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White Paper

Advanced positioning devices for visual guidance in respiratory gated radiotherapy

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Introduction

Modern radiotherapy (RT) is characterized by increasingly complex treatment techniques aiming for high precision and effectiveness. The treatment of thoracic lesions still remains challenging, even with the advances of Image Guided Radiotherapy (IGRT). Target motion as well as the influence of respiratory motion to nearby Organs at Risk (OAR) have to be considered and taken into account for treatment planning and delivery. This uncertainty has driven further developments of respiration management procedures. Thus enabling high conformal, intensity modulated dose distributions in hypofractionated treatment regimes.
The main goal of gated radiotherapy is the reduction of planning target volume and sparing of normal tissue as well as the improvement in dose delivery accuracy by consideration or suppression of respiratory motion. Today there are several different respiratory gating systems commercially available. Their difference is based on the physical property of the underlying motion surrogate. There are gating systems based on spirometry like Elektas ABC System (Elekta, Stockholm, Sweden) or markerblock based systems like Varians Respiratory Gating for Scanners (RGSC) or Real-time Position Management (RPM, Varian Medical Systems, Palo Alto, California, USA). New approaches from third party vendors utilize marker-less optical surface scanning as a surrogate (e.g. C-Rad).
RGSC is in operation in our department and uses a markerblock which is placed on the chest of the patient and detected by an infrared camera mounted in the treatment room. This system correlates the chest movement with the respiratory movement of the lung and thus the target volume. For left-sided breast cancer patients Deep Inspiration Breath hold (DIBH) is recommended due to the fact that larger separation between thoracic wall and the heart can be achieved and thus dose to the heart can be reduced [1].

Figure 1

The original IT-V BreastSTEP (left) can easily be modified to enable visually guided DIBH. The integration of the mirror mount in the IT-V BreastSTEP (middle) serves as a full substitute for the conventional arm rests without demanding additional indexing space at the top of the treatment couch. (right) shows the possibility to use the modified IT-V BreastSTEP with the upcoming Visual Coaching Device on the TrueBeam platform.

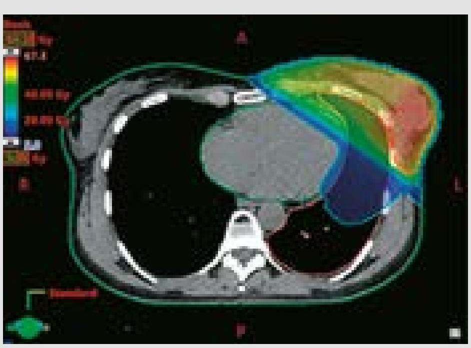
„With the integrative solution Patient set-up times remained unchanged“

According to recently published data by Darby et al the increase of significant coronary events is proportional to the mean dose to the heart during breast cancer radiation [2].
To achieve heart dose reduction, the patient is instructed to perform a deep inspiration for the duration of the treatment simulation and the delivery at one specified breathing amplitude. At present there is no visual feedback system for DIBH with the Varian TrueBeam LINAC and the RGSC System commercially available and patients have no feedback of their breathing amplitude apart from the acoustical commands of the radiation technicians (RTT) from the treatment console. The process of finding the predefined breathing amplitude is therefore an iterative one, involving the RTT giving commands to in- or exhale and the patient reacting to these commands. This lack of information generally leads to the treatment time being prolonged and the need for larger gating window widths.
Therefore the overall aim of this work is to improve patient comfort as well as to reduce the treatment time for respiratory gated radiotherapy in DIBH with the introduction of advanced positioning and feedback devices.

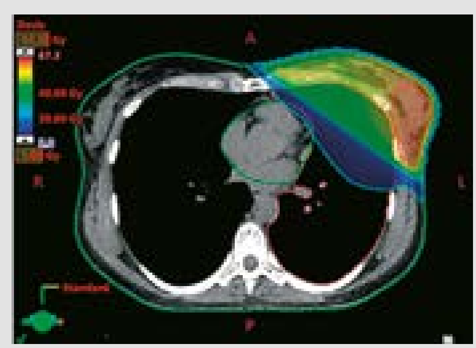
Figure 2

Dose distributions for a left sided breast cancer patient with simultaneous integrated Boost.
With free breathing the heart is partially inside the high dose areas as seen on the left side. With the help of DIBH and the visual feedback system shown in the middle, dose to the heart can be reduced without compromises in target coverage as seen on the right side.

