# Respiratory-Gated Continuously Moving Table 3D MRI

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## Introduction

When continuously moving table imaging is applied to an extended virtual FOV that includes the abdomen and chest, the physiological motion of the patient must be addressed to achieve optimum image quality. Scanning under breath-hold conditions is unacceptable in most cases because scan times are too long. Thus, the incorporation of physiological-motion detection and gating technology is desirable. However, contrary to static MRI, where gating has been widely used (1), this poses several problems in continuously moving table MRI. In particular, the table velocity has to be varied, and the data from contiguous regions of sampling have to be accurately matched. So far, continuously moving table imaging methods, e.g. (2,3), have been applied without compensation of physiological motion. In this paper, the problem of respiratory motion is addressed, and one solution to this problem is presented. Tests on volunteers demonstrate the feasibility and effectiveness of the proposed method.

## Method

Figure 1 gives an overview of the dual-velocity gating concept used in the present feasibility study. The table is moved at the higher velocity $v_1$ as long as respiratory motion is negligible in regions from which MR signal is received, whereas it is moved at the lower velocity $v_2$ when signal is received from the abdominal and chest regions (between $t_1$ and $t_2$ in Fig. 1). In this study, respiratory motion is monitored during the entire scan, but the actual gating mechanism is activated only between $t_1$ and $t_2$. The acceptance window is chosen based on considerations of image quality. The gating efficiency, $\eta$, is estimated from this choice, and velocity $v_2$ is set to $\eta \cdot v_1$.

The continuously moving table method used with this gating concept is based on 3D Cartesian sampling with a lateral (left-right) frequency-encoding direction and slab selection along the direction of motion (4). The position of the excited slab is adapted for each RF-excitation such that the slab moves with the same velocity as the patient during one full traversal of *k*-space (slab tracking). Each complete set of *k*-space data is then reconstructed, using phase corrections (3) to compensate for the moving slab relative to the FOV of the magnet. The timing of transitions between $v_1$ and $v_2$ is chosen such that always an integer number of elementary FOVs is scanned at each velocity.

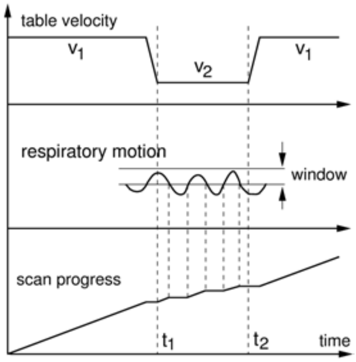

FIG. 1. Illustration of the gating concept.

## Experiments and Results

Volunteer experiments were performed on a 1.5 T whole-body MR scanner (Achieva, Philips Medical Systems), using the body coil for both RF excitation and signal reception during free breathing. A 3D spoiled gradient-echo sequence was applied with TR/TE = 4.3/2.1 ms. The dimensions of the 3D slab were 512×256×100 $\text{mm}^3$ (L/R×A/P×S/I), sampled with a resolution 2×2 $\text{mm}^2$ in the coronal plane and 8 mm A/P. Data were acquired over the entire length of the body. The table velocity was $v_1$ = 11.25 mm/s and $v_2 = 1/3 \cdot v_1$, corresponding to an estimated gating efficiency of 33 %. Gating was active only during four scans of *k*-space, namely those that covered the abdominal and chest regions. A respiratory-gating belt was used to monitor breathing and to steer the gating to accept data only during the end-expiration state, in a gating window of about 4 mm. Figure 2 shows results from two 3D scans, with and without gating, respectively. The improved image quality obtained with respiratory gating is clearly visible in the chest region, where the delineation of organs is substantially sharper. The total imaging time was 168 s for the scan without gating and 240 s for the gated scan.

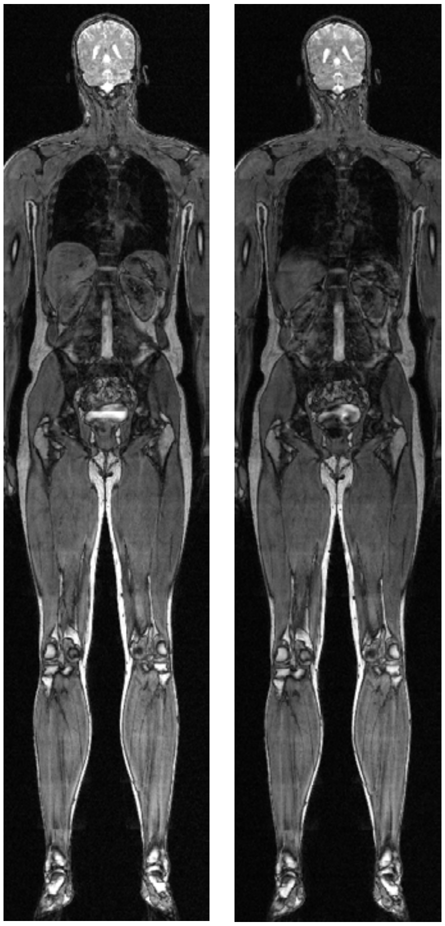

FIG. 2. Coronal images from two 3D head-to-toe scans, acquired using gating (left) and without gating (right).

## Discussion and Conclusion

The feasibility and effectiveness of respiratory gating in continuously moving table imaging has been shown, using a special acquisition method. This method is ideally suited to the required table-velocity variation, thanks to the use of slab tracking over complete *k*-space traversals, which allows reconstruction of successive 3D subvolumes after each *k*-space traversal. A shortcoming of the method implemented so far is that the gating efficiency must be estimated a priori, in order to guarantee full *k*-space coverage in the predetermined gating interval. Refinement and extension of this procedure is possible, however. For example, the accept/reject algorithm could be replaced by more advanced gating strategies like DVA (5), MAG (6) or PAWS (7), which could improve the image quality and/or scan efficiency. A further promising direction of improvement is to control the table velocity based on the progress of the scan, i.e., the accepted lines of *k*-space, which would make the procedure more time efficient. In conclusion, respiratory gating can be included in the continuously moving table imaging scheme, providing substantial image quality improvement.

## References

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