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An unusual case of oedematous prostate volumetric changes observed over the course of radiotherapy on the MR linear accelerator

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ABSTRACT

Introduction

The integration of magnetic resonance (MR) imaging into radiotherapy through new technology, including the MR -linear accelerator (MRL), has allowed further advancements into image guided radiotherapy (IGRT). Better soft tissue visualisation has led to some unusual findings.

Case and outcomes

A patient with T1c N0 M0 prostate adenocarcinoma received 60Gy in 20# radiotherapy on the MRL. Radiotherapy planning (RTP) scans were completed on both CT and MR (using T2 and T1 weighted three-dimensional turbo spin echo sequences, reconstructed transaxially (TRA). The MR scans revealed atypical oedema in the right peripheral zone, visualised on T2-weighted (T2w) MR Images as an accumulation of high signal intensity fluid. Daily MRL treatment includes a (T2w 3D Tra) sequence with which oedematous changes could be monitored. The images demonstrated an increase in oedematous volume over fractions 1–10 causing the prostate contour variations from the initial planning scans. Despite the prostate volume variations PTV coverage was never breached and dose constraints were always met for both PTV and surrounding organs at risk (OAR's), excluding the need for oncologist input.

A single Therapeutic Radiographer (RTT) experienced in MRL delivery, contoured the prostate and oedematous volumes on the radiotherapy plan (RTP) MR and all on-treatment MR images to assess change over the radiotherapy course. The initial volumes were 53.4 cm^3 and 8.3 cm^3 for the prostate plus oedema and oedema alone respectively. The most significant change was seen for both the prostate and oedema on fraction nine (68.0 cm^3 and 10.1 cm^3, respectively). Reductions were noted after this with final (fraction 20) volumes of 55.2 cm^3 and 0.58 cm^3 respectively.

Discussion

The ability to visualise prostatic oedema was new to the radiotherapy treatment team due to better soft tissue visualisation than standard radiotherapy. The results from contouring the prostate and oedema volumes confirmed radiographer observations and demonstrated how oedema impacted the overall prostate volume by quantifying the oedematous variations over time. The changes in oedema volume are presumed to be in response to radiotherapy.

Conclusion

Further adaptive radiotherapy work-flow developments, utilising an "Adapt to Shape" model will allow real-time re-contouring of the prostate to ensure tumour control is not compromised. Further work investigating the frequency and impact of oedemotous changes to external beam prostate patients will help to inform practice.

RÉSUMÉ

Introduction

L'intégration de l'imagerie par résonance magnétique (IRM) dans la radiothérapie par le biais de nouvelles technologies, notamment les systèmes d'accélérateur linéaire avec dispositif IRM embarqué (IRM-linac), a permis d'autres avancées dans la radiothérapie guidée par l'image. Une meilleure visualisation des tissus mous a permis de faire des découvertes inhabituelles.

Cas et résultats

Un patient atteint d'un adénocarcinome de la prostate T1c N0 M0 a reçu 60Gy en 20 fractions de radiothérapie IRM-linac. Des scans de planification de la radiothérapie (RTP) ont été réalisés à la fois par tomodensitométrie et par IRM (en utilisant des séquences tridimensionnelles d'écho de turbo spin pondérées T2 et T1 avec reconstruction transaxiale. Les scans IRM ont révélé un œdème

