Advances in image acquisition and reconstruction now permit generation of temporally varying ("4D") models of periodic movement (e.g. breathing) in patients from a single session of scanning. In currently emerging commercial applications, the methods of data acquisition are generally through the use of fast slip ring CT scanners with single or multi-slice detectors, or through linear accelerator gantry-mounted cone-beam CT (CBCT) scanners. In conventional CT scanners, data are generally oversampled by either acquiring axial cine data over times beyond the expected periodicity of movement (e.g. 4-6 seconds for breathing) at each index of couch position, or via helical acquisition with a very tight pitch. For CBCT, the gantry is generally slowed down to increase the number of projections per rotated gantry angle (limited by the data acquisition rate of the imaging system) compared to what is needed for 3D static CBCT. To generate patient models at various phases of movement, a signal (either external or internal) of movement is used as an index. Example external signals for breathing include air volume measured via spirometry, and movement of the chest or abdominal wall assessed from axial CT data or external sensing of reflecting markers. Internal signals have been used especially in the reconstruction of respiratory-correlated cone beam CT (RCCBCT), in these cases based on features present in the projections (e.g. diaphragm position, tracked anatomic region position). Image processing algorithms make the selection of internal signal automatic. Data from conventional CT may be sorted in either image or projection space. RCCBCT involves sorting in projection space exclusively. With current 4D models, artifacts related to undersampling as well as (irregular) movement are still present to some extent. Further model based approaches, such as temporal regularization and iterative optimization, are currently under investigation to improve the quality of 4D CT.

Educational objectives:

1. Understand the methods of data acquisition for 4D CT
2. Understand methods of data sorting and reconstruction for 4D CT
3. Appreciate current challenges and research opportunities in generating 4D models