4D (Gated) Radiotherapy
A New Dimension of Confidence
Respiratory motion during a traditional CT acquisition can result in artifacts, such as blurring or ghosting, and may lead to misestimation of tumor size. As a result, healthy surrounding tissue may receive more radiation exposure than is necessary – sometimes triggering other treatment-related complications.

To address this problem, special CT hardware and software are used to acquire and reconstruct images at desired points during a patient’s respiration cycle. The use of this 4D CT technology can minimize or eliminate motion artifacts caused by respiration.

4D CT enables physicians to assess tumor motion as a function of respiration. One or more image series with a defined relationship to the breathing pattern can be selected for usage during treatment planning.

Respiratory Gated CT acquisitions generate 4D CT datasets, which allow better visualization and localization of tumors for improved management motion decisions throughout the entire radiotherapy process.

Methods and Material

The Siemens 4D CT solution includes a motion-tracking system (AZ-773V, ANZAI Medical) that monitors respiratory motion during 4D CT acquisition. The system employs a respiratory sensor, which is secured on a patient to detect changes in respiratory motion.

The load cell within the ANZAI system perceives the expansion of the thoracic cavity that results from the respiratory motion caused by pressure changes from the upward and downward movements of the chest and abdomen.

The analog signals from the respiratory sensor are converted to electric current and are multiplied at the sensor port and then transmitted to the wave deck. The signals are converted to a digital format and are ultimately transmitted to the CT control console.

Process Overview

- Chest abdominal belt with pressure transducer detects patient’s breathing motion
- Sensor port amplifies and transmits analog signals to wave deck
- Wave deck receives respiratory signal from the sensor port and converts it into a digital signal that is sent to the CT host computer
- CT acquisition data are synchronized with the respiration signal
- CT images showing respiratory motion are displayed
- Respiration event recognition, e.g., peak inspiration, expiration, cough, patient movement
4D CT Data Acquisition

During a 4D CT acquisition, the patient is encouraged to breathe freely while the respiration trace is recorded. Two different modes of 4D CT acquisition are available on most Siemens SOMATOM® CTs.

(1) Respiratory Triggering or Prospective Gating

Respiratory Triggering is prospective and involves the acquisition of a CT scan in the sequential mode. This is the simplest way to acquire a single volume at a given timepoint.

1. First, a timepoint (of the breathing cycle) is defined via a triggering device, e.g., the ANZAI system.
2. Then, a CT is taken when the patient breathing is at this exact point of the breathing phase. The result is one 4D CT dataset, which is at a specified timepoint (e.g., 100% of exhalation - blue arrows).
3. Several scans could be acquired at distinct timepoints of the breathing cycle to obtain several volume bin’s.

(2) Retrospective Gating

Retrospective Gating is the most efficient solution for simultaneously acquiring multiple 3D bin’s over large scan volumes. Multiple timepoints of respiration are imaged in approximately the same scanning time required to image a single timepoint in the prospective mode. Scanning parameters affect the quality of the datasets in retrospective mode: The X-ray tube, for example, should enable scanning for extended periods of time and temporal resolution should be optimized. Spatial gap between slices at successive respiratory cycles also should be minimized to improve the quality of the 4D CT datasets.

1. During a special RC-CT acquisition mode (spiral acquisition mode while the couch moves very slowly), the breathing curve is synchronized with the CT data upon initiation of the CT scan, so as to “time stamp” each reconstructed slice with the timepoint of the respiratory cycle.
2. The acquisition is completed when the entire target volume area is scanned. Points of interest along the respiratory curve are then selected, from which images are reconstructed.
3. Reconstruction of each bin’s volumes – the slices in the bin’s that correspond to a particular point in the respiratory cycle are combined to create a volumetric image.
4. The results are several 4D CT datasets that are all at specified timepoints, e.g., 10%, 20%, 30%...
Motion Assessment

InSpace4D™ provides an interactive and real-time 4D view of the full range of tumor motion during the breathing cycle. This information may be used to select the appropriate phases of the respiratory cycle in which to plan an accurate radiation treatment.

Evaluation – In Space and Time

InSpace4D – Real-time navigation through moving anatomy
- Automatically sorts the correct images into user-defined phases for each location
- Real-time 4D viewing functionality using volume rendering techniques to assess tumor movement
- Measurement tools that can be useful for margins calculation to eliminate or reduce margins due to respiration
- This information may be used to select the appropriate threshold levels of the respiratory cycle in which to plan an accurate radiation treatment

WorkStream4D™ – The reconstruction capabilities on a second console, the syngo® CT Workplace, allow maximum flexibility and more efficient use of the CT system – in particular for 4D datasets. No transfer is needed even for the GB of data that may be generated to represent full motion. The syngo CT Workplace is installed in parallel to the syngo Acquisition Workplace (main workplace). Both workplaces are connected via a shared database link. The combination of the CT system and the CT Workplace as a second workplace with a shared database is optimal for clinical environments with high patient throughput and workflow needs.

Clinical Benefits

Respiratory Gating CT and Respiratory Triggering CT contain hardware and software components for the visualization of anatomical structures and organs during respiration, allowing:

- High compliance of patients because free breathing capability ensures high patient comfort
- High acceptance of therapists due to easy operation and easy-to-learn user interface
- Exact reconstruction and respiration timepoints; sorting closest image not required
- Reconstruction and motion assessment possible within the planning department
- 4D registration of tumor motion
New Dimension in Treatment

In addition to 4D CT, Siemens offers a Gated Therapy Package, which allows treatment to be gated according to internal anatomy motion and opens a new era of treatment delivery. Using the Siemens 4D CT volumes, the physician can define the internal target volume with much more precision. Triggering the therapeutic beam offers broader possibilities in treatment delivery. Automatic gating of radiation during treatment via the patient’s respiratory cycle is also possible with the ANZAI system. With a gated option at the linear accelerator, the treatment beam can be automatically switched off at specific time points during a patient’s respiratory cycle.

The ANZAI system is used to capture and store the signal, which represents the patient’s respiration. With the respiratory gating function, the user can freely select the starting and end points of the treatment window based on the corresponding respiration amplitude.

Clinical Benefits

- Digital accelerator software upgrade allows automated gating of radiation beam based on the external trigger device
- Designed to turn on/off radiation using an input signal based on patient parameters, such as respiratory cycle or chest movement
- Accuracy in delivering gated segments as low as 1MU for PRIMUS™ and ONCOR™ Linear Accelerators
- Patient comfort
- Gating signal, trigger signal, and beam verification signal graphically displayed on ANZAI user interface for quick visualization and verification of gated treatment progress
- Increased ability to focus radiation on tumor mass and away from healthy tissue
- Optimized dose delivery by focusing radiation on tumor mass
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