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atypique dans la zone périphérique droite, visualisé sur les images RM pondérées en T2 (T2w) comme une accumulation de liquide à forte intensité de signal. Le traitement IRM-linac quotidien comprend une séquence (T2w 3D Tra) avec laquelle les changements oedémateux ont pu être suivis. Les images ont montré une augmentation du volume oedémateux sur les fractions 1 à 10, entraînant des variations du contour de la prostate par rapport aux scans de planification initiaux. Malgré les variations du volume de la prostate, la couverture du volume cible de planification (PTV) n'a jamais été atteinte et les contraintes de dose ont toujours été respectées tant pour le PTV que pour les organes à risque (OAR) environnants, sans qu'il soit nécessaire de faire appel à un oncologue.Un seul radiographe thérapeutique (t.e.t.), expérimenté dans l'administration de l'IRM-linac, a tracé les contours de la prostate et des volumes oedémateux sur les images IRM plan de radiothérapie et sur toutes les images IRM en cours de traitement afin d'évaluer les changements au cours de la radiothérapie. Les volumes initiaux étaient respectivement de 53,4 cm^3 et 8,3 cm^3 pour la prostate plus l'œdème et l'œdème seul. Le changement le plus significatif a été observé pour la prostate et l'œdème sur la neuvième fraction (68,0 cm^3 et 10,1 cm^3, respectivement). Des réductions ont ensuite été constatées avec des volumes finaux (fraction 20) de 55,2 cm^3 et 0,58 cm^3 respectivement.

Discussion

La possibilité de visualiser l'œdème prostatique était nouvelle pour l'équipe de traitement par radiothérapie, en raison d'une meilleure visualisation des tissus mous que la radiothérapie standard. Les résultats du contourage des volumes de la prostate et de l'œdème ont confirmé les observations des radiographes et ont démontré l'impact de l'œdème sur le volume global de la prostate en quantifiant les variations œdémateuses dans le temps. On présume que les variations du volume de l'œdème sont dues à la radiothérapie.

Conclusion

D'autres développements en matière de flux de travail de la radiothérapie adaptative, utilisant un modèle « Adaptation au changement », permettront de redessiner le contour de la prostate en temps réel pour garantir que le contrôle de la tumeur n'est pas compromis. D'autres travaux sur la fréquence et l'impact des modifications oedémateuses chez les patients atteints du cancer de la prostate traités par faisceau externe contribueront à éclairer la pratique.

Keywords: Adaptive radiotherapy; Prostate; MR Linac; Oedema

Introduction

Image guided Radiotherapy (IGRT) utilises regular target and organ at risk visualisation to deliver accurate treatment, offering the potential to decrease target margins and enable dose escalation.[1,2] Modern linear accelerators are equipped with cone-beam computed tomography (CBCT) equipment but the relatively poor soft tissue contrast of CBCT images frequently increases the risk of anatomical matching errors.[3] The magnetic resonance -linear accelerator (MRL) enhances IGRT through use of the enhanced soft-tissue contrast of MR images[1,4] with no concomitant radiation dose. The MRL used for the case reported below was the ELEKTA Unity (Elekta AB, Netherlands) which combines an Elekta Linear Accelerator (Elekta AB, Netherlands) with a 1.5 T (1.5T) Philips scanner (Philips Medical, Best, The Netherlands).[5] The MRL has led to a unique emerging workflow and facilitated up-skilling and enhanced understanding of MR anatomy in the radiotherapy workforce. The case reported illustrates how enhanced anatomic visualisation of the MRL has led to some unusual findings.

Case and outcomes

A 79-year old man with T1c N0 M0 prostate adenocarcinoma was offered the standard of care treatment options of either external beam radiotherapy (EBRT) with 60Gy in 20# or watchful waiting and opted for EBRT. Following this decision the patient was offered MRL based radiotherapy as part of the MOMENTUM trial[6] and underwent both CT and MR imaging (using T2w- and T1 weighted three-dimensional turbo spin echo sequences, reconstructed transaxially) radiotherapy planning (RTP) scans. The MR simulation scans were undertaken on the ELEKTA Unity (Elekta AB, Netherlands), the 2 minute T2w three-dimensional turbo spin echo sequences, reconstructed transaxially is completed at this time point and is used each fraction for patient treatment. The MR scans revealed atypical oedema in the right peripheral zone, visualised on T2w MR Images as an accumulation of high signal intensity fluid.

