The MR-Linac – an adaptive treatment approach

Introduction

In October 2018, the first patient to be treated on a magnetic resonance linear accelerator (MRL) in Denmark was treated at Odense University Hospital. The MRL (Unity, Elekta) is a linear accelerator combined with a high-field 1.5 T MRI-scanner (Philips) (Figure 1). Together with an online adaptive treatment-planning system (TPS, MONACO), the MRL enables real-time MRI that provides high soft-tissue contrast during delivery of conformal treatments adapted to the visualised tumour and normal tissue (1). The improved visualisation can potentially reduce the treated volumes, which can decrease levels of treatment-related morbidity, facilitate radiotherapy dose escalation or enable delivery of the dose in fewer fractions. Furthermore, sites close to critical body structures that previously could not be treated are now treatable (Figure 2) (1).

Patient treatment workflow

In the pre-treatment workflow (WF), patients are simulated with both CT and MRI scans. The MRI scan is used for delineation and to create the reference plan. The CT scan is used to provide information on the electron densities needed for dose planning (upper part of Figure 3).

The online WF is depicted in the lower part of Figure 3. After the patient is positioned on the couch by the radiotherapist (RTT), the MR session is performed and the images are sent to the online TPS. An automatic rigid registration is executed between the reference MRI and the session MRI, followed by a manual adjustment by the RTT.

Depending on the clinical situation of the day, two different plan adaptation WFs are applied. The Adapt To Position WF (ATP) can be used if the target and organs at risk (OARs) do not differ greatly from the reference plan. By using the ATP, the shape and weight of beam segments in the reference plan are adjusted to match the current position of targets and OARs based on the rigid registration.

The second option is to Adapt To Shape (ATS), in which a new plan is created to match the anatomy of the day using deformable image registration for the contours. If necessary, these are manually adjusted by either the oncologist or the RTT.

In the plan adaptation, there is no correction in optimisation parameters for ATP. For ATS, intensity-modulated radiotherapy (IMRT) objectives are adjusted by the RTT to match the anatomy of the day. During plan adaptation, a second MRI scan is performed and fused with the adapted plan to visualise any clinically relevant changes. An oncologist evaluates the plan, and a physicist performs a secondary evaluation of the dose calculation relative to the reference plan before delivering the treatment. The treatment period varies for the two different plan adaptation WFs. The median session time for ATP is 26 min and for ATS 42 min (1). Currently the online treatment WF involves two RTTs, an oncologist and a physicist. In the long term, RTTs will manage the daily treatment, with the oncologist and physicist on call.

Patients treated on the MRL

Currently only patients with targets in the pelvic and abdominal region are referred for treatment on the MRL. A total of 63 patients has been treated and 609 fractions were delivered between October 2018 and October 2019. The target sites are listed in Figure 4. All patients undergoing treatment on the MRL are included in feasibility protocols prior to treatment to be able to record information about delivery time, patient compliance, and treatment side effects and outcome (2,3).

A PhD project, PRO-MR-RT, investigates the integration of electronic patient-reported outcomes (ePRO) in the course of MR-guided radiotherapy to evaluate the acute treatment toxicity and to personalise symptom management (4).

Patient experience

An important aspect of patient compliance during a treatment on the MRL is individualised patient information. The patient is offered both written and audiovisual information together with oral details from a RTT before the first treatment. The information

contains the WF during a single treatment, the patient positioning and MRI safety (Figure 5). During every treatment the patient is informed about the treatment progress by the RTT through the audio-communication system. If the patient experiences any side-effects due to the treatment, the RTTs at the MRL manage the symptoms before or after the treatment and, if necessary, consult an oncologist.

Data on patient experiences were collected from the first 19 patients treated with our MRL. All patients were allocated a performance status (PS) of 0 except for one patient with PS 2. All patients reported that the treatment couch and positioning were comfortable and the noise was easily tolerated. They did not experience any discomfort, dizziness or metallic taste and no anxiety was reported. They also found the treatment duration acceptable. No patient-related issues led to the need for repeated scans or interrupted treatments (1).

Training and collaboration

A new way of preparing and performing radiotherapy requires good cross-departmental collaboration. Training, sharing of knowledge and skills development have been at the forefront of work in the MRL team, which consists of physicians, physicists, technicians and RTTs.

