Letter to the Editor

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Monitoring Pulmonary Thrombectomy: What Information Can Be Gained with Arterial Spin Labeling MRI?

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Acute pulmonary embolism (PE) can be a life-threatening event that requires immediate care to maintain cardiovascular circulation. In addition to systemic thrombolytic therapy, mechanical thrombectomy may be indicated in cases with a high or intermediate risk of mortality, to directly remove obstructive emboli for rapid patient improvement [1]. Several devices for catheter-directed thrombolysis and mechanical thrombectomy are available, and data regarding the efficacy of these procedures are inconsistent. Non-invasive imaging of pulmonary blood flow might help evaluate treatment success and support the acceptance of revascularization procedures. Arterial spin labeling (ASL)-MRI is a well-established technique in brain imaging to measure organ perfusion without the need for contrast agents, using blood as an endogenous tracer. Perfusion imaging with ASL has already been implemented in routine clinical diagnosis of cerebrovascular pathologies, including arterio-occlusive disease, vascular shunts, and neuro-degenerative diseases [2]. In the lung, the complex vessel anatomy, highly pulsatile nature of blood flow, respiratory movements, and low proton density are challenging conditions for ASL-MRI, hindering its translation to routine clinical use. We recently presented electrocardiogram-triggered pseudo-continuous ASL (PCASL) imaging with balanced steady-state free precession readout at 1.5T as a promising approach to enable the imaging of pulmonary blood flow even under free-breathing conditions [3]. We aimed to demonstrate the first use of PCASL-MRI in patients to monitor the treatment success of catheter-directed mechanical thrombectomy.

A 79-year-old female patient was brought to our emergency unit with clinical signs of PE. A contrast-enhanced CT-scan was performed showing a massive occlusion of the right and left pulmonary arteries with signs of right ventricular dysfunction (Fig. 1A-C). Right ventricular strain was diagnosed on echocardiography and electrocardiogram (Fig. 1D). In accordance with the European Society of Cardiology (ESC) guidelines and after interdisciplinary discussion, the patient was brought to the angiography suite in our radiology department for mechanical thrombectomy.

Thrombectomy was performed with a large-bore aspiration mechanical thrombectomy device (FlowTriever®). A dedicated 24 French catheter (Triever24 Aspiration Catheter®) was advanced carefully after passing the right heart using a pigtail catheter to the pulmonary trunk, using a super stiff guide wire (Amplatz). Several clots could be mobilized successfully under suction, especially from the right side (Fig. 2). The mean pulmonary artery pressure was reduced by 7 mm Hg during the procedure. After mechanical thrombectomy, the patient had a speedy recovery and was discharged 6 days after the intervention.

The day before and after thrombectomy, PCASL-MRI examinations of the lung were performed on 1.5T scanner (MAGNETOM AvantoFit, Siemens Healthcare). The PCASL-MRI examination is part of an on-going prospective study registered at the German Clinical Trials

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Register (DRKS00023599) and approved by the local ethics committee. The patient provided written informed consent for scientific evaluation of the examination. To generate perfusion images, ASL MRI does not require the application of contrast agents. Instead, the blood is labeled magnetically by implementing radio-frequency pulses inverting the water protons before entering the imaging plane. The perfusion image can then be generated by

