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Research Letter

Safety and Feasibility of Magnetic Resonance Imaging Simulation for Radiation Treatment Planning in Pediatric Patients: A Single Institution Experience

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Purpose: This study aimed to report on the safety, feasibility, and workflow of using magnetic resonance imaging (MRI) simulation, while immobilized in the treatment position, for radiation therapy treatment planning in the pediatric population.

Methods and Materials: Between May and December 2017, 10 pediatric patients completed both MRI and computed tomography imaging simulation in treatment immobilization for radiation therapy planning for central nervous system disease. We report our initial institutional experience and workflow of the use of MRI simulation in immobilization for treatment planning in this population.

Results: Ten pediatric patients successfully underwent MRI and computed tomography imaging simulation for CNS disease. Two patients required anesthesia for sedation during the simulations. From our initial experience, MRI simulation was tolerated by all 10 pediatric patients without any safety or clinical issues, including those who required anesthesia.

Conclusions: Our initial experience supports the use of MRI simulation for radiation treatment planning in the pediatric population, with and without anesthetic sedation, as a safe and feasible image-guidance tool. This is particularly useful in the treatment of pediatric patients because MRI simulation enables superior, soft-tissue, anatomic imaging for a more robust delineation of organs at risk and target volumes without increasing radiation exposure.

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Introduction

There is a growing interest in the use of magnetic resonance imaging (MRI) in radiation therapy (RT) treatment planning across all disease sites and patient populations. In many radiation centers, diagnostic MRI is integrated by co-registering diagnostic, anatomic MRI scans with RT simulation computed tomography (CT) images to facilitate the delineation of the target volumes and organs at risk (OARs). Although these MRI sets can be imported and provide useful information, differences in patient positioning, plane of image acquisition, and image acquisition protocol can introduce discrepancies in the spatial representation of the tumor and OARs that cannot be completely addressed through co-registration. MRI simulation platforms that include tabletops with indexing capability, external laser-positioning systems, and MRI compatible immobilization have been created to allow for the improved integration of MRI in RT planning.[1] These hardware solutions, in combination with the optimization of imaging protocols to ensure spatial accuracy will result in the best-quality MRI scans for target and OAR delineation for RT planning.

Radiation treatment for central nervous system (CNS) disease in the pediatric population presents a unique set of challenges, and many patients require general anesthesia or sedation for both simulation and treatment. Therefore, having a workflow to streamline the integration of MRI simulation within this process for both efficiency and safety is necessary.

The safety and feasibility of integrating MRI simulation in the treatment planning of pediatric patients (who often require anesthesia) is unknown and, to our knowledge, has not been previously published on. Therefore, the aim of this study is to report our initial institutional experience of the use of MRI simulation for RT treatment planning in this population.

Methods and Materials

This retrospective analysis was performed with an institutional review board–approved protocol. Patients were included if they were between the ages of 3 and 8 years, had been previously diagnosed with a CNS malignancy, and were scheduled for both CT and MRI simulation for RT. The clinical endpoints included the safety and feasibility of MRI simulation in the pediatric population, both with and without the use of general anesthesia for sedation. Safety was defined as the prevention of harm to patients by freedom from accidental or preventable adverse events.[2] Feasibility was defined as the successful completion of both CT and MRI simulation within the scheduled appointment time, by trained therapists, and with minimal interruptions.

Results

Between May and December 2017, 10 patients who ranged in age from 3 to 17 years were scheduled to undergo both CT and MRI simulation. All patients were treated with proton therapy. Two patients required general anesthesia for sedation during both MRI and CT simulations.

Simulation workflow with and without anesthesia support

Simulation preparation

Figures 1 through 3 outline the details of the workflow. Venous access was obtained via port-a-cath or peripheral intravenous placement in preparation for gadolinium contrast. Patients met with our child life specialist, who prepared the child for the simulation experience by encouraging them to engage all their senses to become familiar with the procedure.

Nonanesthesia case

Computed tomography simulation. The patient presented to the CT simulation room with their caregiver and child life specialist, who remained in the CT room to assist during the immobilization. Immobilization was accomplished with a thermoplastic mask and bite block, and the patient was placed on the carbon fiber fixation board. CT images were obtained, and photographs were taken of the set up.

After the CT simulation, patients ambulated to the MRI simulation suite. A time out and safety check was performed by the therapist and treating radiation oncologist to ensure the patient and the immobilization devices were MRI compatible.

MRI simulation. Once all team members were in agreement to proceed, the patient was positioned on the table and re-immobilized in the aquaplast mask on the MRI-safe acrylic fixation board. Two, 4-channel flex coils were placed around the patient's head, and the treatment team left the room.

