Replacement of a CT-simulator with an MRI-simulator within a radiation oncology department

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Department's experience with MRI

The Radiation Oncology Department of the Calvary Mater Newcastle is one of the largest clinical and academic departments providing public radiation therapy in New South Wales (NSW), Australia. The department has five linear accelerators with over 2,000 new patient referrals in 2016 and approximately 30,000 annual linear accelerator occasions of service. As a major centre in regional NSW, the department offers advanced radiation techniques to regional and rural patients with stereotactic cranial radiosurgery, stereotactic ablative body radiotherapy, and gynecological brachytherapy. In 2016 about 60% of patients received complex conformal treatments with either intensity modulated radiation therapy (IMRT) or volumetric modulated arc radiotherapy (VMAT). It is also one of three major centres in NSW identified as providing pediatric radiotherapy.

In 2011 a MAGNETOM Skyra 3T MRI system (Siemens Healthcare, Erlangen, Germany) was installed in the hospital radiology department. As part of this installation the radiation therapy equipment that was required to operate the scanner as an MRI-simulator was purchased and commissioned. This included an external laser bridge for patient positioning (LAP, Lüneburg, Germany), a flat indexed detachable couch top and pelvic and head and neck coil bridges (Civco, Orange City, IA, USA). Previous to

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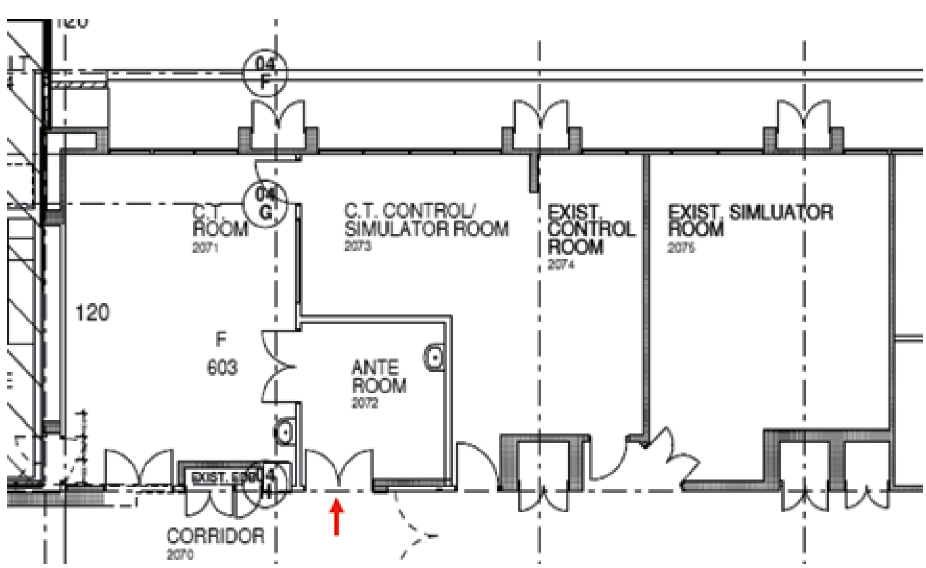

Figure 1: Existing configuration of two CT-simulators.

this, diagnostic radiology scans had been utilized for planning purposes. The availability of this scanner, albeit with limited access resulted in an increase in the use of MRI scanning for radiotherapy planning. The benefit of MRI scanning for many radiotherapy treatment sites quickly become apparent. Gynecological brachytherapy was transitioned to MRI only at that time. The department became one of the main drivers in Australia for the use of MRI simulation, MRI-only planning and clinical studies incorporating MRI.

Justification for a dedicated MRI-simulator

In spite of the benefits, restricted access to a busy radiology scanner meant that the department was limited to less than 10 patients per week for radiotherapy planning scans which were predominantly prostate, brain, cervix, spine and soft tissue tumors. Timely access to MRI scanning slots were by necessity limited as the radiology department must prioritize sessions for acutely unwell inpatients and routine diagnostic procedures. A further diasadvantage of utilizing a radiology MRI was that our patients were required to attend two separate imaging sessions (CT in radiation oncology department and MRI in radiology department) with time intervals of between 2 and 48 hours between them. This not only inconvenienced the patients and was disruptive to departmental workflows but the time interval between scans increased the possibility and magnitude of anatomical changes occurring between the two scans. In the majority of cases it was not possible to setup patients in the treatment position due to time and staff limitations. In addition access for the development of radiotherapy planning optimized scanning protocols or for research and development was very problematic.

