Iterative Motion−Compensated Reconstruction for Image−Guided Radiation Therapy

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Purpose:

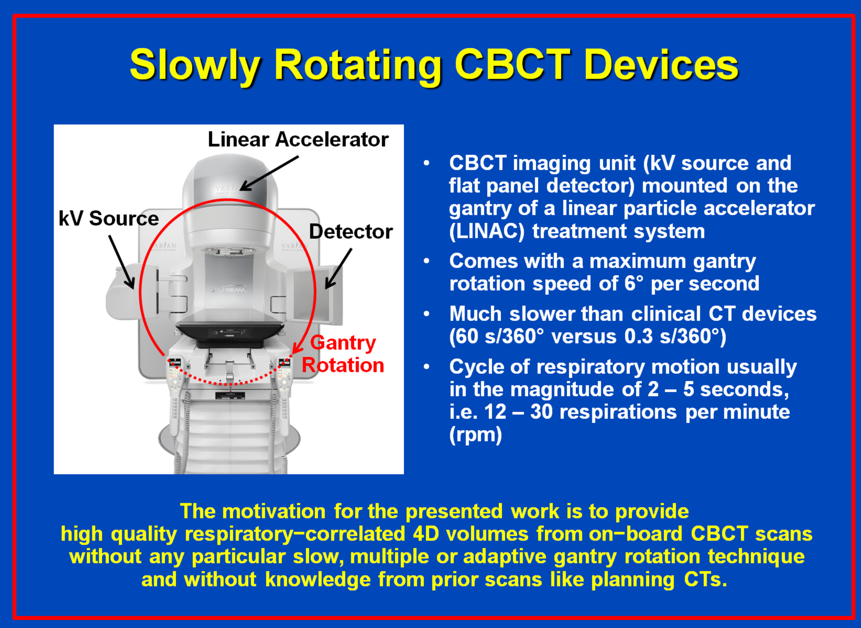
In Image−Guided Radiation Therapy (IGRT) an additional kV imaging system orthogonal to the linear particle accelerator provides information for an accurate patient positioning. However, due to the limited gantry rotation speed during treatment the typical acquisition time is much longer than the patient's breathing cycle resulting in low image quality. In particular, respiratory motion causes severe artifacts such as blurring and streaks in tomographic images.

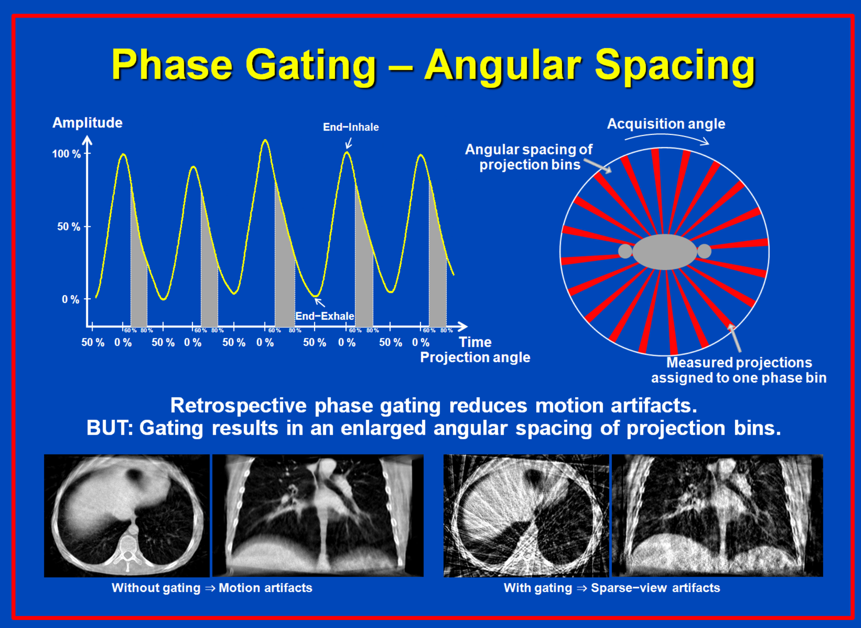
Compensating for motion is an interesting option and capable of providing high quality respiratory−correlated 4D volumes. Our purpose is to estimate the motion and compensate for it in case of 4D cone−beam CT (4DCBCT) scans and in particular 4D on−board CBCT scans for IGRT [1]. The particular challenge is to do this without knowledge from prior scans and without specific requirements on the acquisition as done in references [2,3].

