

# Breathing adapted radiotherapy (BART) of breast cancer using a manually controlled CT scanner for dose-planning: a technical report

Mari Helene Blihovde Hjelstuen ([e-mail:hjem@sus.no](mailto:hjem@sus.no)), Gisle Olaussen, Ingvil Mjaaland, Johan Vikström, Aravinth Sivanesan, David Byberg, Birgitte Lura, Kristin Iversen, Vidar Bergersen and Kjell Ivar Dybvik.  
Department of Hemato-Oncology, Stavanger University Hospital, Stavanger, Norway.

## Background and Aims

Breathing adapted radiotherapy (BART) of breast cancer has been shown to reduce irradiation to the heart and ipsilateral lung when the radiation is given during deep inspiration. Several radiotherapy equipment manufacturers have developed systems to deal with BART. However, many CT scanners are not, or only partly, compatible with these systems. Particularly, deep inspiration breath-hold is a challenge to some systems or combination of systems.

Our institution installed the Varian respiratory gating system (RPM™) in September 2005. However, our CT-scanner (General Electric HiSpeed CTi) did not have an interface port for the RPM™-system to use as a scan trigger. We therefore had to use an alternative strategy to scan the patients to utilise BART.

This technical report describes how we carried out a manually controlled breathing adapted CT scanning.

## Patients and equipment

### Patients

BART will be used in the treatment of women with left-sided breast cancer stage II (i.e. with axillary lymph node metastases) who are referred for adjuvant radiotherapy after ablatio or lumpectomy (2Gy/fraction x 25 fractions = 50 Gy).

### CT

The General Electric HiSpeed CTi (single-slice) was installed in our institution in 1998. Thoracic CT scans for doseplanning are acquired in helical mode with a slice thickness of 3 mm. Both lungs are fully included in the scan volume.

### The RPM™-system

The Varian RPM™ (Real-time Position Management)-system consists of a video camera that records the vertical motion of an infrared reflecting marker placed on the chest wall of the patient, close to the xiphoid process. The motion of the reflecting marker is tracked and projected in real-time on a computer screen. A beam-on window in the breathing curve can be selected by placing two horizontal lines at the upper and lower amplitude threshold which specify when the beam should be turned on and off. In our institution the RPM™-system is mounted both on the CT and the linacs, as well as in a separate training room. Our GE CT is not communicating with the RPM™-system because it has no applicable interface port.

## Manually controlled CT scanning

### CT scanning

The breathing curve on the gating computer screen is used to visually guide the manual starting and stopping of the CT scanner repeatedly to make a complete patient scan. In practice this means that the CT operator is manually pressing the button to beam-on and beam-off position when the patient's breathing curve enters into and leaves the predefined beam-on window, respectively (fig.1 and fig.2).

The beam-on window is defined individually for each patient during a training session prior to the CT scanning. During this session the patient is in treatment position and is coached in the preferred breathing technique.

### Breathing technique for manual scanning

Our GE CT has a delay of almost 12 seconds after each manual stop before it is ready to scan again. It also takes some time before it starts scanning after pressing the beam-on button. This made it difficult to use breathing techniques with beam-on windows lasting only a few seconds (short duty-cycle), because the time to complete a full thoracic scan was very long. With a beam-on window of 4 seconds per respiration cycle it took more than half an hour to acquire a complete thoracic scan.

We therefore chose to use the deep inspiration breath hold (DIBH) technique for women with left-sided breast cancer. Figure 3 shows a typical DIBH breathing curve. We coach the patient to take a deep breath and hold the breath for 10-20 seconds. The longer the patient manages to hold the breath within the beam-on window, the faster the whole scan is completed. Due to the long delay time after each manual stop, we coach the patients to breathe normally for at least 15 seconds between each DIBH (fig.3). The whole thoracic scan is usually completed within 1-3 minutes. Newer CTs with multi-slice detectors provide complete thoracic scans when run in helical mode within 10-20 seconds, and the whole scan can be completed during one breath hold.

However, DIBH might be a challenge even to new multi-slice CTs that have an interface port for the RPM™-system. Some of them do not offer the option to perform prospective auto-triggered gating at all. Other CTs scan only during one detector rotation every time it is triggered when in axial mode. The benefit of a long breath hold is then lost.

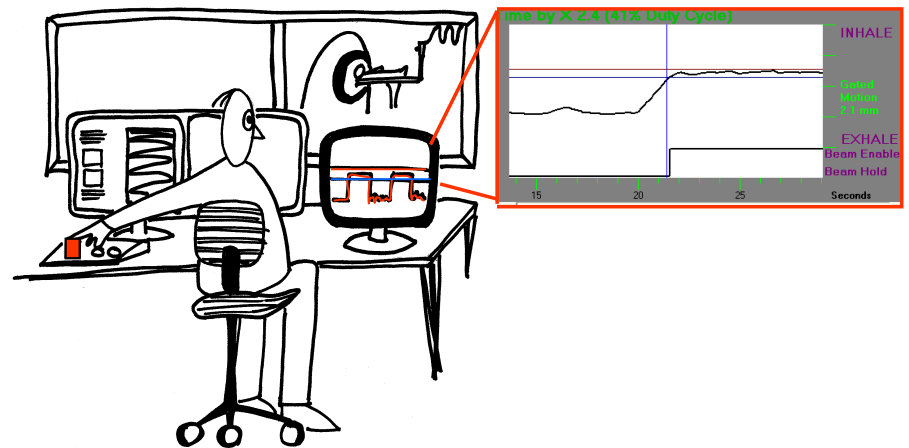
### Sagging of the CT table and visual coaching

Visual coaching is an advantage because it helps the patient to reach the selected beam-on window repeatedly. However, due to sag of our CT table i.e. vertical displacement of the CT table when it is moved towards and through the gantry, visual coaching became very difficult. The patients compensated for the increasing sag by gradually increasing their breathing amplitude.

