Multi-Phase Transmission RF Systems: Utility for improvement of B1 Inhomogeneity and Image Quality on 3T MR System as compared with Single- and Multi-Transmit RF Systems

Katsusuke Kyotani[1], Yoshiharu Ohno[1,2], Nobukazu Aoyama[1], Hideaki Kawamitsu[1], Takeshi Yoshikawa[2], Satoru Takahashi[2], Hisanobu Koyama[2], Mizuho Nishio[2], Sumiaki Matsumoto[2], Saori Satou[3], and Kazuro Sugimura[2]

[1]Radiology, Kobe University Hospital, Kobe, Hyogo, Japan, [2]Radiology, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, [3]Toshiba Medical Systems, Ohtawara, Tochigi, Japan

Introduction: The clinical use of 3.0T systems has been expanded from neuro MR imaging to body imaging (1, 2). 3.0 T MR scanners, which have come into widespread use in many institutions worldwide over the past few years, allow the acquisition of images with higher spatial and temporal resolution, due to the increase in signal-to-noise ratio (SNR) compared to that of 1.5T. Other advantages of 3.0T MRI include improved contrast-to-noise ratio (CNR) on post gadolinium images, and better and faster fat suppression. However, in routine clinical practice, the image quality at 3.0T for all sequences in body MR applications can not be improved due to several drawbacks including specific absorption rate (SAR) constraints, an increase in imaging artifacts and longer T1 relaxation times (2-5). In this situation, multi-transmit (i.e. 2-channel 2-port) and multi-phase transmission (i.e. 2-channel 4-port) RF systems may be one of the solutions for improving image quality and capability of 3T MR system not only pulmonary MR imaging, but also other body MR imaging. However, no direct comparison of capability for improving B1 homogeneity and image quality among single-transmit (i.e. 1-channel 2-port), multi-transmit (i.e. 2-channel 2-port) and multi-phase transmission (i.e. 2-channel 4-port) RF systems on 3T MR system. We hypothesized that multi-phase transmission RF system could improve B1 inhomogeneity and image quality on basic and clinical studies as compared with single-transmit and multi-transmit RF systems. The purpose of this study was to directly and prospectively compare B1 homogeneity and image quality of chest MR imaging among single-transmit (i.e. 1-channel 2-port), multi-transmit (i.e. 2-channel 2-port) and multi-phase transmission (i.e. 2-channel 4-port) RF systems on 3T MR system.

Materials and Methods: Basic study for determination of improvements of B1 homogeneity was performed as phantom study, and five patients with chest disease were evaluated as clinical study. On basic study, our proprietary phantom images were obtained by using a gradient-echo sequence with double-angle method adapted a long TR (TR 5000ms/ TE 1.8ms/ Flip angles 40 and 80 degree, 2 NEX), at two 3T MR systems (Achieva 3T: Philips Healthcare, Vantage Titan 3T: Toshiba Medical Systems). Single- and multi-transmit RF systems were used on a former scanner, and multi-phase transmission RF systems was used on a later scanner. Then, B1 maps were calculated, and B1 inhomogeneities were assessed as standard-deviation of B1 maps by ROI measurements. At each RF system, five phantom studies were performed. On clinical study, chest MR examinations were performed by using ECG- and respiratory gated black-blood T1-weighted (TR: 1<R-R>, TE eff : 8-10ms) and T2-weighted (TR: 2-3<R-R>, TE eff :80-100ms) turbo spin-echo sequences at both 3T system by using single- and multi transmit or multi-phase transmission RF systems. In each patient, signal-to-noise ratio was calculated as quantitative parameter from ROI measurements, and overall image quality was calculated as qualitative parameter by using five-point visual scoring systems. To compare the capability of improving B1 inhomogeneity among three RF systems from the basic study, standard deviations within the phantom were statistically compared by Fisher's protective least significant difference test. To determine the quantitative image quality improvements from the clinical study, SNRs were statistically compared by three RF systems by means of Fisher's protective least significant difference test. To compare overall image quality among three RF systems, Fisher's protective least significant difference test was performed. A p value less than 0.05 was considered as significant in all statistical analyses.