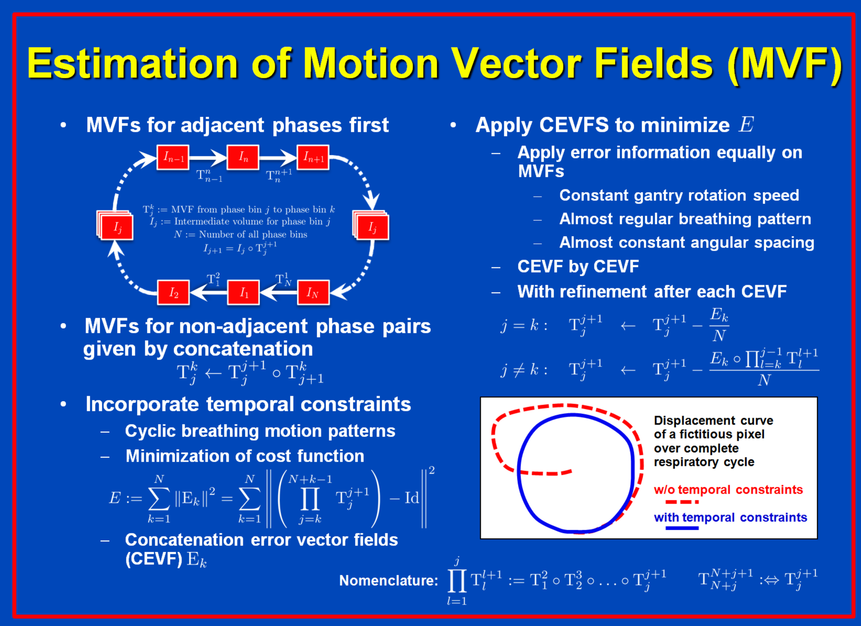
Materials and Methods:

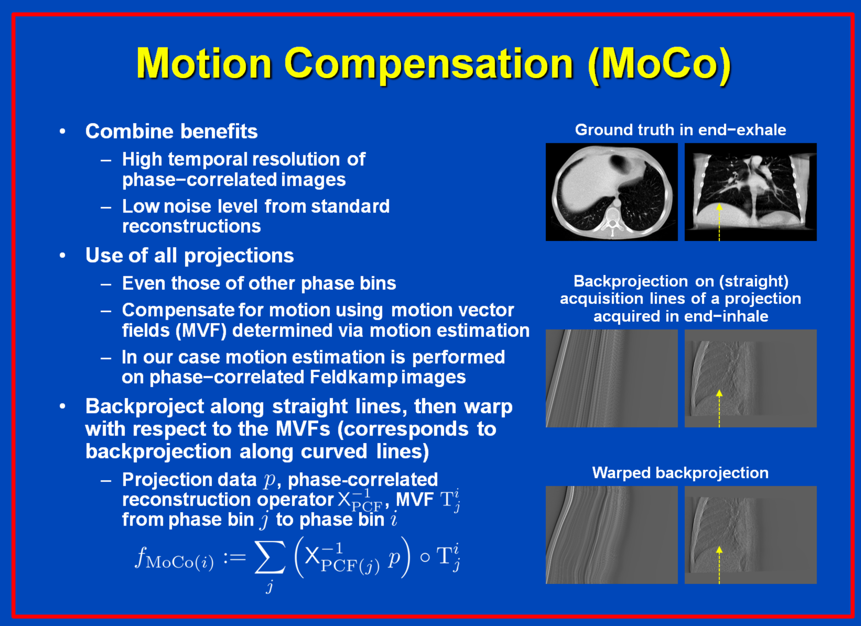
Standard CBCT reconstruction approaches, e.g. using Feldkamp algorithm [4], backproject all projection data without considering patient motion properly and thereby suffer from motion artifacts. Retrospective phase gating in case of 4DCBCT sorts the data into different sets according to the respiratory motion phase. Performing a separate reconstruction of each phase reduces motion artifacts, but results in artifacts due to an increased angular spacing. Thus, sparse−view artifacts and a high noise level deteriorate the image quality.