The role of MRI in clinical radiation oncology and radiotherapy treatment planning is evolving and to adopt new and emerging practices it is necessary to have a level of control and access to MRI that requires it to be within the radiation oncology department.

It has been recognized that instead of the acquisition and registration of two separate imaging modalities CT and MRI, that an MRI-only process would have advantages to reduce costs, patient burden, and reduce registration induced systematic errors [1]. Methods to develop synthetic CT scans from MRI scans for MRI-only prostate planning have been developed [2]. Advances in the methods of synthetic CT generation and number of treatment sites is an active area of continued development.

MRI provides vastly superior soft-tissue contrast than CT for a large number of treatment sites including brain, head and neck, prostate, rectum, anal, pelvic sites, and gynecological treatments. This has been shown in multiple studies to reduce the inter-clinician variation in tumor delineation as well as to increase sparing of some normal tissues including the penile bulb for prostate cancer treatments. In addition to the the benefit of improved anatomical information from T1 and T2-weighted images, multiparametric MRI combining anatomical and functional MRI methods can increase the sensitivity and specificity of cancer detection and staging and also yield additional information about the cancer status, used to predict and monitor treatment response [3, 4]. This opens up the possibility of personalized treatment based on an individual's imaging profile for dose boosting or on-treatment response monitoring for treatment adaptation [5, 6]. There is also the prospect of improving imaging of tumor motion with MRI using both cine and 4D-MRI techniques that are currently under development.

Departmental MRI-simulator

In 2016 the decision was made to replace our two CT scanners due to their age. A multi-disciplinary working group was established comprising medical physicists, radiation therapists, radiation oncologists, a nurse, and a business manager. An initial recommendation was made to investigate if an MRI-simulator could replace one of the CT scanners. It was concluded that the installation of an MRI-simulator would meet the department's needs for MRI simulation by integrating the MRI within the department allowing improved access for patient scanning and development. A streamlined MRI simulation process would ensure that regional and rural patients would have timely and ready access to high-quality radiation treatment. In a single appointment a patient would undergo either an MRI simulation scan alone or both an MRI and CT scan. Our department felt that this recommendation was in concordence with the rapid increase in MRI utilization in radiation therapy as well as international recommendations. The recent Cancer Strategy 2015–2020 for England report that states "The greatest improvements in radiotherapy over the next decade will likely be driven by improvements in imaging technology" and their recommendation that "NHS England should support the provision of dedicated MRI and PET imaging facilities for radiotherapy planning in major treatment centres" [7].

MRI vendors were approached to assess if the space requirements were adequate for their MRI scanners given the current building construction and room space. All of the vendors approached confirmed that an MRI-simulator could be installed in the current space given some relatively minor modifications. This required engineering reports to determine which walls were load-bearing and could be modified and which could not. The room layout for the two existing CT-simulators is shown in Figure 1.

