Cynthia Eccles

CoRIPS Research Grant 173

£10,000 awarded

Title: Validation and implementation of an MRI-only treatment planning pathway for proton and photon based radiotherapy outside of the prostate.

Principle Aim

To validate Magnetic Resonance for Calculating Attenuation (MRCAT) software and test the feasibility of the implementation of MRI-only radiotherapy planning and delivery pathways for patients undergoing radical radiotherapy to the pelvis using proton beam and MR-linac based treatments.

Primary research question

Can MRCAT provide a robust MRI-only planning solution for pelvic and head and neck cancer patients undergoing radical radiotherapy when compared to computed tomography (CT) based treatment plans?

Secondary research questions

- Evaluation of plan robustness compared to validated prostate plans for proton and photon beam MRCAT based plans?
- Feasibility of MRI-only treatment planning pathway for pelvis/head and neck patients undergoing proton beam radiotherapy
- Feasibility of MRI-only radiotherapy pathway for pelvis/head and neck patients undergoing photon beam radiotherapy on the MR-Linac

Outcomes

- Production of MRCAT based proton and photon plans with minimal (≤ 3%) variation from correlating CT based plans
- Development of MRI-only planning workflow for proton beam radiotherapy
- Development of MRI-only radiotherapy pathway for photon beam MR-linac based radiotherapy

Review of literature and identification of current gap in knowledge

In this modern era of radiotherapy, imaging for treatment planning for many patients requires both computed tomography (CT) and magnetic resonance imaging (MRI). The former for the electron density values required by most commercial treatment planning systems, and the latter providing superior soft-tissue contrast for tumour and normal tissue delineation. (1) (2) (3) (4) (5) (6) (7)(32)

Variation in target delineation can lead to errors with magnitudes exceeding those accounted for in daily treatment setup. (8) (9) (10) (11) (12)These in turn can have significant impact on both proton and photon radiotherapy in terms of reduced tumour control and/or increased normal tissue toxicity. (13) (14)

Studies have demonstated that MRI can reduce inter- and intra- observer contouring variations, resolve tissue boundaries not distinguishable on CT, and identify tumour not otherwise visible wtihoutht the use of intra-venous contrast. (15) (16) (17) (18) (1) However when used in a conventional radiotherapy treatment planning pathway, the co-registraiton of MRI to CT can result in registration errors that have been reported to be in the range of 2-3mm, depending on treatment site, adequacy of images acquired, image quality and user experience/expertise. (19) (20) (21) (22) (23) In light of this several groups have reported on the potential of MRI-only radiotherapy planning pathways. (24) (25) (26) (27) (28) (29) (30) (31)

The two greatest challenges of MRI-only planning pathways are the resolution of geometric distortions, and the production of a synthetic CT as electron densities required for dosimteric calculations as Houndsfield Units (HU) are not uniquely related to MRI signal as they are to CT intensties. As such, once satisfied that geomteric distortions are a minimum, a method of generating HU maps based on MRI signal must be employed. This can be achieved by voxel-based, atlas-based or hybrid methodologies. (38) (39)(40)

Several steps can be taken to minimise geometric such as imaging as close to isocentre as is feaible, increasing gradient amplitude and bandwidth, applying distortion correction matrices prior to final image generationand selecting pulse sequences with appropriate parameters. (33) (34) (35) (36) (37)

At present, only two vendors have clinically released MRI-only packages, which are validated soley for prostate cancers. Philips (Koninklijke Philips N.V., 2004 – 2019) and Spectronic Medical (Spectronic Research AB), have clinically released MRI-only packages specifically for prostate cancers. The Philips solution, MR-CAT is integrated in-line with MRI reconstruction software to generate synthetic CTs using a duo echo 3D mDIXON fast fised echo sequence and assigned bulk density values for air, fat, water, cortical and spongey bone. (31) (29) The Spectronic solution, MriPlanner, uses a T2w dataset to generate a synthetic CT using a statistical decomposition algorithm (SDA) described by Siversson et al. (30)

The benefits on MRI-only radiotherapy planning are not limited to the prostate. However with no clinically released products currently validated outside the prostate, we propose to undertake post-market validation and feasibility testing in tumour sites we are keen to treat on the MR-Linac (cervix and rectum) and with proton beam therapy. To do this we will undertake off-line radiotherapy planning studies using MRI data from patients undergoing radical radiotherapy to these tumour sites and compare the performance against the validated prostate pathway at our institution.