Free breathing



Deep inspiration breath hold



Methods

There are several possibilities to present the visual feedback information to the patient. All systems have electronic devices in common that are in the direct vicinity of treatment beams. Also they require additional space beside the regular positioning devices. This leads to interruption of the clinical workflow and thus increases set up times for patient positioning. Based on our previous work, an easy to implement solution to provide the visual feedback prompt from the operator screen in the treatment room, was available **[3]**. Further information can be found following the link or QR code at the end of this paper.

For the representation of the feedback prompt a robust and integrative solution combined with the positioning devices for thoracal treatments like the IT-V BreastSTEP (IT-V, Innsbruck, Austria) is preferred. Automatic gantry rotations should not be hampered by obstacles like cables or tubes and the clinical workflow should not be affected adversely.

We conducted a monocentric study comprising of 20 breast cancer patients (19 left sided, one right sided) consecutively taken from the clinical routine. Different target volumes to be treated, ranging from the irradiation of the breast only, simultaneous integrated or sequential boost and the inclusion of lymphatic nodes were represented in the patient cohort. Ten patients were treated with acoustical guided (Group A) and ten with visual guided (Group B) feedback for DIBH.

All patients were positioned using the IT-V BreastSTEP as standard. Group A was treated under acoustical guidance of the operating RTT. Group B is based on a new workflow with a protoype armholder carrying a mirror. This enabled the patient to see a wall mounted monitor in extension of the treatment couch to display the feedback signal taken from the operator screen at the treatment console (Figure 4).

Figure 3

Overview of a Patient prepared for visual guided DIBH on a Siemens SOMATOM Definition CT with Varian RGSC. The IT -V BreastSTEP can be either equipped with the mirror solution with RPM or the newly available Visual Coaching Device within RGSC as seen on this picture.

To assess the performance of both feedback approaches, ARIA-database analysis has been carried out to extract treatment times excluding online positioning verification. For each patient, 15 fractions and in total 300 treatment fractions have been analysed. The Normalized Treatment Time (NTT) was defined by the ratio of gated treatment time and non-gated treatment time. This ratio represents the gated beam-on time in comparison to the pure beam-on time which is physically the shortest possible treatment time. A NTT value of two for example indicates that twice as much time as the pure beam-on time was needed for the gated treatment.
With this normalisation the influence of different treatment techniques, different dose prescriptions and different target volume constellations was eliminated.
All data points collected were analysed and potential fits were extracted as learning curves for both patient groups. The average NTT values were plotted and compared for both groups to assess differences in the acoustical and visual feedback systems, respectively (Figure 5).

Figure 4

Illustration of the visual feedback system in the treatment room equipped with a Varian TrueBeam. (A) IT-V BreastSTEP prepared for DIBH treatment. The visual feedback prompt is visible on the feedback monitor (B) and can be seen through the mounted mirror arm (A).

