# Is Sub-Pixel Registration Necessary for Continuously Moving Table MRI ?

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## Introduction

Continuously moving table (CMT) methods with constant and variable table speeds have been proposed for large field-of-view (FOV) MR imaging, in particular for peripheral MR angiography.[1-5] In CMT MR imaging with a coronal or sagittal acquisition, the large FOV is constructed by acquiring **k**-space data as the conventional, local $FOV_x$ is translated along the patient (in the readout or *x*-direction). In general, the table motion might be such that the displacement along *x* from one $k_x$-readout to the next is not equal to the pixel resolution, $\Delta x$, in the *x*-direction. To maintain consistency, readout data must be registered by shifting in increments of $<\Delta x$. Sub-pixel registration is particularly important for CMT techniques that use one or more periods of constant table velocities. In this CMT implementation sub-pixel mis-registrations are coherent and result in severe ghosting artefacts in the final large FOV image if left uncorrected.[1,2,6] To minimize these artefacts, a phase twist along $k_x$ (equivalent to the subpixel registration in *x*) has been applied along the sampled echo.[1] Alternative registration methods included sweeping the frequency of the scanner receiver at a rate matching the table speed.[2] This second registration method, however, requires a known table speed before starting the acquisition. It would be inconsistent with the interactive CMT (iCMT) method that has enabled adaptive table motion.[4] In this work, we demonstrate that the sub-pixel registration is not a necessary step in variable-rate iCMT method.

## Materials and Methods

Contrast-enhanced MR angiography experiments were performed in vascular phantom on a 3 T clinical MR scanner (Signa VH/i; GE Healthcare, Waukesha, WI) using a real-time CMT platform with interactive table motion.[7] The phantom was filled with water which was circulated at constant flow rate of 1.2 L $min^{-1}$. Diluted MR contrast agent (20 ml of 2% Magnevist; Berlex, Berlin, Germany) was injected (1 mL $s^{-1}$) into the phantom. The scanner operator tracked the contrast bolus as it traveled down the phantom using a real-time feedback and a floating table. Typical scan parameters were: TR/TE/flip = 4.4 ms / 1.8 ms/ 30°, number of slices = 18, local $FOV_x$ = 35 cm (256 × 128 acquisition), and large FOV = 105 cm (768 × 128 reconstruction matrix). Large FOV images were reconstructed with and without sub-pixel correction. In the case of correction, a phase twisting was applied on the readout data prior to reconstruction.[1,6] The results were compared for any artifacts and SNR reduction.

## Results and Discussion

Fig 1a-b show a hypothetical constant table motion profile that produced positions that were not multiples of the pixel dimension, *i.e.*, $x = N\Delta x + \delta x$ where $0 \leq \delta x < 1.37$ mm, resulting in a periodic sub-pixel error coherence pattern during the readout acquisition. If uncorrected, this pattern leads to coherent mis-registration of the readouts in the hybrid-space matrix producing severe ghosting in the final image, as seen in Ref [1]. Fig 1c-d illustrates an irregular constant table motion profile and coherence pattern obtained during a CE-MRA phantom experiment (Fig 2). This profile generated random sub-pixel remainders, δx and led to incoherent readout mis-registrations in the hybrid-space matrix. The average table velocity in both scenarios was ~ 0.8 cm $s^{-1}$. Fig 2 shows images acquired using the table motion of Fig 1c with and without sub-pixel correction. The difference between two images is also shown which is small. The reconstruction without sub-pixel correction did not produce ghosting in the final image. It also did not reduce the SNR noticeably. This is because the random sub-pixel mis-registration results in incoherent registration error in hybrid-space. Therefore, the ghosting artefacts spread across the entire image and the effect is minimized; this observation is analogous to a dithering process.[8] Results of Fig 1 and Fig 2 also suggest that a uniformly-distributed random distance, $0 < d < \Delta x$, can be added to the table positions (if this is practically justified) in a constant motion scenario to avoid the necessity of sub-pixel registration at the cost of negligible SNR degradation.

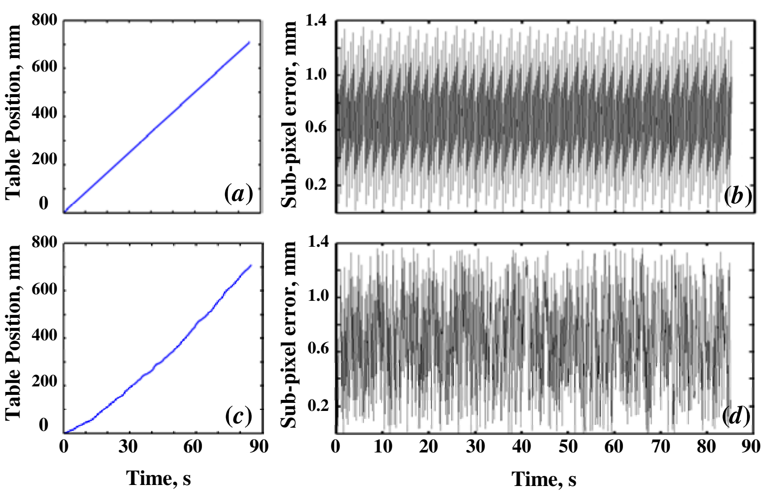


*Fig 1: Sub-pixel position remainders, δx, in CMT. (a) A hypothetical constant table motion produces (b) sub-pixel remainders with periodic coherent pattern. (c) Irregular table motion (used in Fig 2) generate (d) random incoherent pattern led to incoherent mis-registration in hybrid-space matrix. The average table velocity was ~ 0.8 cm $s^{-1}$.*

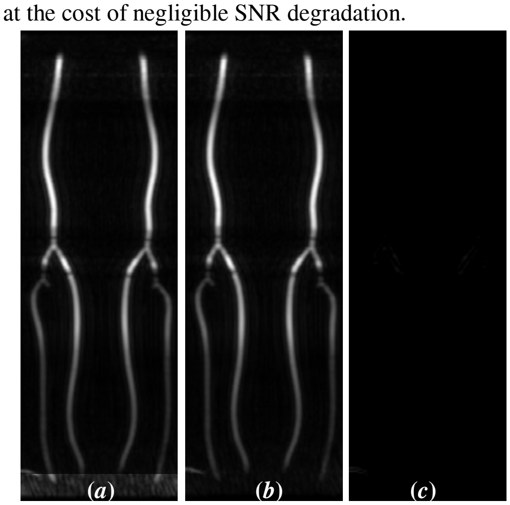


*Fig 2: Effects of sub-pixel correction in non-perfectly constant table motion. Two large FOV CMT MIP images from table motion profile of Fig 1c reconstructed (a) with and (b) without phase twisting. (c) The difference MIP image of (b) from (a).*

## Conclusions

Sub-pixel registration is required for a constant table motion profiles in order to reduce image ghosting. However, even when slightly non-uniform table motion is used, no difference is seen with and without applying phase twisting along each readout data for sub-pixel registration. Avoiding the sub-pixel registration can be important to reduce the complexity in real-time data processing and the reconstruction time in a large FOV CMT test. Nevertheless, post-processing algorithms could be applied to the acquired data to enhance the quality of the final large FOV images. The non-constant, variable table motion allowed by iCMT obviates the need for sub-pixel registration required in the constant speeds CMT methods.

## References

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