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Technical Innovations & Patient Support in Radiation Oncology 13 (2020) 21–23

Contents lists available at ScienceDirect

Technical Innovations & Patient Support in Radiation Oncology

journal homepage: www.elsevier.com/locate/tipsro

Short communications and technical notes

Laser-free pelvic alignment in an online adaptive radiotherapy environment

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ARTICLE INFO

Article history:
Received 21 November 2019
Received in revised form 8 January 2020
Accepted 16 January 2020
Available online 17 February 2020

Keywords:
Laser-free
ART
MR Linac
Alignment

ABSTRACT

The MR-Linac (MRL) provides a novel treatment modality that enables online adaptive treatments, but also creates new challenges for patient positioning in a laser-free environment. The accuracy and duration of prostate patient set-up on the MRL using two different methods for patient alignment was determined to establish standard of practice on the MRL. Differences in set-up accuracy were significant in the longitudinal direction and are accounted for in online plan adaption. Both methods recorded similar set-up times. The vendor recommended alignment method involves less manipulation of the patient and will be adopted as the standard positioning method for prostate and other pelvic patients on the MRL in future.

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Introduction

Geometric accuracy in radiotherapy is affected by patient set-up errors, changes to the target volume and inter/intra fractional motion of the target, all of which can affect the dose distributions of treatments, causing significant changes from the pre-treatment plan. This is especially important in the use of advanced techniques such as intensity modulated radiation therapy (IMRT), arc therapy and stereotactic ablative body radiotherapy (SABR) where geometric accuracy is key to delivering treatment according to the planned dose distribution [1]. Patient positioning methods and immobilisation devices can help the patient maintain a stable and consistent position for radiotherapy treatment and planning, which is advantageous as it can reduce set-up errors and inter-fractional motion of both the patient and target [2].

The efficacy of immobilisation and patient set-up can be affected by the skill of the therapeutic radiographers/radiation therapists (TR/RTT) and the co-operation of the patient. It cannot be assumed that new set up methods will offer equal or superior patient positioning [2]. With the introduction of the MR Linac (MRL) (Elekta AB, Stockholm, Sweden) into the radiotherapy department a new standard of practice for patient set-up on this innovative machine was required.

The MRL provides a novel treatment modality that can be used to adapt a patient's treatment plan daily to account for positional errors and organ motion, but also creates new challenges for patient positioning and immobilisation. Unlike a conventional C-arm linac, the MRL couch cannot be adjusted AP or LR. The longitudinal couch position for treatment is a pre-determined value, created during the planning process. Once set the longitudinal position of the couch cannot be adjusted and positional errors are corrected during the online adaptive process. The two treatment options on the MRL are adapt to position (ATP), a virtual couch shift, and adapt to shape (ATS) where the target and surrounding organs are delineated and the treatment plan modified online to create an optimal solution for that fraction. The MRL requires the use of MR safe or conditional immobilisation equipment and is installed without calibrated lasers for patient alignment. The treatment machine comes with a vendor recommended method for patient set-up, which differs to our current departmental standard [2].

In this study we compare two patient set-up methods, both using the ATS workflow on the MRL. These are described in Table 1. Method A is vendor recommended and requires minimal manual manipulation of the patient. Method B is adapted from current protocol within the limitations of the MRL environment. In the absence of transverse or coronal lasers, rulers are utilised for tattoo

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https://doi.org/10.1016/j.tipsro.2020.01.001
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Table 1
Alignment procedures for set-up methods A and B.

	Method A	Method B
Superior-Inferior (SI)	Lateral tattoos aligned to the couch index by eye	Lateral tattoos aligned to the couch index using rulers
Right-left (RL)	Anterior tattoo aligned to sagittal indicator light	Anterior tattoo aligned to sagittal indicator light
Anterior-Posterior (AP)	Patient assessed for pelvic roll by eye	Lateral tattoos aligned with each other by measuring height from the couch top

alignment. This audit will compare patient set-up accuracy using the vendor recommended method against the adapted departmental standard. Both set-up methods will utilise the Combifix™ immobilisation device currently in use in our department, which is a combination of knee support and foot stocks that can be indexed for reproducibility. Treatment set-up times will also be recorded.

Methods

The audit was approved by the Royal Marsden NHS Foundation Trust audit committee. The first 10 patients treated for prostate cancer with 60 Gy in 20 fractions external beam radiotherapy on the MRL under the PRISM trial (NCT03658525) were included in this audit. Patients were set-up either using the vendor method (A) or department method (B) for fractions 1–10 and the alternate method for fractions 11–20, therefore acting as their own control. The method used for fractions 1–10 alternated between each patient. Patient position can change over time as the patient becomes accustomed to the treatment process, alternating the initial method used should help to reduce the effect of this on displacement results.