Finally, our standardized brain MRI simulation protocol was acquired: precontrast T1-weighted, T2-weighted, FLAIR, diffusion tensor imaging, and T1 postcontrast sequences. Further details regarding MRI simulator image acquisition are outlined in Supplement E1 (available online at https://dx.doi.org/10.1016/j.adro.2018.12.002).

Anesthesia case

Computed tomography simulation. For patients who required anesthesia support, the patient and their caregiver met with the anesthesia team, and were induced with propofol and placed on nasal cannula oxygen. MRI-safe

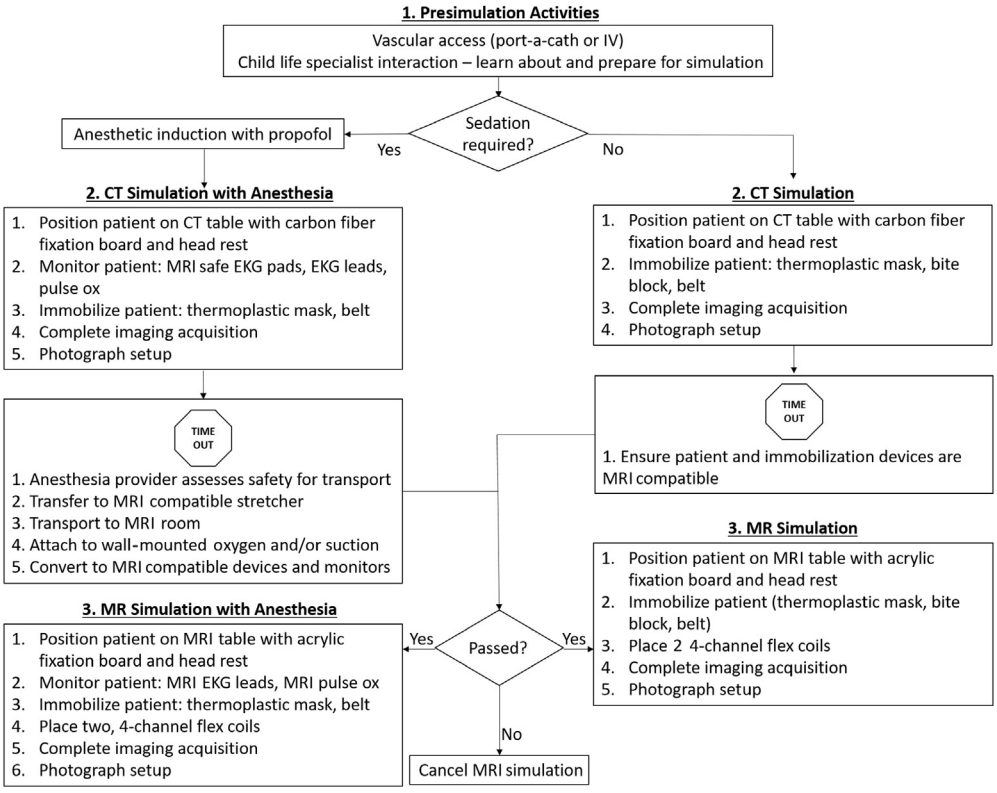

Fig. 1 Workflow of magnetic resonance imaging simulation with and without sedation

electrocardiogram (ECG) pads were placed, and traditional ECG leads (placed on the thorax, as per standard of care) and pulse oximeters (placed on a finger) were used to monitor. Subsequently, the patient was positioned on the CT simulation table, and a thermoplastic mask was made in coordination with the anesthesiology team to ensure that an adequate airway was maintained. CT imaging was then performed in the same way as for nonanesthetized patients.

Time out and safety assessment. After simulation, the anesthesia team ensured that the patient was safe for transport. The patient was moved to an MRI-compatible stretcher and transported into the neighboring MRI simulation room, which was equipped with 2 hubs of wall-mounted suction and oxygen so that no oxygen tanks were required. The patient was connected to an MRI monitor, and ECG leads and pulse oximeters were exchanged for MRI-compatible devices. A time out and safety check was performed to ensure that the patient had tolerated the transfer and all components of the patient system were MRI compatible.

MRI simulation. The patient was transferred from the stretcher to the table, and re-immobilized in the aquaplast mask on the MRI-safe acrylic fixation board. Two 4-channel flex coils were placed around the patient's head, and the treatment team left the room. The MRI simulation room was equipped with a custom portal that allowed for the propofol pump to remain outside of the room, with the anesthesiology provider and a dedicated Bluetooth anesthesia monitor adjacent to the MRI console for continuous monitoring. Our standardized brain MRI simulation protocol was acquired, and the patient was transferred to the postanesthesia care unit for recovery from sedation.

