MR Simulation System for MR Guided Radiation Therapy at 3.0T

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Introduction: In general, MR Imaging can not co-exist with other imaging modalities like CT, X-Rays, LINACs, etc. which, are essential tools in the Radiation Planning and Therapy (RT) treatments. Over the last couple of years, hybrid systems integrating MRI with Radiation therapy units [1, 2] have been successfully introduced. Although CT remains the only essential tool in predicting accurate radiation dosage necessary for planning and treatment on a targeted tumor area, MRI can provide unprecedented soft tissue contrast far superior than any CT scanner. Therefore, MR can replace CT for the RT planning stage. For tumors residing on the head and neck area, a head-neck mask is used to immobilize the patient on the CT table. This same mask is used for CT imaging for RT planning and, LINAC treatment. The mask uniquely indentifies each individual patient. It conforms to the exact size and shape of the patient's head and neck and, remains unchanged through every stage of the process from the radiation planning to the radiation therapy. A dedicated immobilization backboard device with indentations for accepting the head neck mask is designed to be securely locked on both the CT table and, the LINAC table. The head-neck mask is then secured to the immobilization board prior to CT scanning or LINAC RT treatment. Fiducials placed on the mask are registered relative to a set of laser devices that exist in both CT and LINAC rooms. Co-registering these points ensures high accuracy of patient positioning during the planning and treatment sessions.

Due to CT's limited ability to image in oblique planes, and large FOVs, MRI has recently been used to overcome these limitations and, provide additional information as a guidance tool [3] during the planning stage. Although it is desirable to use MRI as the primary image acquisition tool for the RT planning stage, at the present time there are no MR compatible simulation systems that can combine MR imaging with RT planning.

In this paper, a new MR simulation system for RT planning of head-neck tumors that include an MR compatible board combined with a head-neck mask, and, a dedicated conformal set of three phased array coils are presented. The use of such system provides superior uniform coverage of the head-neck down to the T6 region of the spine with substantial increase in SNR compared to a commercially available coil.

Methods: The MR simulation system included the head-neck mask, an immobilization board, and a set of three (3) receive only phased array coils. The immobilization board was secured on the table underneath the head-neck region of the patient. It was designed to incorporate the mask as well as the rigid posterior head-neck coil. The immobilization board is constructed from MR compatible radiolucent materials. The anterior head and neck coils are flexible and designed to be conformal with masks of any shape and size. The combined head-neck array consists of 18 channels and, was tested on a 3T scanner (MAGNETOM Verio, Siemens Healthcare, Erlangen, Germany) along with the head-neck mask and the MR compatible immobilization board (Figure 1). The three coils can operate independent of one another. In addition, for the posterior coil the operator can select the elements covering the region of interest in the head-neck area. The flex anterior and rigid posterior coils were fabricated on Kapton and, FR4 respectively with 2oz copper of 10mm width for the head and 6.35mm width for the neck and posterior coils. The physical coverage areas of the coils are provided in table (1). Active and passive detuning circuits were built across the match capacitors using variable inductors and PIN diodes. Fuses with a rating of 315mA were added as an additional protection to the active/passive detuning circuits. A combination of individual coil geometry and element overlap/shared decoupling were used in the design.

Table 1 Physical dimensions of the coils (mm)

Coil	AP	LR	SI
Flex Head	260	160-220	225
Flex Neck	180	160-200	175
Posterior	100	256	408

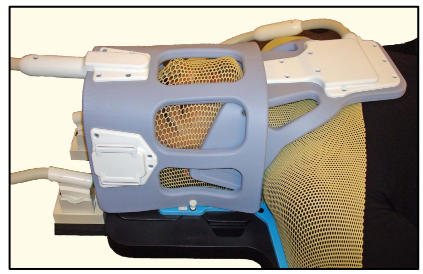

Figure 1 Combined head-neck mask with coils and immobilization board.

Results: The measured ratios of the unloaded and loaded Q factors (Q_{UL}/Q_L) of all the elements exceeded 5. The worst S_{21} decoupling between coil elements is -14dB without pre-amps. Additional low impedance pre-amp decoupling provided isolation greater than 30 dB amongst the elements. Phantom imaging was performed with a Siemens 1900mL plastic bottle phantom using a SE sequence (TR/TE = 300/10 ms, Slice Thickness = 3 mm, BW = 130.2 Hz/pixel, FOV = 300 mm). Average SNR compared with a Siemens head/neck matrix showed a minimum increase in SNR of 40% over the same FOV. After safety tests were performed, volunteer imaging was conducted with a T2 weighted sequence (TR/TE=3000/86, TA=1:03, acceleration factor R=2, Slice thickness=3.0 mm FOV=300 mm, BW=260 Hz/pixel) as depicted in Figure (2). TOF images of the neck region (TR/TE = 21/3.6 ms, BW = 186 Hz/pixel, FOV = 180mm x 200mm) are shown in Figure(3). The MRI images indicate a high level of SNR and uniformity across the entire image extended up to T6

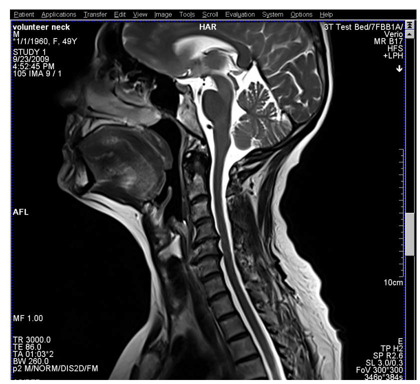

Figure 2 Large FOV up to 300 mm, Sagittal T2 weighted image.

Conclusion: We have successfully demonstrated a novel MR simulation system used for MR guided radiation planning and therapy. The unique combination of the MR compatible radiolucent immobilization board, the head-neck mask and, three phased array coils, granted significant coverage up to T6 of the spine. The phased array coils provided superior image quality and, uniformity over the targeted imaging areas with minimum SNR improvements of 40% and higher compared to a commercially available coil.

Figure 3 Volunteer TOF image

Reference:
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