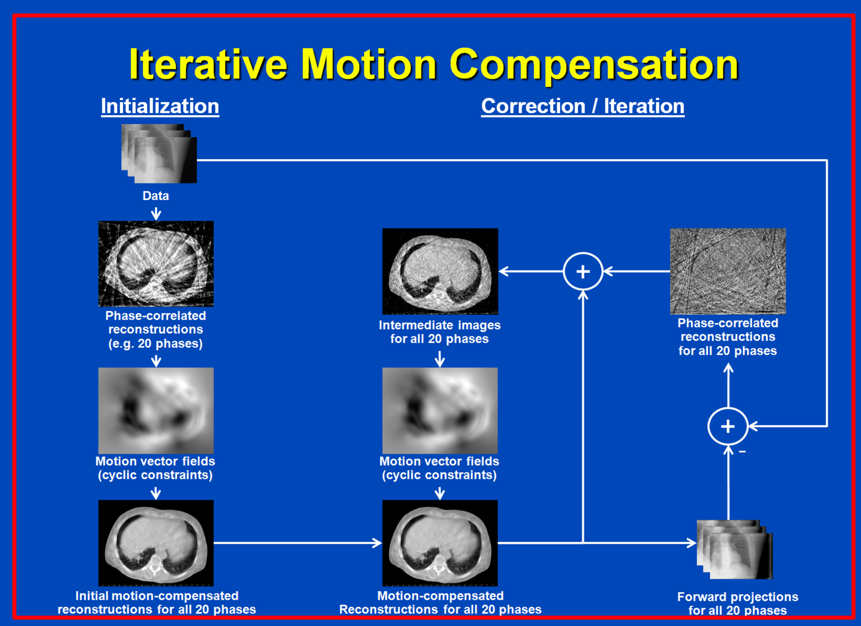
State−of−the−art methods for estimation of the motion vector fields suffer from the low sampling of the data and thus from image artifacts that appear in the reconstructions. In applications like ours conventional registration algorithms tend to register artifacts rather than anatomy. Our idea is to address this problem by a new deformable registration algorithm mainly based on a cyclic regularization that avoids the algorithm being sensitive to the above−mentioned streak artifacts. Our new deformable registrations algorithm consists of a spatial registration method [5] and a temporal correction part given by constraints like the cyclic motion patterns of respiration. A potential overcorrection by the temporal part is avoided by iterative refinement.