This finding was new and concerning to the Therapeutic Radiographers involved in this case. Review of previous images revealed that this oedematous change had been noted previously and had remained unchanged so no further action was required. The MRL treatment workflow with repeated sequences made it possible to monitor the oedema through daily MR imaging throughout the course of radiotherapy as seen in Fig. 1. The workflow followed by the radiographers for this patient was the 'Adapt to Position' workflow described in Fig. 2. All scans were acquired using T2w three-dimensional turbo spin echo sequences, reconstructed transaxially (T2w 3D Tra). Contours delineated by the clinical oncologist using the RTP images were used for each fraction as part of this workflow. Volumes from the initial session MR acquired to complete the virtual couch shift from fractions 1–20 were contoured in the treatment planning system (TPS) Monaco used for Elekta Unity delivery (Monaco v 5.40.01, Elekta AB, Stockholm). These images demonstrated an increase in oedematous volume over fractions 1–10 which caused the prostate contours to vary from the initial planning scans. Despite the variation in prostate volume throughout the treatment, PTV coverage was never breached therefore dose restraints always met for both PTV and surrounding

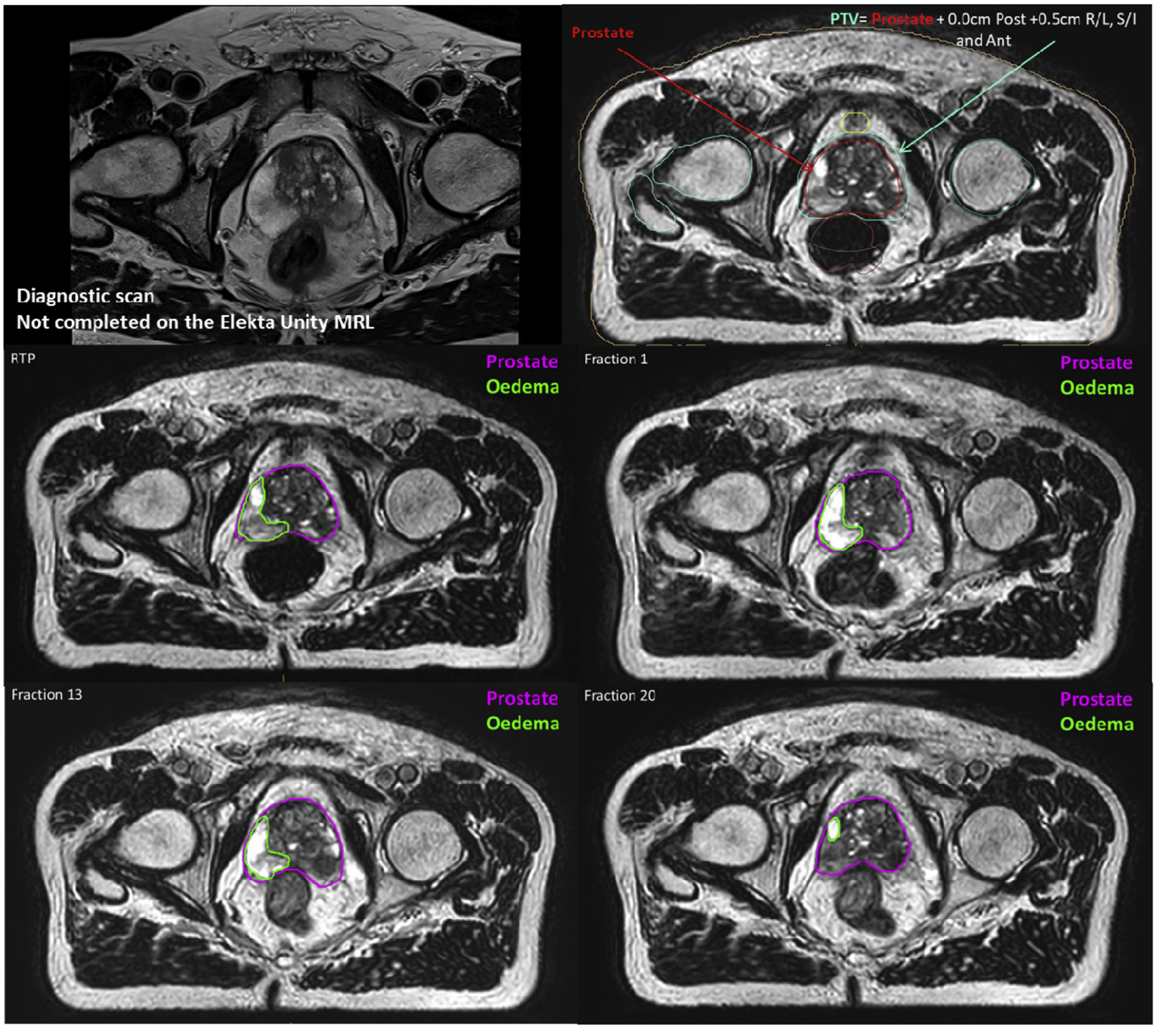

Fig. 1. Oedematous changes over course of radiotherapy.

Organs at risk (OAR's), excluding the need for oncologist input. During the final week of treatment the oedema reduced significantly to below the original oedema contour size but there was no significant change in the prostate volume (see Fig. 3).

