Phase-Contrast Cine MR Imaging of Pulmonary Artery to Assess Outcome of Balloon Pulmonary Angioplasty in Patients with Chronic Thromboembolic Pulmonary Hypertension

Yoshiaki Morita[1], Naoaki Yamada[1], Emi Tateishi[1], Kumi Ozaki[1], Yoshihiro Sanda[1], Suzu Kanzaki[1], Akihiro Tsuji[2], Shigefumi Fukui[2], Takeshi Ogo[2], Tetsuya Fukuda[1], Masahiro Higashi[1], Norifumi Nakanishi[2], and Hiroaki Naito[1]

[1]Department of Radiology, National Cerebral and Cardiovascular Center, Suita, Osaka, Japan, [2]Division of Cardiology, National Cerebral and Cardiovascular Center, Suita, Osaka, Japan

Target audience: Clinicians who are related to diagnosis of pulmonary hypertension. Scientists who are interested in assessment of pulmonary hemodynamics using MRI.

Purpose: Phase-contrast MR imaging (PC-MRI) allows accurate and reproducible quantification of blood velocity and flow, and previous studies suggest the utility in the assessment of pulmonary hypertension.[1] Chronic thromboembolic pulmonary hypertension (CTEPH) causes the severe pulmonary hypertension and leads to significant morbidity and mortality. Recently, balloon pulmonary angioplasty (BPA) has been performed as an alternative treatment option for non-surgical cases and reported to improve clinical status and hemodynamics with a low mortality.[2] The long-term prognosis after BPA, however, remains uncertain, and thus regular follow-up studies are needed. Although mean pulmonary artery pressure (mPAP) measured by right heart catheterization is considered the current standard for assessment of pulmonary hypertension in routine clinical practice, it is an invasive procedure and not well suited for repeated follow-up. Currently Doppler echocardiography (cardiac US) is widely used for noninvasive measurement, but cardiac US has a disadvantage in the limited acoustic window and the observer dependency. In this study, we evaluated the potential of PC-MRI in pulmonary functional assessment before and after BPA in patients with CTEPH.

Methods: Twenty-four patients (17 women, mean age 66.2 years) with CTEPH underwent PC-MRI at 1.5 T clinical machine (MAGNETOM Sonata,Siemens AG Healthcare Sector, Erlangen, Germany) before, immediately after, and 3-months after BPA. 2D-cine PC image was acquired in the pulmonary trunk with breath-hold using prospective ECG triggering (echo time 3.1msec, temporal resolution 26msec, flip angle 15 degree, slice thickness 5mm, FOV 320x240mm, matrix 125x256, VENC 150 to 200cm/sec). The following hemodynamic parameters of main pulmonary artery were measured: average velocity, peak velocity, forward volume, AT/ET (acceleration time to ejection time ratio, Figure 1) and distensibility (calculated as (maximum area – minimum area) / maximum area). The correlation between the change of each parameter by PC-MRI and that of mPAP by catheterization was assessed.

Results: The mPAP significantly decreased after BPA from 38.7±9.8 mmHg to 30.3±5.1 mmHg (immediately after) and to 29.1±6.8 mmHg (3-months after), respectively. PC-MRI showed that average velocity, AT/ET and distensibility significantly increased immediately after and 3-months after BPA. Peak velocity and forward volume after BPA were higher than those before BPA, but these differences did not reach statistical significance. Table 1 showed the correlation between the change of each parameter by PC-MRI and that of mPAP by catheterization. The change of AT/ET had the best correlation with that of mPAP (between before and immediately after BPA: r=-0.708 / p=0.0051, between immediately after and 3months after BPA: r=-0.656 / p=0.03, Figure 3).