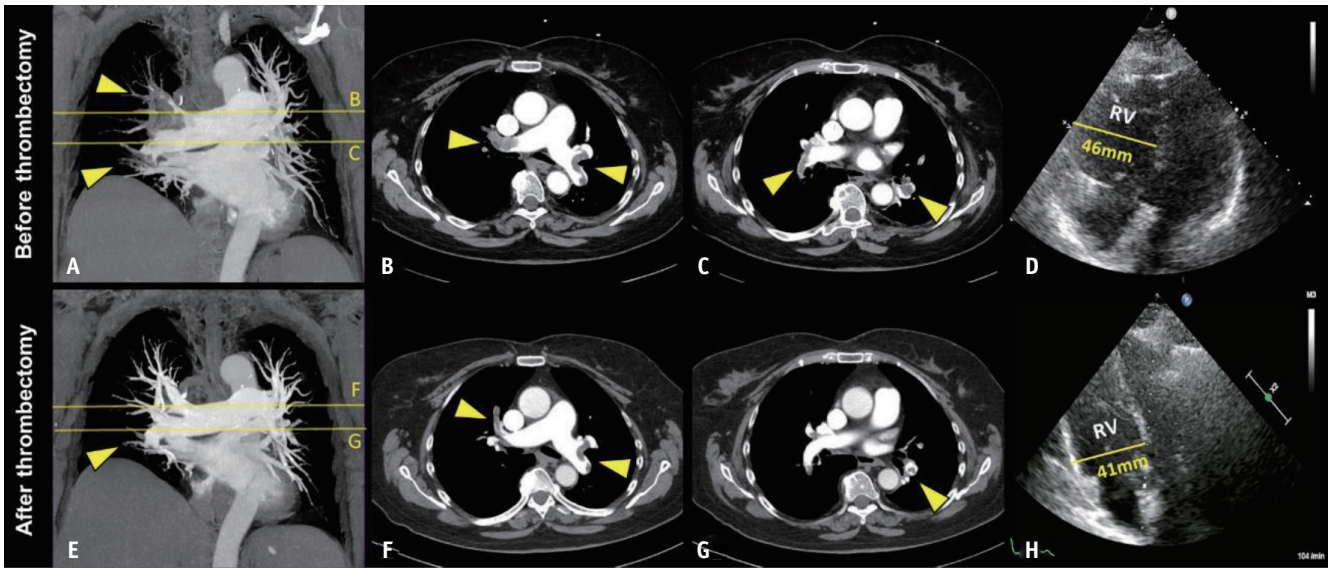

Fig. 1. CT scan before (upper row) and after (lower row) thrombectomy with arrowheads indicating massive filling deficits within the pulmonary vasculature before thrombectomy and the residual filling deficits after thrombectomy (A-C, E-G).
A, E. Coronal maximum intensity projection were the layers of the axial CT scans indicated in **(B)**, **(C)** and **(F)**, **(G)**. **D, H.** Echocardiography with diameter of the right ventricle before and after thrombectomy.