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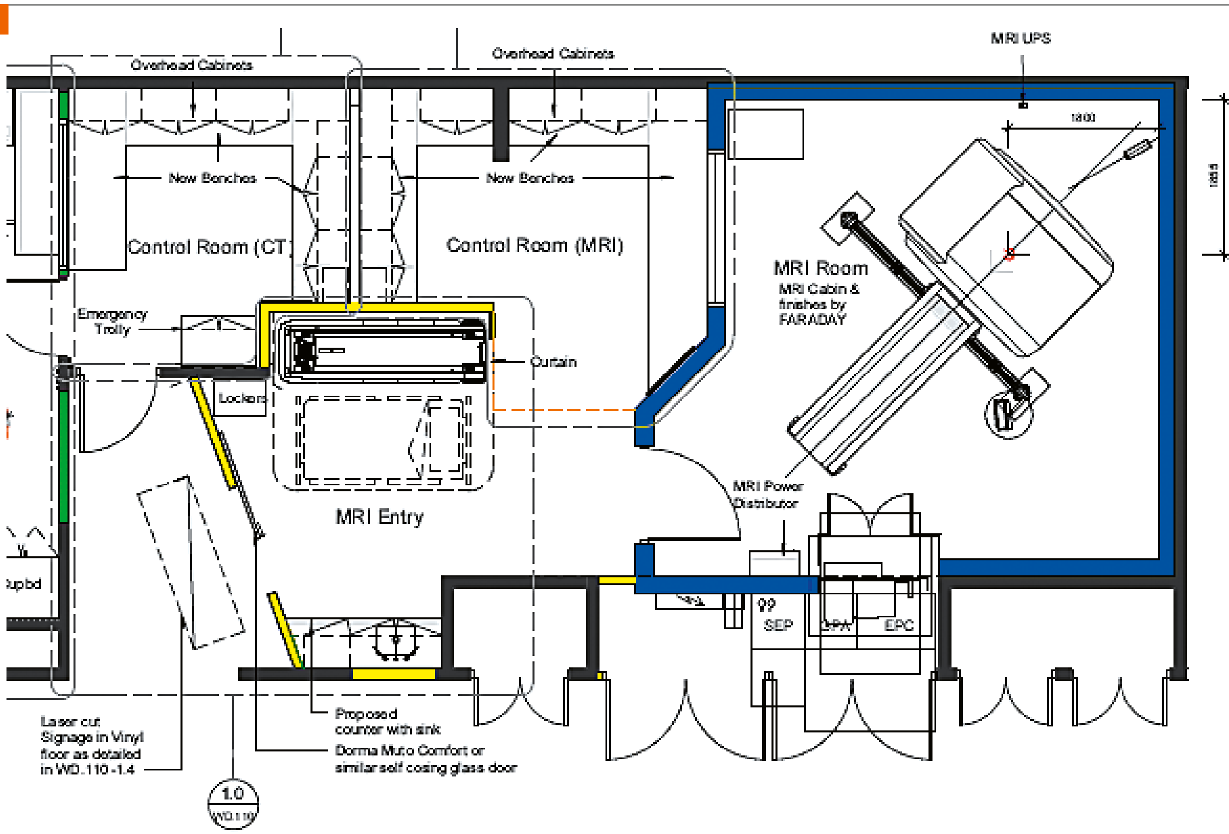

Figure 2: Concept plans for remodelling of area for a CT-simulator and an MRI-simulator.

While the two existing simulator rooms were relatively small, an advantage was the large control area that was shared by the two scanners and an ante room that was used for patient consults that gave some flexibility. However use of the space was restricted by existing load bearing walls, concrete cabinets housing supply infrastructure, and fire doors which could not be altered. This resulted in a single practical option for the placement of door access to the CT and MRI scanner control areas which has been shown with the arrow in Figure 1.

Following this, broader consultation was undertaken within the department where issues could be raised by staff and addressed by the working group. A major concern arising from moving to a single CT was addressed with a trial of a single CT to ensure that reduction in CT capacity could be managed.

Requirements

A technical specification (available on request) was made after consultation with other sites that had or were considering purchasing MRI-simulators. Site visits were also made to two existing centres with MRI-simulators.

With the implementation of a new MRI-simulator into the radiotherapy department where such equipment had not previously been housed the addition of specialist staffing was required. This included a dedicated MRI radiographer, MRI physicist, and part-time radiologist. These were included to ensure optimal MRI scanning and facilitate development and research into improved scanning techniques including MRI-only planning, functional (metabolic) scanning techniques for improved tumor visibility and assessment of treatment response, as well as scanning to measure tumor motion (4D-MRI) to ensure dose coverage of tumors. They are also critical to train other staff including radiation oncologists, radiation therapists, and medical physicists in MRI safety, technology, scanning, imaging features, and physics.

Concept plans

A plan was developed by Siemens Healthineers to enable the installation of the MRI-simulator in one of the CT-simulator rooms. Only minor structural modifications were necessary to the wall between the room and console area. For reasons of safety, the MRI suite is required to be in a controlled access environment.

The MRI suite design consisted of an MRI examination room, MRI control room, and prep room (Fig. 2). The design allows a single entry access to the MRI suite restricted to authorized personal via swipe card while allowing unhindered access to the CT console area. The suite provides an MRI preparation area including a patient change and transfer area. Access to the high magnetic field MRI-simulator room is via a second appropriately signed and secured door.

The project is being staged so that CT-simulator access is continuous. In the first stage the CT-simulator was replaced in Room 2071 (left) along with console area modifications. This allowed the second CT-simulator to continue clinically. Once this new scanner was operational the installation of the MRI-simulator commenced and it will be operational in April 2018.

Summary

Based on the clinical benefit of increased accuracy and taking a forward looking approach to our radiotherapy simulation needs, we have determined to replace a CT-simulator with an MRI-simulator. The inherent limitations of space and site configuration when adapting an existing area have been accommodated in the design. Ready access to, and control over the MRI-simulator will allow for the increased utilization of MRI in treatment planning, response monitoring and treatment adaptation.

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