Discussion and Conclusion: Our results demonstrated that PC-MRI enables to quantify the pulmonary hemodynamic improvement after BPA. Especially, the change of AT/ET has the best correlation with that of mPAP, suggesting that AT/ET might offer clinical use for the noninvasive and repeatable monitoring after therapeutic intervention. As pulmonary artery pressure increased, the earlier deceleration of pulmonary systolic flow occurred and AT/ET became shorter. Previous study showed that there were significant but weak correlations between AT/ET by PC-MRI and mPAP.[3] This may be due in part to the limited temporal resolution (about 100msec). In our protocol, higher temporal resolution (about 26msec) could help depict small changes in AT and ET.

References:

1. Nogami M. et al. Utility of phase contrast MR imaging for assessment of pulmonary flow and pressure estimation in patients with pulmonary hypertension: Comparison with right heart catheterization and echocardiography. J Magn Reson Imaging. 2009;30:973-80
2. Mizoguchi H. et al. Refined balloon pulmonary angioplasty for inoperable patients with chronic thromboembolic pulmonary hypertension. Circ Cardiovasc Interv. 2012;5:748-55
3. Sanz J et al. Pulmonary Arterial Hypertension: Noninvasive Detection with Phase-Contrast MR Imaging. Radiology. 2007;243:70-9

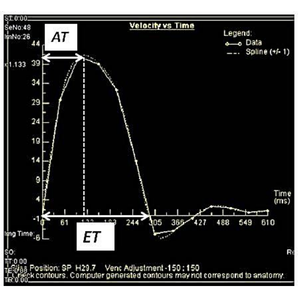

Figure 1. Time-velocity curve of pulmonary artery in healthy volunteer. Acceleration time (AT) was defined as the time interval from the beginning of anterograde flow upslope in systole to the peak systolic flow. Ejection time (ET) was defined as the interval from the beginning of the systolic flow upslope to the horizontalization of the flow curve, crossing of the zero flow line.

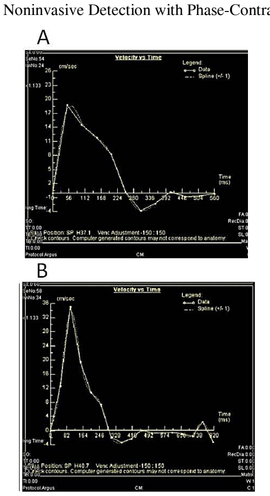

Figure 2. Time velocity curve before (A) and after BPA (B) in 51-year-old female with CTEPH. AT/ET was short before BPA (0.28, A), and AT/ET increased after BPA (0.48, B).

A

	r	p
Δ Peak velocity	-0.1254	0.5782
Δ Average velocity	-0.3565	0.1034
Δ Forward volume	-0.3799	0.0811
Δ AT/ET	-0.7082	0.0051
Δ Distensibility	-0.2578	0.2467

B

	r	p
Δ Peak velocity	-0.2159	0.5004
Δ Average velocity	-0.4666	0.1275
Δ Forward volume	-0.4423	0.15
Δ AT/ET	-0.6561	0.0323
Δ Distensibility	-0.1879	0.5587

Table 1. The correlation between the change of each parameter by PC-MRI and that of mPAP.
A. between before and immediately after BPA.
B. between immediately after and 3months after BPA

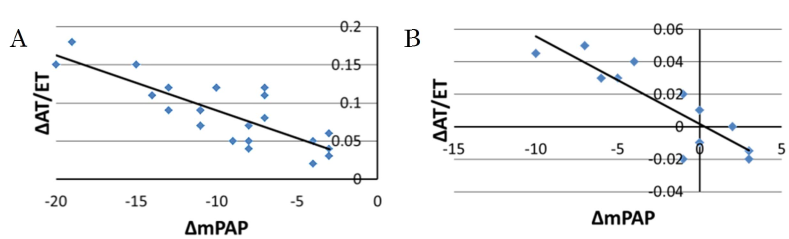

Figure 3. The correlation between the change of AT/ET and that of mPAP.
A. between before and immediately after BPA.
B. between immediately after and 3months after BPA