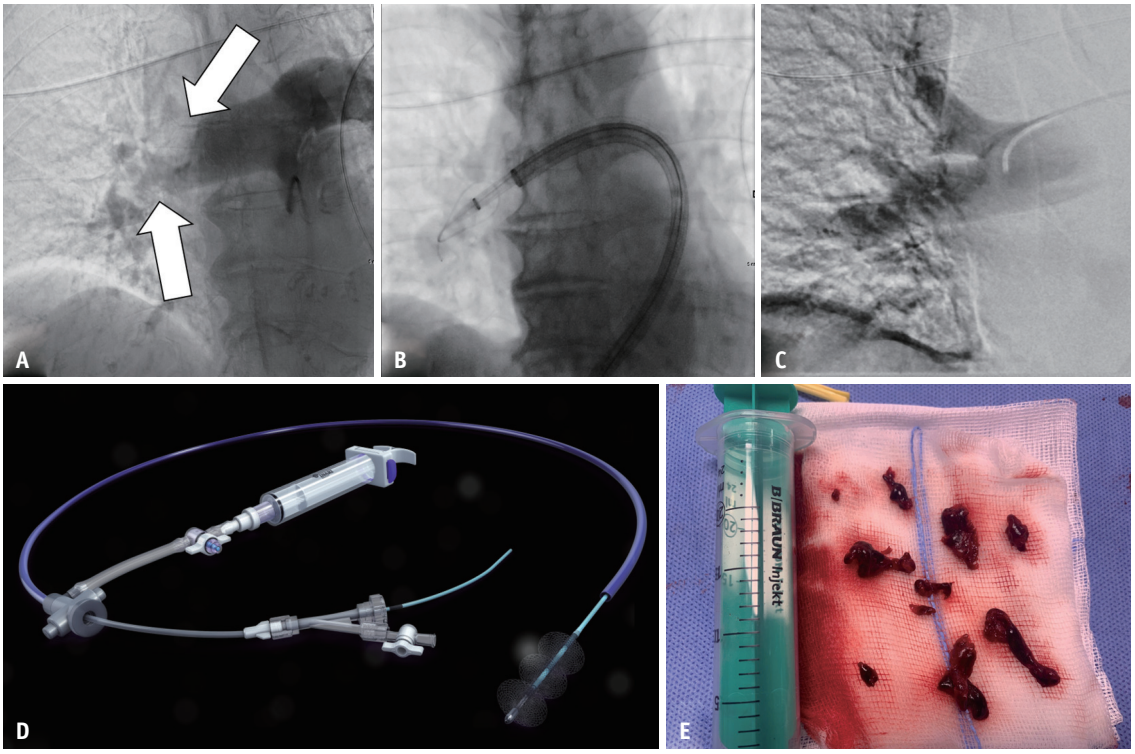

Fig. 2. Mechanical thrombectomy after massive pulmonary embolism.
A-C. Fluoroscopy and digital subtraction images from the angiography suite before **(A)** during **(B)** and after **(C)** thrombectomy. A large embolus is seen in the right pulmonary artery before thromobectomy (arrows). **D, E.** Thrombectomy was performed with a large-bore aspiration mechanical thrombectomy device (FlowTriever®) using a 24 French catheter **(D)**, and several clots were removed **(E)**.

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subtracting images with labeled blood from images without labeling (control image) [4]. A scheme of the examination is given in Figure 3. Further details about the PCASL sequence are presented in an earlier study [3]. Extensive deficits in lung perfusion were detected, most notably in the right lung (Fig. 4). The day after the intervention, a distinct improvement of lung perfusion was visible with a recovery of perfusion signal especially in the right upper lobe. No further perfusion signals could be detected in the right lower lobe.

We present PCASL-MRI as a new non-invasive gadolinium-free technique to image the recovery of lung perfusion after

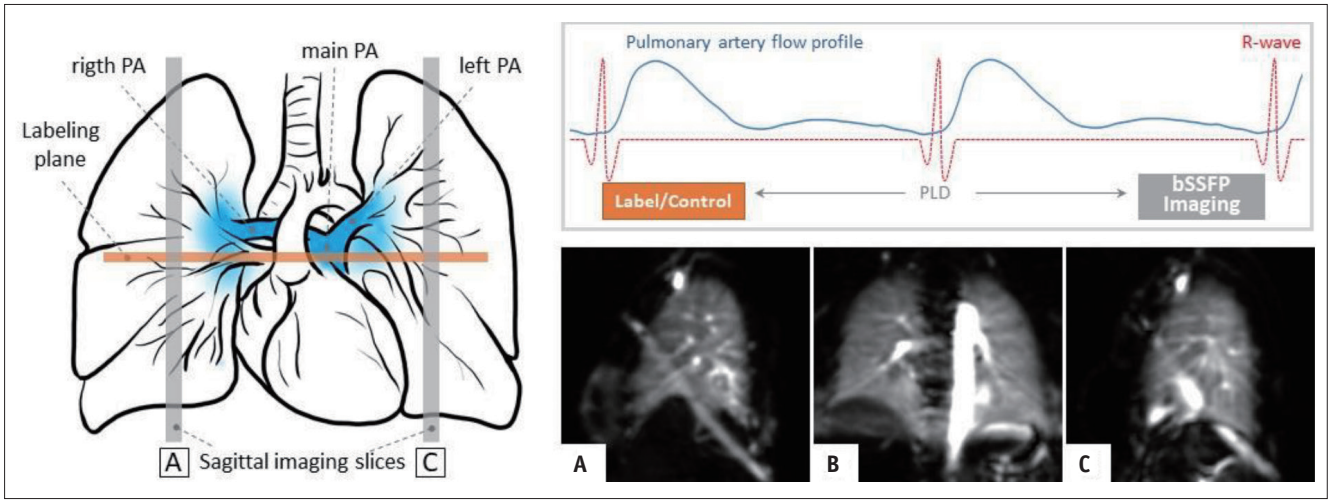

Fig. 3. Scheme of PCASL-MRI examination with imaging slices (grey) and positioning of the labeling plane (orange) to invert the magnetization of blood in the pulmonary trunk during systole (blue).
A-C. Subtraction images of a patient with normal lung perfusion. bSSFP = balanced steady-state free precession, PA = pulmonary artery, PCASL = pseudo-continuous arterial spin labeling, PLD = post labeling delay