Results: B1 maps obtained three different RF systems are shown in Figure 1. Standard deviation of multi-phase transmission RF system was significantly lower than that of single-transmit and multi-transmit RF systems ($p<0.05$). Representative case is shown in Figure 1. SNRs of multi-phase transmission and multi-transmit RF systems were significantly higher than that of single-transmit RF system on T1- and T2-weighted MR imaging ($p<0.05$). Overall image quality of multi-phase transmission RF system was significantly higher than that of single- and multi-transmit RF systems ($p<0.05$).

Conclusion: Multi-phase transmission RF system has a potential to improve B1 inhomogenity and image quality of chest MR imaging at 3T MR system, when compared with single- and multi-transmit RF system.

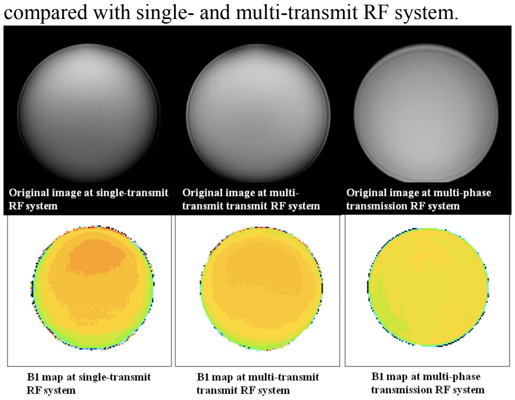

Figure 1. Original phantom image and B1 map at each RF system (L to R: single-transmit, multi-transmit and multi-phase transmit RF systems).

Although B1 inhomogeneity within the phantom was improved by using multi-transmit RF system as compared with single-transmit RF system, B1 inhomogeneity within the phantom using multi-phase transmission RF system is markedly improved as compared with single-transmit and multi-transmit RF systems.

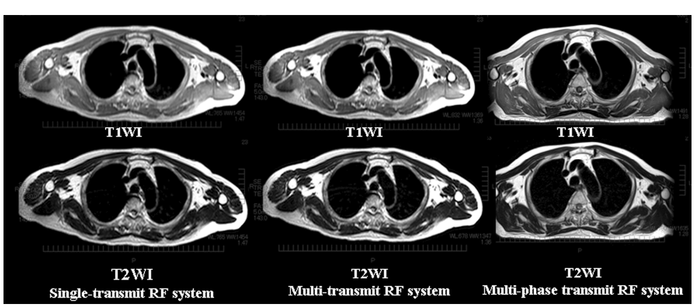

Figure 2. An example of chest MR imaging at each RF system (L to R: single transmit, multi-transmit, and multi-phase transmit RF systems; Upper to Lower line: ECG- and respirator-gated black-blood T1-weighted turbo spin-echo and T2-weighted turbo spin-echo images).

Inhomogeneities of signal intensity between anterior to posterior and between right and left are improved, when multi-phase transmission RF system is adapted. Image qualities of T1- and T2-weighted turbo spin-echo images by using multi-phase transmission RF system are better than those using single- and multi-transmit RF system.

References:

1. Ramalho M, Herédia V, Tsurusaki M, et al. J Magn Reson Imaging. 2009; 29: 869-879
2. Lee VS, Hecht EM, Taouli B,et al. Radiology. 2007; 244: 692-705
3. Merkle EM, Dale BM. AJR Am J Roentgenol. 2006; 186: 1524-1532
4. Barth MM, Smith MP, Pedrosa I,et al. Radiographics. 2007; 27: 1445-1462
5. van den Bergen B, Stolk CC, Berg JB, et al. Phys Med Biol. 2009; 54: 1253-1264.