A single therapeutic radiographer (RTT) experienced in MRL delivery, contoured the prostate and oedematous volumes on the radiotherapy plan (RTP) MR and all on-treatment MR images to assess change over the radiotherapy course. The initial volumes were 53.4 cm^3 and 8.3 cm^3 for the prostate plus oedema and oedema alone respectively. The most significant change was seen for both the prostate and oedema on fraction nine (68.0 cm^3 and 10.1 cm^3, respectively). Reductions were noted after this with final (fraction 20) volumes of 55.2 cm^3 and 0.58 cm^3 respectively.

Discussion and teaching points

The ability to visualise oedema within the prostate was new to the radiotherapy treatment team; the variation of oedema would not previously have been noted during conventional radiotherapy and has been possible due to the superior soft tissue contrast of MR imaging. The impact of the oedema on the clinical target volume (CTV) was determined after the conclusion of radiotherapy by volumetric analysis. Prostate and oedematous volumes were both contoured on the RTP MR and all on-treatment MR images. These results confirmed the observations of the radiographers and demonstrated how oedema impacted on overall prostate volume by quantifying the oedematous variations over time. Despite the variation in size of oedematous volumes no positional change was observed.

The changes in oedema volume are presumed to be in response to radiotherapy as both the RTP and diagnostic MR scans observed the oedema and throughout the first week volumes were consistent. There is paucity in the literature relating to this phenomenon, with publications mostly concerning oedema induced by High Dose Rate Brachytherapy (HDRB).[7] The overall prostate volume was greater at the end of treatment by 1.8cm^3 this could be deemed not significant as can be account for by contouring variation. However, this could be investigated further if similar results found

