A learning programme qualifying radiation therapists to manage daily online adaptive radiotherapy

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Accurate treatment delivery and correct patient positioning is important for the successful outcome of radiotherapy (RT). Today, most radical RT courses are delivered with online image guidance, using on-board imaging capabilities, such as cone beam computed tomography (CBCT) scanning for online (bony or soft tissue) anatomy registration. Daily variations in shape and size of, e.g. the bladder, changes in density of the lung, e.g. due to atelectasis and tumour shrinkage can be visualised using CBCT imaging. Following the introduction of image-guided radiotherapy (IGRT), this has spurred interest in exploring adaptive radiotherapy (ART) strategies, e.g. for bladder [1] and lung tumours [2,3].

Online image-guided ART requires radiation therapists (RTTs) with skills for analysing, optimising and evaluation of CBCT images used for bone or soft tissue matching. In a busy clinic, the time slots for imaging and evaluation must be at a minimum, and this is also important to reduce the influence of short-term internal organ motion (e.g. bladder filling) including tumour movement. Professional development of RTT skills for assessment of daily online ART have to be ensured, and multidisciplinary teams, responsible for defined areas, must be organised before clinical implementation [4,5]. Clinics organised with RTTs managing daily online ART on a large scale are limited, and only a few papers focusing on the achievement of RTTs skills for online assessment have been published [5–8]. To our knowledge learning programmes for management of IGRT and ART in large-scale and education in soft tissue match for lung cancer have not been presented. This paper therefore presents our experience from a learning programme with stepwise professional development of the qualifications of RTTs to manage daily online image-based decision making on a large scale, starting with IGRT for bony anatomy registration and followed by ART strategies for plan selection for bladder cancer and soft tissue match for lung tumours.

Material and methods

A virtual reality (VR) learning centre was established in 2007 in our department, including both an IT laboratory with a copy of the clinical software match-

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(Received 19 May 2015; accepted 11 June 2015)

ISSN 0284-186X print/ISSN 1651-226X online © 2015 Informa Healthcare
DOI: 10.3109/0284186X.2015.1062914

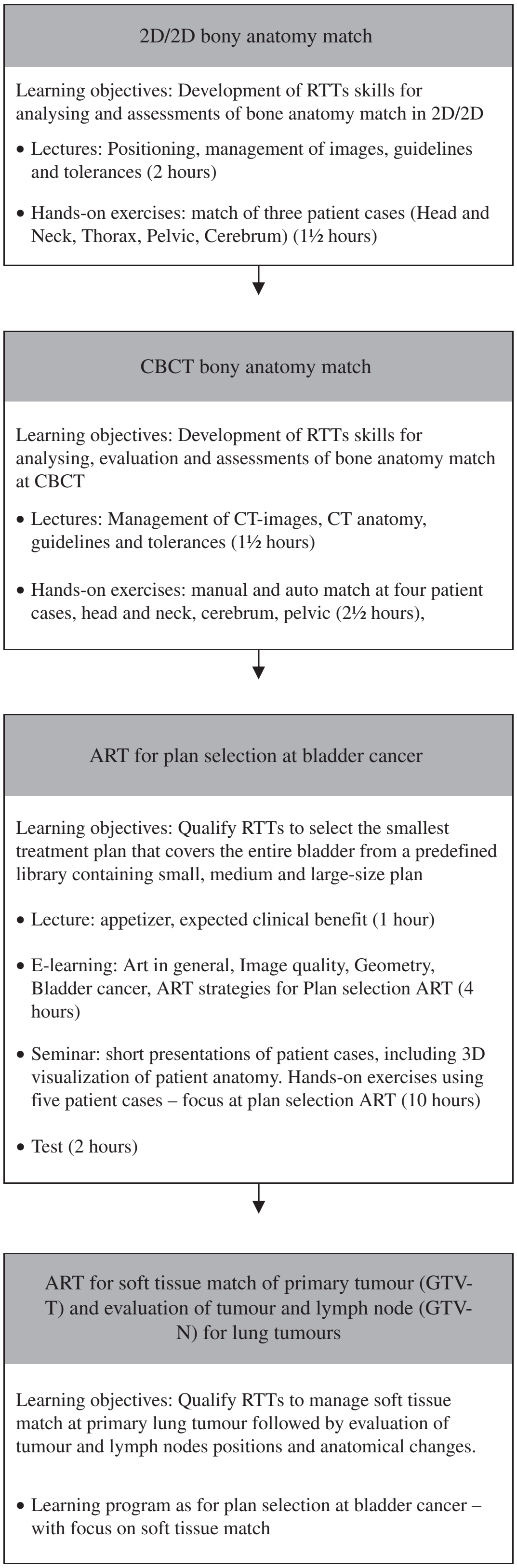

Figure 1. Learning programmes for 2D/2D, 3D CBCT and ART.

ing our clinic (Varian Medical System) as well as a three-dimensional (3D) accelerator (VERTUAL). In this centre, training can be scheduled without interfering with the clinical workflow [9]. In Denmark, professional skills for RTTs are based on a BSc degree as nurse supplemented with a one-year mandatory RT course. Concurrent professional developments of RTTs have been in focus; a course in quantitative research methodology and an interdisciplinary journal club attended by RTTs were established.