Discussion

In this study, we describe our institution's experience with MRI simulation of pediatric patients while immobilized in the treatment position. The simulation workflow (Figs. 1-3) describes the careful interaction between anesthesia providers, radiation oncologists, child life specialists, and therapists, who are all accountable for the safety of the child during the simulation. Based on our limited experience, all patients safely completed the entire CT and MRI simulation workflow with no safety concerns or adverse events. The simulations were completed within the scheduled time, without issue, by the trained therapist, and with minimal interruptions, which suggests that our proposed workflow and MRI protocol is clinically feasible for the pediatric population.

The integration of MRI into the simulation workflow not only provided for superior soft-tissue contrast to aid in our delineation of OARs and tumor target volumes, but

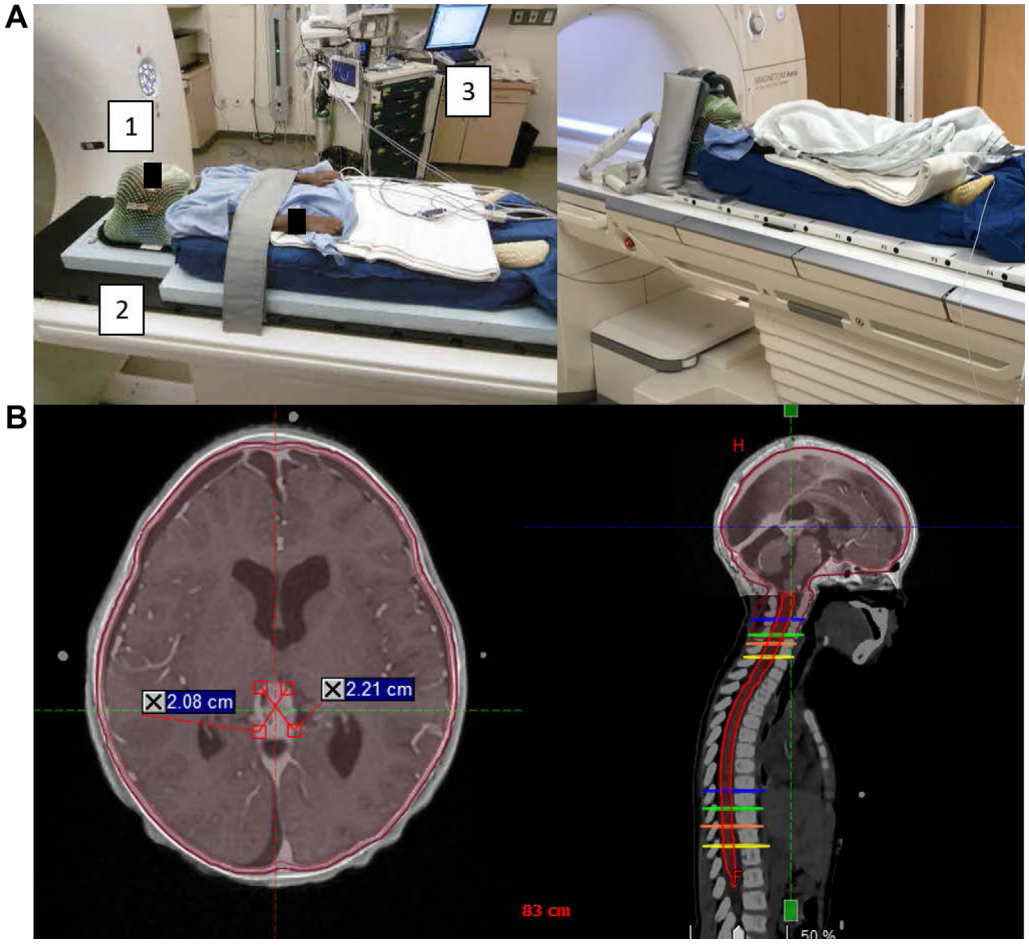

Fig. 2 (A) Patient positioned in immobilization during computed tomography and magnetic resonance imaging simulation with anesthesia; and (B) magnetic resonance imaging simulation images acquired in the treatment position and immobilization. (1) Thermoplastic mask with bite block. (2) Carbon fiber fixation board. (3) Anesthesia cart with monitoring.

also up-to-date imaging of these structures immediately before the start of the radiation. Currently, diagnostic MRI is commonly fused to the simulation CT, but these images can be obtained anywhere from 1 day to potentially several months before the simulation day. In one of our patients, an increase in residual tumor size was noted on the MRI scans images, but not apparent on the most recent diagnostic MRI, which would have been used for a fusion with the CT simulation images within a commonly practiced workflow. The information from the new MRI simulation scans resulted in a change in the patient's risk categorization, and therefore affected the overall treatment plan. This demonstrates the added value of timely and coordinated MRI simulation for the purposes of treatment planning and clinical management.