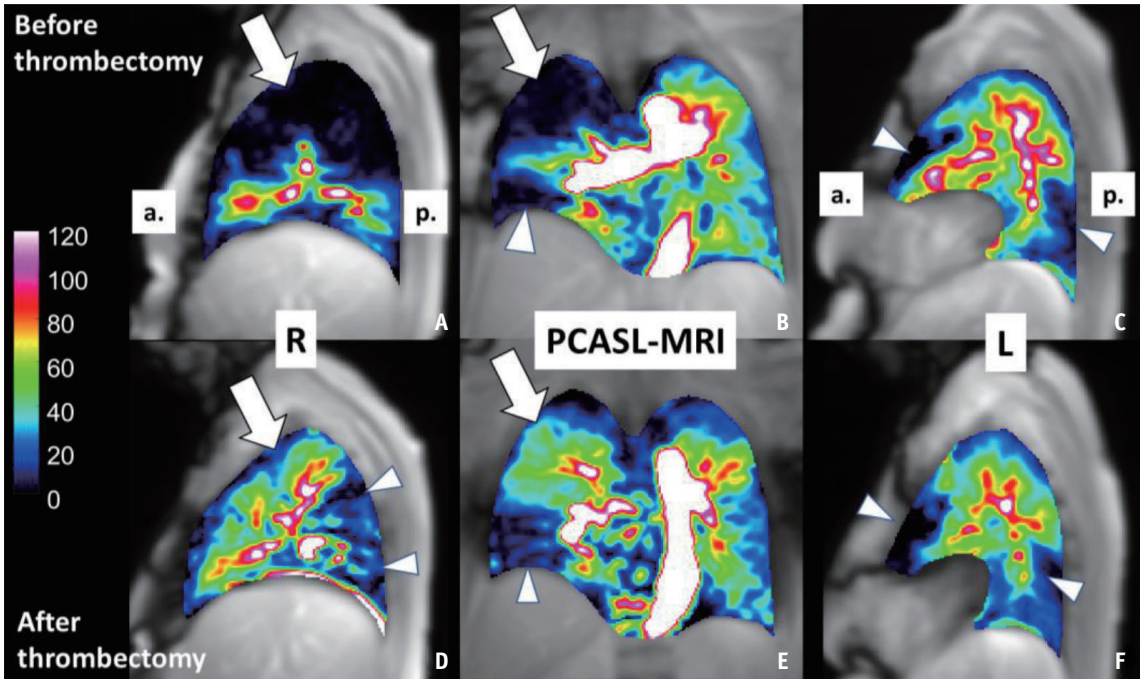

Fig. 4. PCASL-MRI before (upper row) and after (lower row) mechanical thrombectomy in coronal view and in sagittal plane from the right lung (R) and the left lung (L). Perfusion images are color coded, cropped, and copied to the M0-image for facilitated visualization. The color scale on the left provides the color encoded quantitative perfusion values in mL/min. Before the intervention, deficits in lung perfusion can be seen in the right upper lobe (arrows), right lower lobe, and peripheral regions of the left upper and lower lobe (arrowheads). Note the significant improvement of the parenchymal perfusion of the right upper lobe after the procedure, while perfusion deficits persist in the right lower lobe and in peripheral segments of the left lung. PCASL = pseudo-continuous arterial spin labeling

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catheter-directed mechanical pulmonary thrombectomy. PCASL-MRI provides complementary functional information to CT, and future perspectives might include its use for monitoring treatment success of re-perfusion procedures with acute PE and in clinical applications requiring longitudinal settings, such as detection of pulmonary infarction in follow-up examinations or the evaluation of pulmonary post-COVID complications.

Availability of Data and Material

All datasets generated or analyzed during the study are included in this published article.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Methology: Petros Martirosian, Rolf Pohmann. Project administration: Ahmed E. Othman, Ferdinand Seith, Cecilia Zhang. Resources: Gerd Groezinger, Klaus-Peter Kreißelmeier. Software: Petros Martirosian, Rolf Pohmann. Supervision: Ahmed E. Othman, Ferdinand Seith. Validation: Cecilia Zhang. Visualization: Cecilia Zhang, Petros Martirosian, Gerd Groezinger. Writing—original draft: Cecilia Zhang. Writing—review & editing: Petros Martirosian, Ferdinand Seith.

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