Image-guided radiotherapy - daily online bony anatomy match

A stepwise learning programme to improve RTTs skills for analysing and assessments of online bone anatomy match was set up, starting with 2D/2D and followed by 3D CBCT matching (Figure 1). Learning sessions were scheduled for groups of 6–8 RTTs, practicing on retrospective patient data [10]. Clinical implementation, at all linacs, was scheduled immediately after the last teaching lessons. Two dedicated RTTs acted as supervisors the first eight weeks, and a medical physicist was available in case of doubt. All 3D assessments for online match of 76 patients/1549 fractions (fx) (March 2009–April 2009) were evaluated retrospectively.

Adaptive radiotherapy – daily plan selection for bladder cancer

A systematic learning programme was developed before introduction of online plan selection of bladder cancer. Experience from courses in bony anatomy match was combined with e-Learning, followed the report from Foroudi et al. [5]. Fourteen RTTs were qualified to select online the smallest treatment plan that covered the entire bladder from a predefined library, containing a small, medium and a large-size plan. The learning programme included four parts: 1) A lecture, presenting the method for ART and expected clinical benefit; 2) e-learning sessions (LäraNära AB) teaching in ART strategies, geometry, image quality, bladder cancer and plan selection with an estimated duration of four hours; 3) Seminars with education based on retrospective data from five different patient cases were scheduled for 10 hours. The anatomy of the bladder, examples of various bladder shapes and volumes were presented in the 3D accelerator and adjacent organs were pointed out. The main part of the seminar time was scheduled for hands-on exercises in the IT laboratory, practicing plan selection several times and following the clinical guidelines; 4) A test with retrospective data from eight bladder cancer patients (including one patient with a catheter), a total of 196 CBCT's, concluded the learning programme. The RTTs were working in teams of two on data from 16 randomly chosen treatment fractions. Plan selections were assessed, and the duration of the decision making was measured. Scheduled time for the test was two hours. The selected plans were compared to a "gold standard" chosen by a dedicated physicist and a clinician. Subsequently test assessments were discussed with all students. Additional education was possible if needed (Figure 1).

Plan selections were further evaluated in a prospective study with 22 patients/555 fractions (December 2012–September 2014). All assessments were compared to an expert's selections. Time stamps for all fractions were collected from the Aria database (Varian Medical Systems). Match evaluation time (MET) was defined as the time from the last image was saved to the database until the delivery of the first field. MET for nine patients were acquired from the 2D/2D bony anatomy match (Marts 2008–March 2009), 33 patients from CBCT (June 2008–October 2010), and 22 patients with plan selection ART for bladder cancer (December 2012–September 2014).

Adaptive radiotherapy – soft tissue match for lung cancer

ART strategies for lung cancer were organised using the same template as for plan selection in bladder cancer (Figure 1). A group of 29 RTTs were educated for decision making. CBCTs from 22 patient cases were uploaded for hands-on exercises. A guideline for online decision making and tolerances had been developed in advance. The RTTs performed soft-tissue match on primary tumour and noted if deviations above a pre-set tolerance were observed for primary tumour, lymph nodes, spinal cord and mediastinum at selected fractions from each patient case, following the guidelines. In addition, normal tissue changes, e.g. appearance of an atelectasis or pleural effusion were registered. Three consecutive deviations indicated systematic deviations and should cause the student to require an offline review by a medical physicist. The test contained two fractions from each of six retrospective patient cases. To pass the test 80% of the scorings should be correct. Additional education and learning including a new test was planned if a participant did not pass the test. Two dedicated medical physicists and two dedicated RTTs evaluated the test.

All registrations for the first 50 patients/1550 fractions were retrospectively evaluated offline by one of the dedicated RTTs as follow-up. If a patient case with three consecutive deviations were not retrieved by the dedicated RTT at the offline evaluation, the online patient registrations were evaluated to be incorrect. Similarly, if three consecutive deviations were not retrieved online but offline, the registrations were evaluated to be incorrect. Time stamps for all treatment fractions were collected from the Aria data base. The learning effect was based at the total fraction delivery time, recorded as the time from loading the treatment plan until the end of treatment, when the plan was closed and saved in the database. Time consumption was calculated as a weekly average time per patient based at all ART soft tissues matches for lung cancer patients.