The sag of our CT table was found to gradually shift the whole breathing curve 4-6 mm downward depending on the weight of the patient (fig.4). Because of this sag it is crucial to coach the patient to reach the same DIBH amplitude repeatedly without visual coaching. Verification of the DIBH amplitude reproducibility corrected for sag is always performed after the CT scanning.

Most newer CTs have negligible sag of the table which make visual coaching possible.

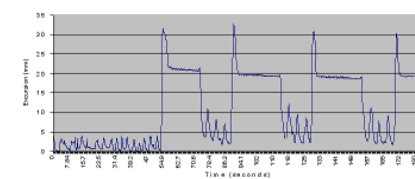
Figure 5 illustrates the benefit of using BART for women with left-sided breast cancer. The degree of benefit depend on the anatomy of the woman.



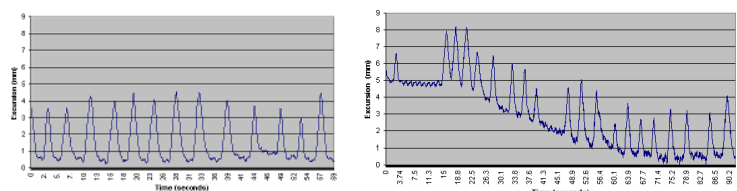
**Figure 1.** The CT operator is carefully watching the real-time breathing curve and is manually starting and stopping the CT scanning when the breathing curve enters and leaves the predefined beam-on window. The upper and lower limit of the beam-on window is shown by the red and blue horizontal line, respectively.



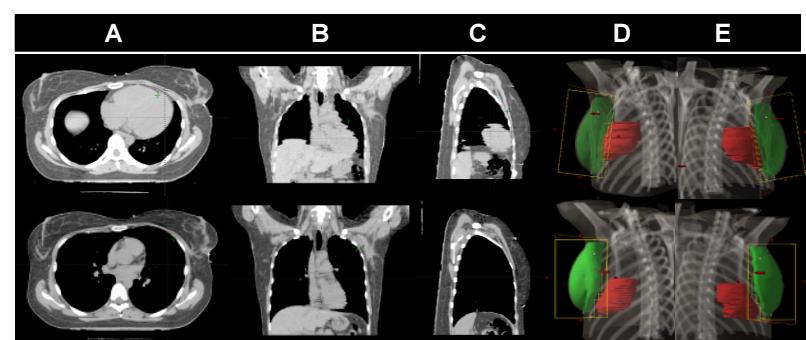
**Figure 2.** Manually operating the CT scanner demands a watchful CT-operator who starts and stops the CT scanner by looking at the breathing curve. Too early or too late beam on/off is easily seen as bulks in an otherwise smooth surface in a sagittal (left) or 3D body surface model (mid) view. If there are only a few slices acquired outside the beam-on window, these slices can be removed and an interpolation can be done (right).



**Figure 3.** A typical DIBH breathing curve used for manual CT scanning, with gaps of free breathing between each DIBH. For patients with amplitude peaks at the start of the DIBH, which is quite common when not using visual coaching, the CT was started when the amplitude stabilised. The DIBH amplitude is usually 15-22 mm.



**Figure 4.** A typical free breathing curve is shown in the left panel. In the right panel the CT table is moved the same distance as during a full thoracic scan. The free breathing curve is shifted downward due to sag in the CT table. The total vertical displacement is about 5 mm when our CT table is moved about 40 cm.



**Figure 5.** Transversal (A), frontal (B) and sagittal (C) views of the same patient during free breathing (upper row) and DIBH (lower row). The DIBH sections show a better organ visualisation compared to the sections taken during free breathing, due to removal of breathing artefacts. Most important, DIBH leads to a separation of target (breast/breast wall) and organ at risk (heart). The total lung volume was increased more than 2.5 times using DIBH (1479 cm<sup>3</sup> vs 3783 cm<sup>3</sup>). For this patient DIBH totally expels the heart from the beam portals (D and E), and relative heart volume receiving more than 25 Gy was reduced from 11.5% to 0%. The CTV/PTV were covered by the 95%/90% isodose, respectively.

## Conclusions

Even if a CT scanner has no interface for the RPM™-system it is feasible to manually control the CT to acquire a breathing adapted CT scan.

Breath hold techniques (DIBH in our case) is recommended when the CT delay time is long.

Manually controlled CT scanning might be necessary even with CTs that have an interface port for the RPM™-system if breath hold techniques are to be used.

Usability of visual coaching is correlated to the extent of CT table sag.