Methodology

This will be a prospective observational study of 40 patients undergoing radical radiotherapy to the pelvis or head and neck, who will be recruited from radiotherapy clinics at our institution and asked to undergo a single MRI session on the same day as their CT-Simulation for routine radiotherapy.

Patients included in this single site observational study will include 10 men with prostate cancer, 10 women with cervical (or other gynecological cancer) and 10 men or women each with rectal or head and neck cancers requiring radical radiotherapy. All patients will be screened for MRI contra-indications, and will be deemed ineligible for the study should they have any MRI contraindications.

An MRI- Simulation appointment will be arranged by the research team to take place immediately prior to or following routine CT-Simulation whenever possible. Patients will be imaged on the flat table top, in (or as close as possible to) the radiotherapy treatment position using the specific MRCAT sequence following a localizer and any other routine MR imaging required for radiotherapy planning. The MRCAT images will be sent to the secure radiotherapy planning systems used for proton beam and MR-linac based radiotherapy planning. They will be identified as research so as not to be used clinically. Tumour site specific radiotherapy treatment plans will be generated in these treatment planning systems using both the planning CT and MRCAT following departmental protocols.

Plan evaluations will include comparison between contoured targets and organs at risk on both the MRCAT and the conventional plan, as well as target and OAR doses from both the CT-based and MRCAT-based plans. As this is a feasibility study and the sample size is small in both the overall, and site specific sub-groups, analysis will be undertaken primarily using descriptive statistics.

Further to the dosimetric evaluations, the MRCAT generated plans for the MR-Linac will be transferred to the MR-linac record-and-verify system to test its feasibility in the online image guidance and plan adaptation workflow.

Patients treated on the MRL or willing to return for a single imaging-only session on the MR-Linac, will be asked to consent to the use of these MRI images to be used in the determination of the feasibility of a fully MRI-only radiotherapy pathway which will include registration of MR-Linac based images and a mock treatment delivery using the MRCAT based plan to interrogate MR-MR online image registration, and undertake a timing to study for comparison with standard of care radiotherapy delivery.

Potential impact

Although this is a feasibility study and will require further validation, it has the potential to be highly impactful to the patient and radiotherapy departments alike. Literature shows that MRI can be of benefit in target and normal tissue delineation for pelvic radiotherapy. Should the MRCAT sequence prove robust in pelvic radiotherapy planning outside the prostate it could potentially reduce the limitations of current MR-CT based methods, for example registration errors and a robust MRI-only planning solution could improve this further through the elimination of registration inaccuracies

The implementation of an MR-only radiotherapy planning pathway could also reduce the number of imaging sessions required by patients in radiotherapy thereby reducing the burden to the patient and costs to the department by eliminating the planning CT.

Additionally, to date the only commissioned MRCAT planning pathways are available for the prostate, this feasibility study has the potential to act as a catalyst for commissioning of MRCAT tools not only for other pelvic sites, but also outside the pelvis such as the head and neck or hepatobiliary-pancreatic or pediatric cancers which are truly under-served by CT-imaging.

In proton beam therapy this may prove a particularly useful tool as due to the dosimetric sensitivity of protons patients are re-imaged weekly or mid-treatment imaging to confirm the plan is still suitable or if re-planning is required due to changes in patient (e.g., weight loss) or tumour (e.g., shrinkage) providing a non-ionizing radiation alternative to CT, and again reducing interval radiation doses to patients.

In the MR-Linac, a truly MR-only workflow has the potential to improve speed and accuracy of image registration using like-for-like images at the time of treatment delivery.

Dissemination Strategy

We plan to disseminate the findings of this work in the following ways:

1. A post-market validation joint white paper with our industry partners Philips, who have developed the MR-CT sequence
2. Presentation at Society or Radiographers Annual Meeting 2021 and publication of workflow feasibility findings in radiography
3. Presentation at ESTRO 2020 and publication of findings in Radiotherapy and Oncology

We have budgeted £1800 for the registration and attendance at one national and one international meetings to disseminate the findings of this study.

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