Results

Overall, the stepwise learning programme starting with education in online bony anatomy match and followed by two different ART strategies has resulted in RTTs with skills for management of daily online ART for bladder and lung cancer. The template with different pedagogic approaches for learning was found to be useful for these two different ART strategies. As e-learning and hands-on exercises preexisted, the programme was easy to reuse when a new group of RTTs had to be educated. A VR learning centre is a prerequisite for implementation of match strategies at large scale due to the comprehensive learning programme and the clinical work flow.

Implementation of online bony match was qualified by offline evaluation of RTTs assessments. All fractions with 3D CBCT were delivered within the tolerances of 5 mm deviations on the bony structures.

All 14 RTTs trained for plan selection for bladder cancer were accepted for clinical practice. Time used for selection of treatment plan in connection to the test was on average 2 minutes: 10 seconds (range 0:20; 5:31); the most difficult cases were patients with catheters. A prospective review of 22 patients/555 fractions showed that 11 fractions (2%) had a wrong plan selection (border of urachus especially for patients with catheter). The average MET time was 5 min:36 s (SD 3 min:40 s) for 2D/2D bony anatomy registration and 2 min:26 s (SD 1 min:43 s) for 3D bony anatomy registration, a difference that was statistically significant ($p < 0.0001$). For plan selection the average MET time was 5:20 (3 min:40 s). Clinical implementation did not demonstrate a MET learning curve, and the MET has not been reduced significantly subsequently.

For ART in lung cancer 22 (76%) of the RTTs passed the first test. The remaining seven RTTs had additional individual learning, where six (21%) passed a second test, one RTT (3%) passed a third test after eight weeks clinical supervision. Offline evaluation of the first 50 patients resulted in 54 cases, registered as systematic errors and retrieved as correct, in nine cases incorrect deviations were found and in 18 cases deviations were missed. For all other fractions, either no deviations were found or the deviations were not systematic. Systematic deviations were most common for lymph nodes and 91% of these deviations were scored correctly as deviations and 9% were missed. Deviations were also registered for the primary tumour, where 57% were scored correctly and 43% were missed, primarily due to a low contrast available in online evaluation. Finally, 88% and 80% of the changes due to atelectasis and pleural effusion respectively were scored correct. The average time for daily treatments at 3D bony match before implementation of ART was 23 ± 2 minutes. The total fraction delivery time increased initially to 36 minutes after ART introduction, but declined to 30 minutes in the first few weeks of implementation. However, after 11 weeks the time stabilised at 27 ± 1 minute, effectively increasing the treatment time by 4 minutes. A pronounced learning curve was demonstrated the first 11 weeks after implementation.

Discussion

A learning programme qualifying RTTs in large scale to manage daily online ART has successfully been developed. The stepwise learning programme starting with professional development of skills in online bony match has contributed to experience in match before implementation of two different ART strategies. The competencies have been developed over a period of six years.

For plan selection in ART for bladder cancer the RTTs should be able to identify the bladder on the CBCT and select the proper treatment plan from a predefined library. Off-line expert review revealed only 2% of cases with marginally wrong choice of plan, indicating that the learning programme was adequate for implementation of plan selection. Meanwhile the limited number of patients might be a problem when a large group of RTTs have to maintain the skills. Use of portfolio and audit as in the study of McNair et al. could be introduced [8].

ART for lung tumours requires skills to discern tumour, lymph nodes, and changes in anatomical structures. The ART strategy is different from plan selection and learning is quite complicated. The dramatic increase of total fraction delivery time the first weeks after clinical implementation, as well as the need for extra training for 24% of the RTTs after the test, suggest that the learning programme was insufficient for clinical introduction. Increase of hands-on exercises in the VR learning centre might have resulted in a smoother clinical implementation process with less time consumption for the daily treatments.

The learning programme was easy to re-use for staff returning after leave (e.g. for maternity) and if several RTTs need learning, e-learning and hands-on exercises were already prepared. Development of learning programmes with interactions of e-learning and hands-on exercises seems to be a good solution for education in advanced treatment modalities [7,11,12]. The template is expected to be used for implementation of additional ART strategies. Interdisciplinary teams were organised for the sake of the workflow. Subsequently, the teams reported a high degree of learning in cooperation with other professions.

In conclusion, a stepwise learning programme has resulted in sufficient qualifications for RTTs to manage daily online ART in large scale safely and with a moderate increase in treatment time.

Acknowledgements

The authors would like to thank Margit Andersen, Annette Schouboe, Anne Kirk, Christian Søndergaard, Eva Kjærsgaard, Jimmy Søndergaard, Lars Nyvang, Marianne Knap, Rune Hansen, Ulrik Elstrøm, Vincentia Nordentoft and Anja Andresen for their contribution to this work.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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