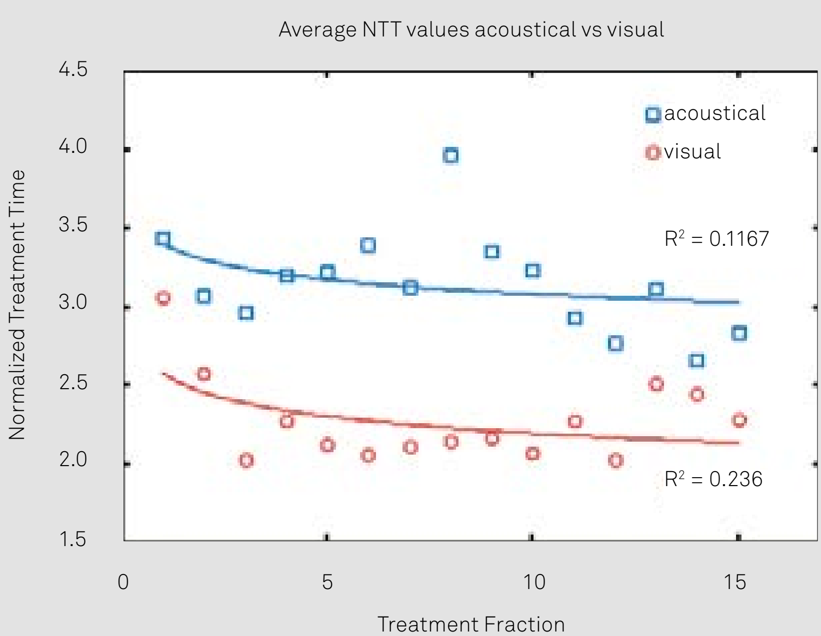
Results and Discussion

To increase the acceptance and comfort of DIBH gated treatments, appropriate feedback for the patient is crucial for the RGSC and RPM gating system. Complex respiratory data has to be interpreted by the RTT and converted into simple breathing commands. Consequently important information like the actual position of the breathing amplitude in real time is lost. This can lead to increased treatment times, discomfort for the patient and therefore increased intrafraction motion.
In this novel approach, the aim was to describe steps to enable an advanced feedback system for DIBH patients based on clinical experiences. A sophisticated mirror system enabled the patient to stay in the planned treatment position without compensation movement in the head and neck area which is especially important when lung or breast cancer patients are treated and lymphatic target volumes are included in the treatment. The integration of the mirror mount in the IT-V BreastSTEP provides several advantages. It serves as a full substitute for the conventional arm rests without demanding additional indexing space at the top of the treatment couch (Figure 1, comparison left and middle). It could be shown that the combination of the mirror and wall mounted feedback monitor is both reliable and robust in its run time. It is cost efficient, easy to implement and does not affect the clinical workflow negatively.
Based on statistical data of 300 analysed fractions, our study showed significant improvements in treatment efficiency for DIBH patients. The derived learning curves showed a constant difference in NTT of 30% from fraction five throughout the whole treatment course in favor of visual guidance (Figure 5).

Figure 5

This diagram shows the average values (n = 20) of Normalized Treatment Times of the acoustical guided Group A (indicated in blue) and the visual guided Group B (indicated in red) for 15 treatment fractions. All average values of Group B have been significantly lower ($p < 0.001$). Learning curves (solid lines) described by powerfits to the data, supported the assumption that after initial progress the learning ability converges to a certain saturation and that improvement stagnates with increasing fraction number.

"This allows a larger patient cohort to benefit from DIBH in the treatment of breast cancer in our department."



Treatment time reduction

Acoustical vs visual

-30%

When comparing the average values of each fraction for Group A and B, the NTT for Group B was significantly lower in all treatment fractions ($p < 0.01$).

For Group B the standard deviations were expected to be lower than for Group A. This can be explained by the unclear character of audial guidance and the dependence on instructions given by the RTT. The average decrease in standard deviation was 53% in favor for visual feedback and indicates a more stable breath hold procedure (Data not shown). Powerfits to the data supported the assumption that after initial progress the learning ability converges to certain saturation and that improvement stagnates with increasing fraction number. Lower treatment times and increased breath hold stability allows a larger patient cohort to benefit from DIBH in the treatment of breast cancer. In a recent study Bahrainy et al. showed that further treatment time reduction of 22% for breast cancer patients can be achieved with the use of high dose rate 6MV flattening filter free beams [4].

Conclusion

It could be shown that treatment times for DIBH were reduced with increased breath hold stability and repeatability. Through integration into the IT-V BreastSTEP patient set-up times remained unchanged. The system showed to be robust in its run time and provides a cost efficient way to implement visual guided DIBH. Our clinical experience with this system has shown that smaller gating window widths can be applied and that the CBCT workflow and image quality could be improved substantially.

This advanced positioning device and feedback system provides the possibility to safely expand visual guided DIBH to other treatments such as normofractionated lung cancer where possible advantages of visually guided DIBH are tested within the INHALE Study [5].

Thus enabling patient groups that previously have been considered ineligible for DIBH or even untreatable to benefit from visual guided DIBH RT and decreased treatment times.

References

[1] Boda-Heggemann J, Knopf AC, Simeonova-Chergou A et al. Deep Inspiration Breath Hold-Based Radiation Therapy: A Clinical Review. Int J Radiat Oncol Biol Phys. 2016 Mar 1; 94(3):478-92

[2] S. C. Darby, M. Ewertz, P. McGale et al. Risk of ischemic heart disease in women after radiotherapy for breast cancer. N. Engl. J. Med. Mar 2013, 368(11):987–998

[3] Jöst V, Kretschmer M, Georg D et al. Clinical implementation of an in-house visual feedback system for inspiration breath hold radiotherapy. Strahlenthera Onkol 2017, 193(Suppl.):111

[4] Bahrainy M, Kretschmer M, Jöst V et al. Treatment of breast cancer with simultaneous integrated boost in hybrid plan technique: Influence of flattening filter-free beams. Strahlenther Onkol. 2016 May; 192(5):333-41

[5] Gitte Fredberg Persson, Rigshospitalet, Denmark. Deep Inspiration Breath Hold as Primary Strategy for Locally Advanced Lung Cancer Radiotherapy (INHALE). www.clinicaltrials.gov/ct2/show/NCT02540499

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Further Information
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