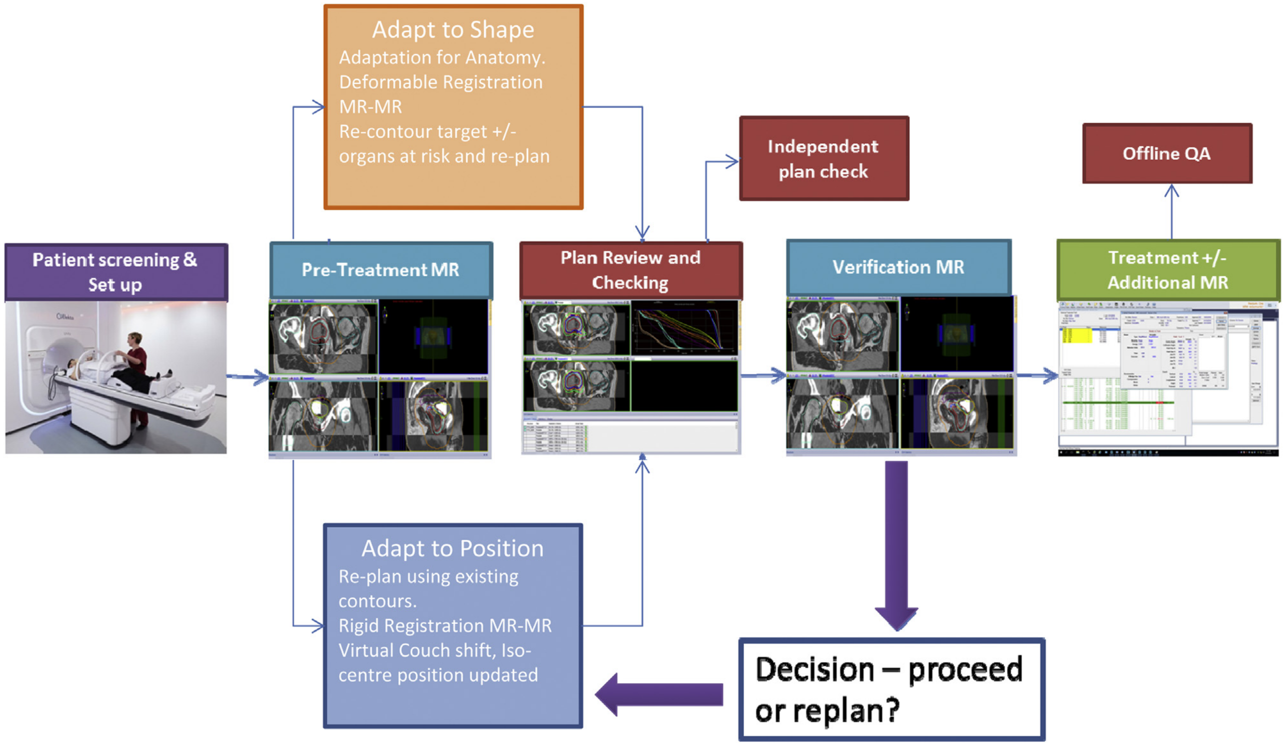

Fig. 2. MRL workflow overview.

within a larger data set as this could also be linked to radiation responses within the tissue.

Recommendations

Additional research is needed to identify the cause and any clinical impact of the oedemotous changes in IGRT prostate patients. It is likely that increasing use of the MRL will identify further occurrences and help determine the frequency of the changes. The relationship between oedematous change and tumour response could be explored using the MR-IGRT. The MRL can facilitate enhanced adaptive radiotherapy treatment through the 'Adapt to Shape' workflow which allows for daily re-contouring to adapt to any anatomical variation meaning more conformal treatment can be achieved which the aim to improve the therapeutic ratio (Fig. 2).

Conclusion

In this institution, prostatic oedema has only been observed in one of twenty-three men treated on the MRL. Further adaptive radiotherapy work-flow developments, utilising an "Adapt to Shape" model will allow re-contouring of the prostate to ensure tumour control is not compromised. Further work investigating the frequency and impact of oedemotous changes to external beam prostate patients will help to inform practice.

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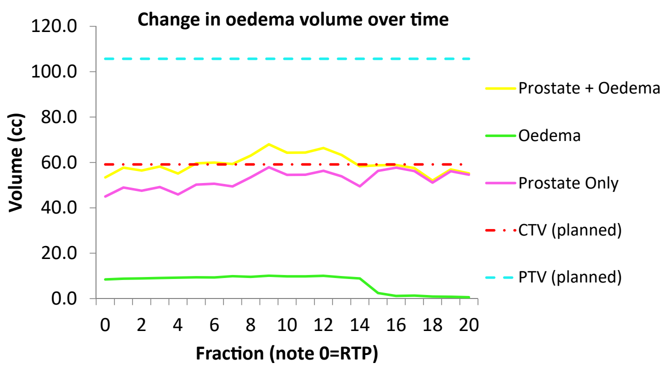

Fig. 3. Plot of prostate and oedema volumes over time from radiotherapy planning to end of treatment.

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