Child life specialists were used during the MRI simulation process and daily throughout the patient's radiation treatment for all patients. The primary goal of this service for patients who require sedation is to assist with port-a-cath access through the use of a Medikin doll and EMLA cream using role reversal, to allow the patient to become the medical provider of the doll. The use of child life specialists for diagnostic imaging has been shown to decrease the use of sedation in young patients through sensitization to the procedure.[3] In contrast, given that young patients are required to remain still for extended periods of time for numerous days in a row, our goal is not to decrease the sedation or avoid the anesthetic, but to make the process less traumatic and quicker each day. This was successful by the demonstration of all procedures having been completed during the allotted times.

Conclusions

Serial MRI after this baseline may better reflect treatment response, and the incorporation of serial advanced structural and biologic imaging may provide earlier measures of response and toxicity. In conjunction with accurate dosimetric data in the pediatric population, serial MRI has great potential to evaluate the radiation dose-response relationships of brain substructures that contribute to radiation-related morbidity and the impact of radiation on the developing brain.[4]

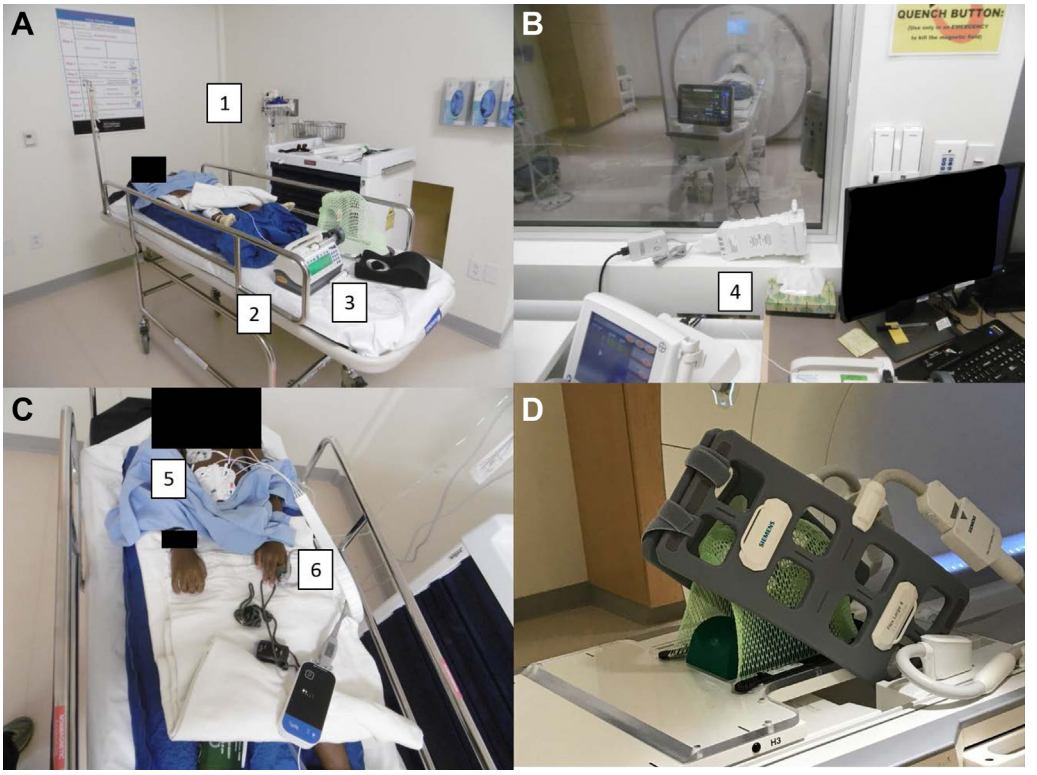

Fig. 3 (A) Magnetic resonance imaging (MRI) preparation room; (B) MRI simulator through the console window; (C) MRI-compatible devices; and (D) 4-channel flex coils positioned around head immobilization for a brain MRI simulation. (1) Wall-mounted oxygen and suction. (2) MRI-compatible stretcher. (3) Propofol pump. (4) MRI portal for propofol pump and monitors. (5) MRI-compatible echocardiogram pad. (6) MRI-compatible pulse ox.

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Supplementary Data

Supplementary material for this article can be found at https://dx.doi.org/10.1016/j.adro.2018.12.002.

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