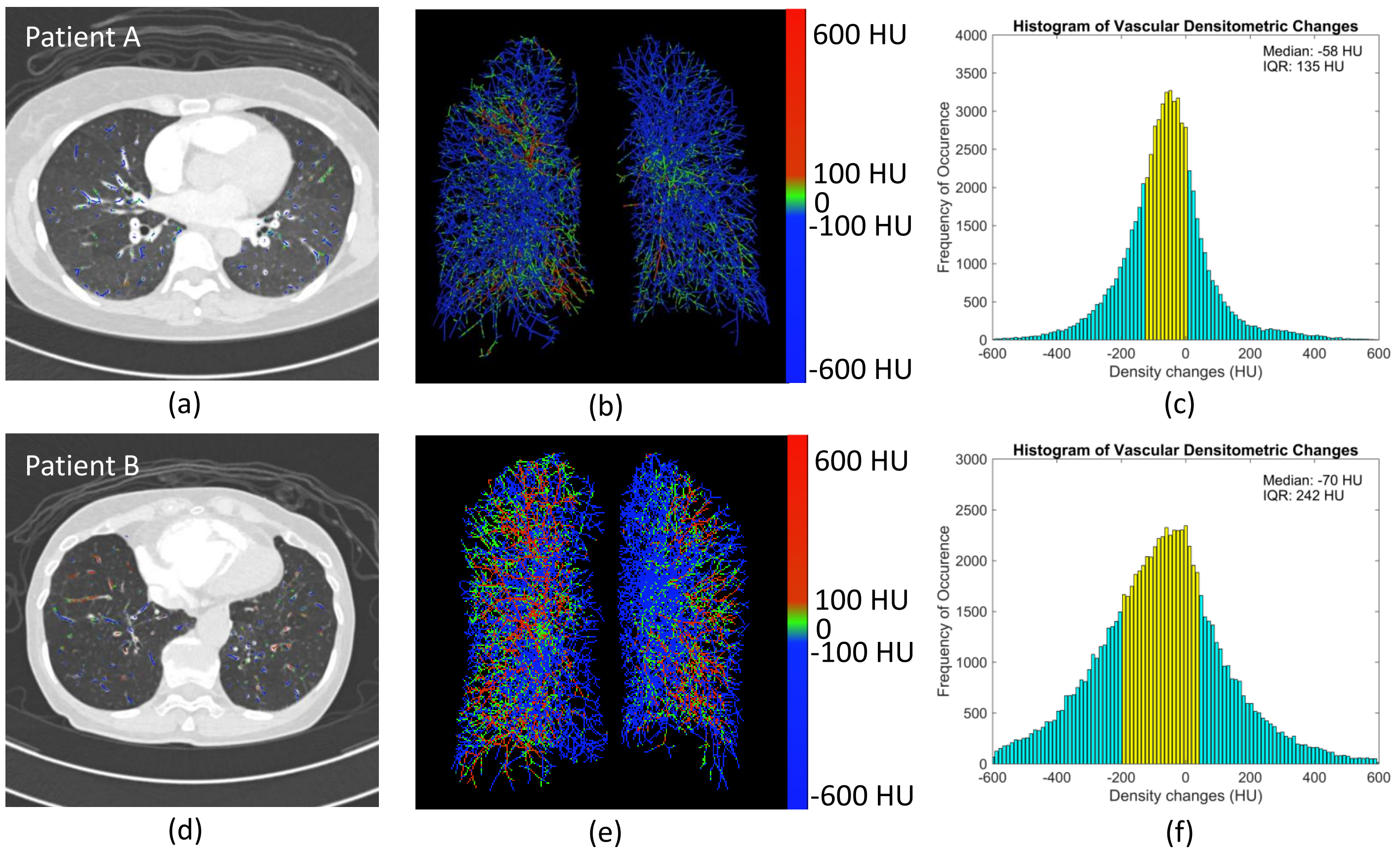


(b)

Correlation between ΔmPAP, ΔPVR and IQR of ΔVD

Results





Vascular densitometric changes quantification of 2 patients.

Limitations

- The sample size of studied group is small
- Artery/vein were not separated

Conclusions:

- Hemodynamics were significantly improved after BPA, in the studied patient group
- Vascular densitometry can provide insight into local perfusion changes
- IQR of ΔVD is correlated with hemodynamic changes and may be used as a non-invasive measurement for assessing BPA treatment effects

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Thank you!

- Acknowledgements:

Leiden University Medical Center

- Berend Stoel
- Marius Staring
- Jan Stolk
- Denis Shamonin
- Ningning Xu
- Boudewijn Lelieveldt

Tohoku University Hospital

- Hideki Ota
- Koichiro Sugimura
- Kei Takase
- Wenyu Sun

CSC scholarship No.201406120046.

China Scholarship Council
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