Iterative Reconstruction Techniques to Enable Intrinsic Respiratory Gated CT in Mice

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Purpose: Longitudinal studies of lung function in mice need the ability to image different phases of ventilation in free-breathing mice using retrospective gating. However, retrospective gating often produces under-sampled and uneven angular samples, resulting in severe reconstruction artifacts when using traditional FDK based reconstruction algorithms. We wanted to demonstrate the utility of iterative reconstruction method to enable intrinsic respiratory gating in small-animal CT.

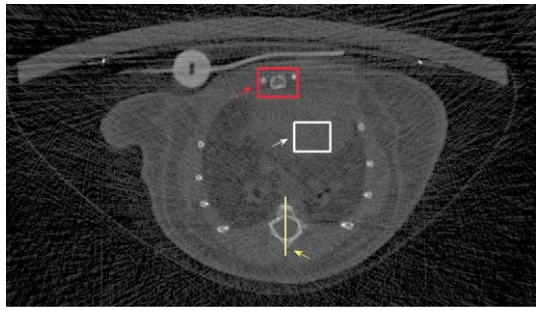
Method: Free-breathing mice were imaged using a Siemens Inveon PET/micro-CT system. Evenly distributed projection images were acquired at 360 angles. Retrospective respiratory gating was performed using an intrinsic marker based on the average intensity in a region covering the diaphragm. Projections were classified into 4 and 6 phases (finer temporal resolution) resulting in 138 and 67 projections respectively. Reconstruction was carried out using 3 methods: conventional FDK, iterative penalized least-square (PWLS) with total variation (TV), and PWLS with edge-preserving penalty. The performance of the methods was compared using contrast-to-noise (CNR) in a region of interest (ROI). Line profile through a specific region was plotted to evaluate the preserving of edges.

Results: In both the cases with 4 and 6 phases, inadequate and non-uniform angular sampling results in artifacts using conventional FDK. However, such artifacts are minimized using both the iterative methods. Using both 4 and 6 phases, the iterative techniques outperformed FDK in terms of CNR and maintaining sharp edges. This is further evidenced especially with increased artifacts using FDK for 6 phases.

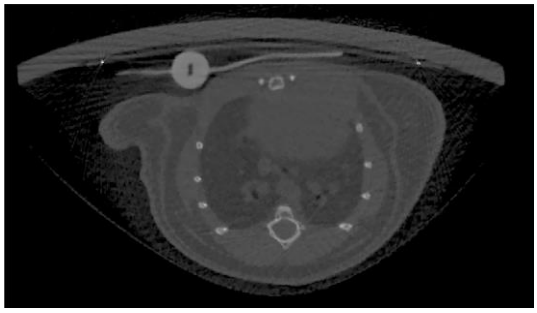
Conclusions: This work indicates fewer artifacts and better image details can be achieved with iterative reconstruction methods in non-uniform under-sampled reconstruction. Using iterative methods can enable free-breathing intrinsic respiratory gating in small-animal CT. Further studies are needed to compare the computational complexity for large datasets.

Innovation/Impact: Retrospective respiratory gating in small-animal CT results in non-uniform and under-sampled angular projections, especially if one wants to divides the respiratory cycle into multiple phases (4-8 phases). Iterative methods are known to shows better ability in handling such data as compared to analytical FDK method, thus is a better choice for intrinsic respiratory respiratory gating. This work enables imaging of free-breathing mice at different respiratory phases without the use of intubation or any other surgical intervention. Successful demonstration will enable researchers to not only evaluate tidal volumes but also estimate regional ventilation in small animals[1].

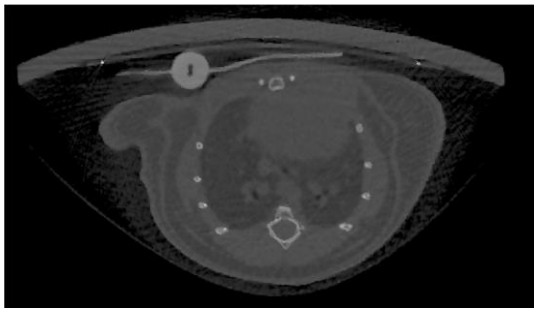
Key Results: Raw projection images each with 1504×896 pixels imaged at 360 angles, was classified into 4 phases (Case I) with 138 projections in phase 1 (full-inhale), and into 6 phases (Case II) with 67 projections in phase 1. Results for Case I are shown in Fig 1. Noise level was characterized by the standard derivation of a uniform region (indicated by a white square in Fig 1:(a)). A region of interest (ROI) (indicated by a red square in Fig 1:(a)) was used to calculate contrast-to-noise (CNR). A profile through a specific region (indicated by a yellow line in Fig 1:(a)) was plotted to evaluate edges. Iterative methods used a tradeoff parameter between data-fidelity term and penalty term so that the noise levels are matched.



(a)



(b)



(c)

Figure 1: One slice of reconstructed images of phase 1. (a) FDK; Iterative method with (b) TV penalty and (c) edge-preserving penalty.

Iterative methods with TV penalty[2] and edge-preserving penalty[3] show higher CNR than FDK. In Case I, CNR of ROI in FDK and two iterative results are 0.29, 0.52 and 0.49, respectively. In Case II, CNR are 0.23, 0.84 and 0.81. Fig 2 shows the profiles in Case I. As can be seen that both iterative results have higher intensity at peaks and better edges than FDK.

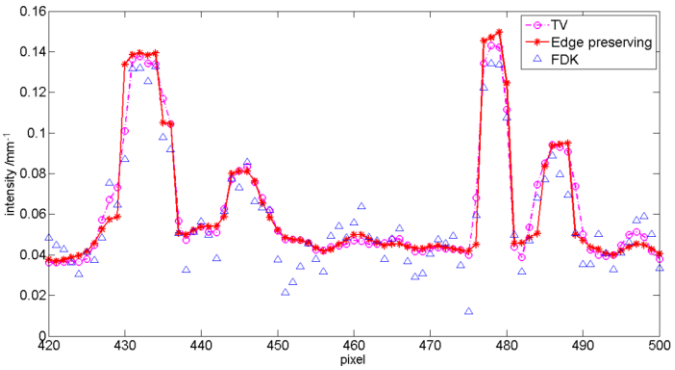


Figure 2: plot of profiles through specific region.

Reference:

[1] N. Mistry, et al, *Med. Phys*.40, 513(2013)

[2] L. Ouyang, et al. *Physics in medicine and biology* vol. 56, ed, 2011, p. 5535.

[3] J. Wang, et al., *Med Phys* vol. 36, ed, 2008, pp. 252-260.