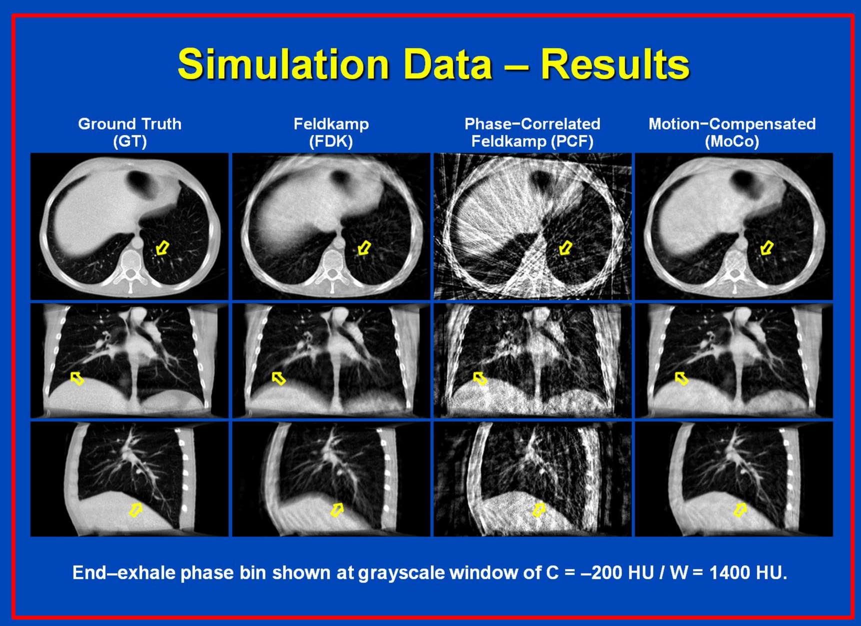


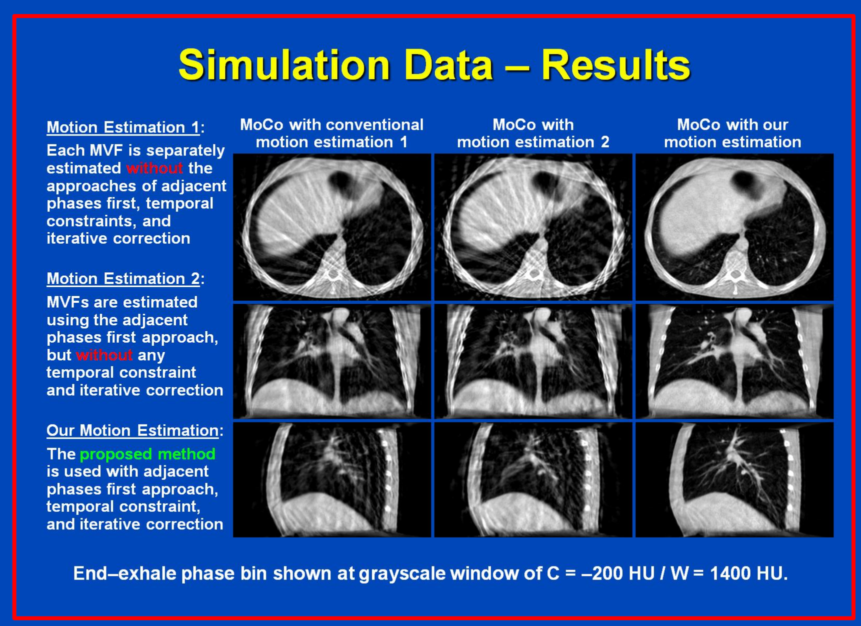


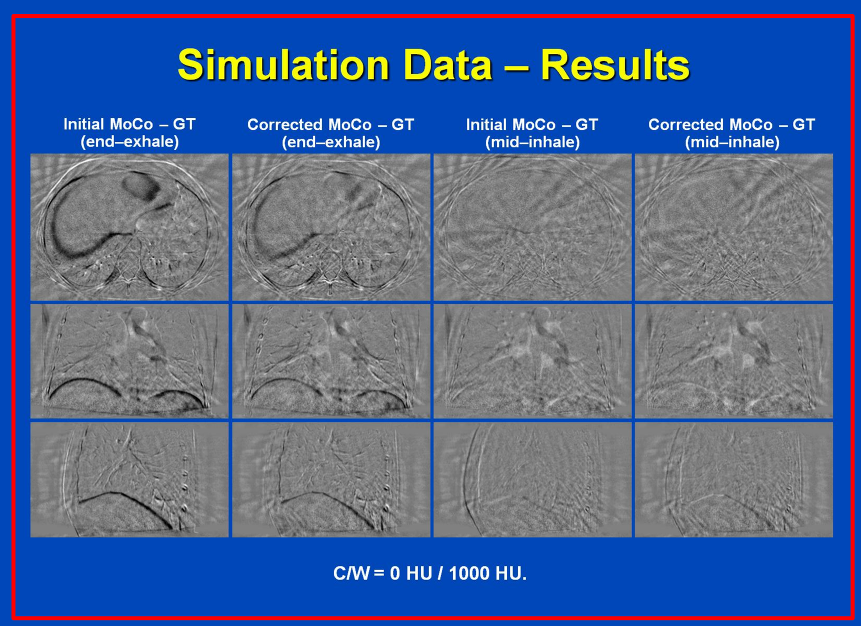


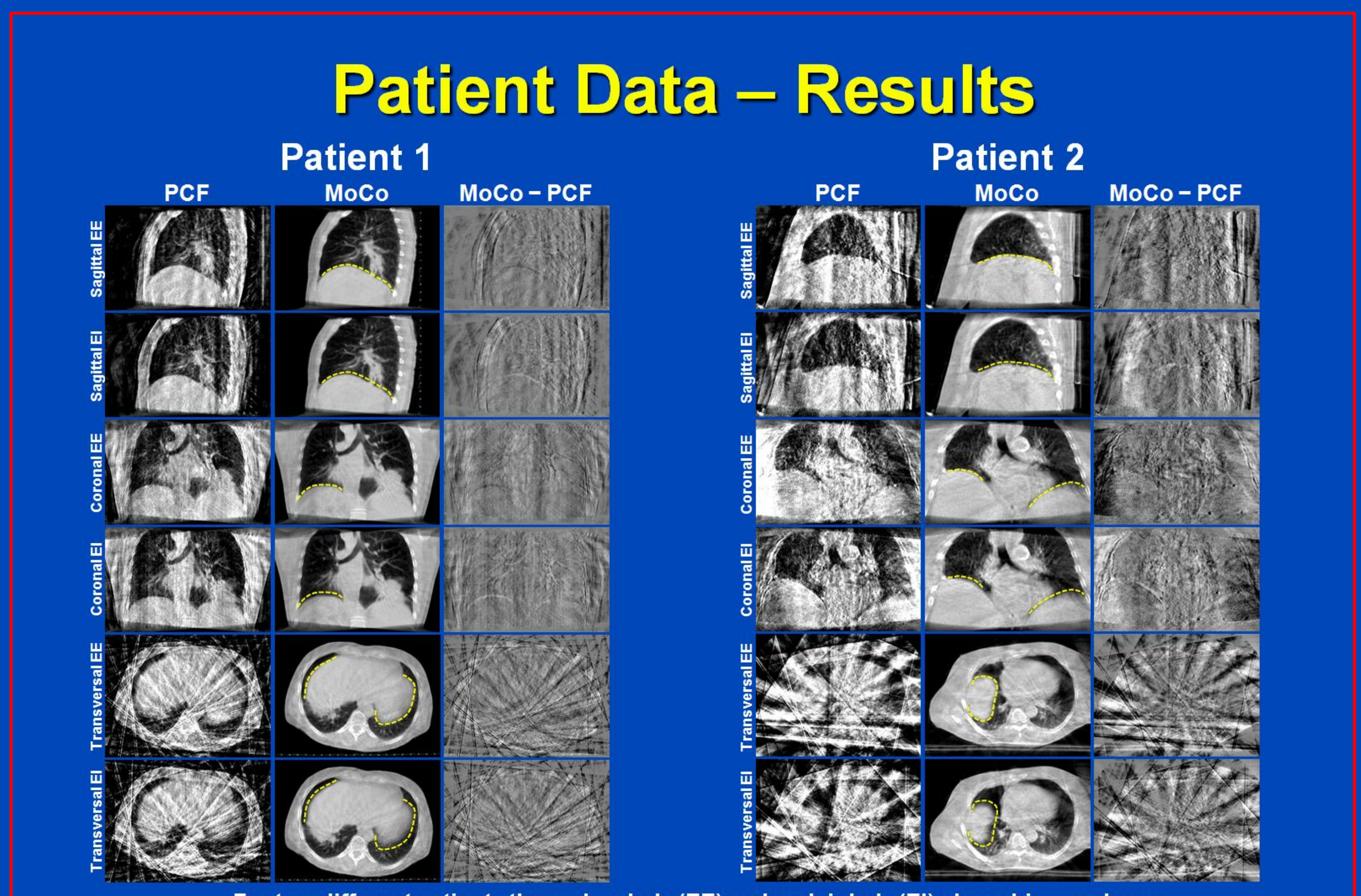












For two different patients the end−exhale (EE) and end−inhale (EI) phase bin are shown at grayscale window of C = −200 HU / W = 1400 HU. Difference images are shown at C = 0 HU / W = 2000 HU and the dotted lines mark edge positions in end−exhale.

Results:

The test set consists of synthesized data, obtained by deforming a clinical patient dataset, and patient scans including RPM information acquired with the On–Board Imager's® and the TrueBeam's™ integrated kV imaging unit (Varian Medical Systems, Palo Alto, USA).

The standard Feldkamp CBCT reconstruction results in a poor temporal resolution. The respiratory–correlated 4DCBCT reconstruction comes with a high temporal resolution and reduced motion blurring, but image quality is deteriorated due to the increased angular spacing of applied projections. Our motion compensation with cyclic motion estimation shows a good temporal resolution and highly reduced impact of few–view artifacts at the same time. The registration algorithm shows low sensitivity on image artifacts and is able to recover respiratory motion. Finer details like pulmonary vessels hidden by motion or streak artifacts become visible in motion−compensated images. The drawback of potential underestimation of motion in case of initial motion compensation is reduced by a correction step.

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