Patient displacement data in the right-left (RL), superior-inferior (SI) and anterior-posterior (AP) directions were collated from the Raystation® treatment planning system (RaySearch, Stockholm, Sweden) retrospectively using an in-house script according to the definition of set-up error [3]. Set-up displacement was recorded from the initial bone match rather than a soft tissue match to the target, to prevent the inclusion of any additional errors caused by internal prostate movement. Individual and population means (M) were calculated along with the population systematic and random error for patient displacement [3]. A two tailed T-Test was used to test for statistical significance. The time taken for patient set up was defined as the time between the patient entering the room and the first MRI scan starting and was tested for statistical difference using a Wilcoxon rank test.

Results

Both methods produced mean, random and systematic displacement errors within acceptable limits established in previous studies [2] (see Table 2). There was no significant difference between random and systematic error for the RL and AP directions. There was a significant difference in the SI direction in the M ($p < 0.01$) and Σ error ($p = 0.04$), with method A recording greater systematic set-up error (5.5 mm) than method B.

The population average set-up times of 4:02 min (set-up A) and 4:20 min (set-up B) were determined not to be statistically significantly different ($p = 0.139$).

Table 2
Mean (M), standard deviation (SD), systematic (Σ) and random (σ) displacements.

	RL (mm)	SI (mm)	AP (mm)
Method A M (SD) displacement	1.9 (3.9)	−0.3 (7.0)	0.9 (2.4)
Method B M (SD) displacement	2.6 (3.2)	2.9 (6.1)	1.2 (2.2)
Method A Σ displacement	2.3	5.5	2.2
Method B Σ displacement	1.9	4.8	2.1
Method A σ displacement	3.3	4.6	1.1
Method B σ displacement	2.8	4.1	1.1

Discussion

Both set-up methods were completed in a clinically acceptable time with neither providing a statistically significant reduction in set-up time. Overall treatment times on the MRL are unlikely to be affected by set-up method and therefore set-up time will not dictate which method is implemented on the MRL.

The significant difference in set-up accuracy SI between the two methods is likely due to the large SD and the difference in population means. Alignment SI to the couch index on the MRL using method A can be subjective and is likely to differ between TR/RTTs. All treatments included in this audit recorded SI displacements within the 5 cm system tolerance for online adaption and these were corrected online using the ‘adapt to shape’ workflow. No fractions of treatment required the patient to be re-set up. Though there is a significant difference in set-up accuracy SI between the two methods, both are within tolerance of the workflow and the subjectivity of SI alignment for method A does not impede accuracy of adapted treatments. Set-up accuracy in the RL and AP directions were comparable between the two methods, with no statistically significant differences. AP random and systematic errors though similar for both MRL set-up methods, were smaller than those from previous studies [2]. This is likely due to a reduction in displacements caused by couch sag on a standard C-arm linac, which are not present on the MRL.

Both methods A and B provided adequate set-up accuracy for MRL treatments, but the two methods do provide a potential variance for the patients’ experience through differing levels of manual handling. The vendor recommended method (set-up A) generally involved less manipulation of the patient and potentially greater comfort and tolerability. With this in mind set-up A would be a suitable method to adopt moving forward as it produced appropriate levels of accuracy and only differed in precision from set-up B in one direction, the benefits of which would be negligible considering the online adaptive workflow in use on the MRL. Further developments may allow for tattoo free treatments where the vendor recommended set-up method (A) could be further adapted to use anatomical surface anatomy to align patients.

Future considerations should be made as to whether laser free pelvic alignment could be incorporated into more radiotherapy situations. As online adaptive workflows and improved image guidance are being implemented into multiple machine settings, potentially the need for alignment using lasers for pelvic radiotherapy could no longer be required.

Conclusion

The MRL has provided us with new and exciting opportunities to verify patient positioning with MR and utilise MR real time imaging during radiation delivery, but has also created challenges in the way we align patients for treatment. Comparisons of patient displacements and set-up times were compared for two different methods of patient alignment on the MRL to determine an appropriate department protocol for pelvic patients on the MRL.

Set-up accuracy was comparable in AP and RL directions, but significantly different SI. These offsets were within tolerance for acceptable precision and can be corrected for using the standard

MRL adaptive workflow, therefore having no impact on treatment accuracy using the MRL. The two methods recorded no statistical difference in set-up times and therefore neither will benefit the patient by reducing overall treatment times. The vendor recommended set-up method will be adopted for prostate and other pelvic treatments on the MRL as it may be more tolerable for the patient and could therefore improve overall patient experience, without compromising treatment. Further investigations will be required to establish standards of practice for other body sites and additional investigations into MRL patient positioning and alignment may facilitate tattoo free workflows in the future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We acknowledge NHS funding to the NIHR Biomedical Research Centre at The Royal Marsden and The Institute of Cancer Research. The views expressed in this publication are those of the authors and not necessarily those of the NHS Executive. The Institute of Cancer Research is supported by Cancer Research UK Programme Grants (C33589/A19727 and C33589/A19908) and the CRUK ART-NET Network Accelerator Award (A21993); MRC Grant MR/M009068/.

Helen McNair is funded by a National Institute for Health Research and Health Education England (HEE/NIHR), Senior Clinical Lecturer award.

Alison Tree acknowledges the funding of the Rosetrees' Trust.

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