References

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[4] Krause Møller PK. Systematic web-based patient-reported outcome measures for a personalized, patient-centered symptom management and clinical assessment of pelvic toxicity to magnetic resonance radiation therapy. Available from: https://open.rsyd.dk/OpenProjects/openProject.jsp?openNo=775&lang=en

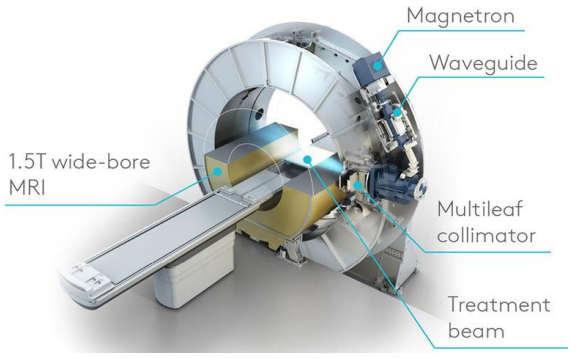

Figure 1: Unity by Elekta AB, Stockholm, Sweden

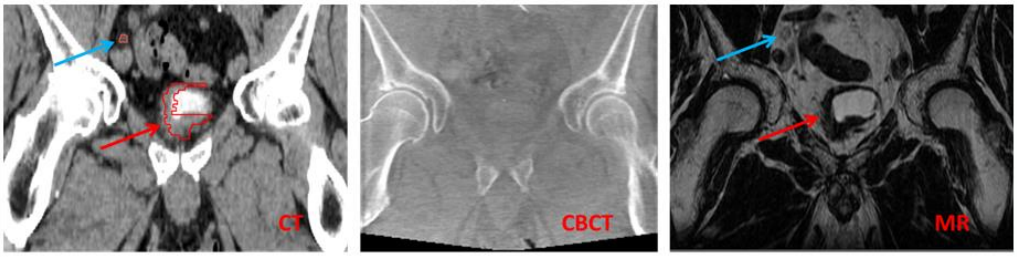

Figure 2: Scans of patient with bladder cancer: CT, cone-beam-CT (CBCT), which we use in image-guided radiotherapy on standard accelerators, and MRI from the Unity machine.

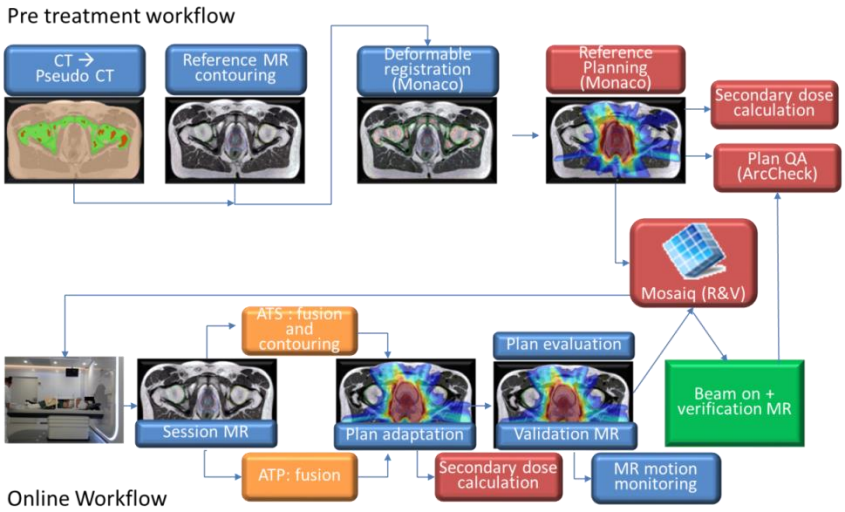

Figure 3: Flow chart for pre-treatment and online MRL workflow (1)**.**

Treatment site	Number of patients
Prostate	26
Bone SBRT	9
Soft tissue SBRT	11
Cervix (recurrence)	3
Pancreas (recurrence)	2
Bladder (boost)	1
Ovaries (actinic castration treatment)	4
Total	**63**

Figure 4: Overview of treatment sites at the MRL in Odense from Oct. 2018 to Oct. 2019.

Figure 5: Patient positioning at the MRL

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