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PRESENTATION TITLE
Radiologically Transparent RF Coils for Parallel-field Linac-MR

AUTHOR(S)
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ABSTRACT

PURPOSE
Close-fitting surface coils and arrays provide higher image signal-to-noise ratio (SNR) than volume coils. However, proximity to the skin can increase its radiation dose due to electrons ejected when a treatment beam travels through the coil. In this work we evaluate the performance of thin aluminum and copper conductors as a means to limit skin dose while maintaining acceptable SNR.

MATERIALS & METHODS
Surface dose was measured in polystyrene for a 6 MV photon beam (Varian Silhouette) using a parallel plate PTW Markus ion chamber, both with and without a 0.2 T magnetic field. Sheets of aluminum and copper of various thicknesses were placed at the beam entrance surface. The magnetic field was parallel to the beam and generated with two GMW electromagnets [1]. Surface dose measurements were normalized to maximum dose ($D_{\text{max}}$), which is at a depth of 1.5 cm in the polystyrene phantom.

Surface coils designed for a 0.5 T linac-MR system [2] were constructed from aluminum foils (9, 13 and 20 µm thickness), copper tape (32 µm), flexible PCB (18 µm and 35 µm), and copper sheet (125 µm). At the operating frequency of 20.56 MHz the penetration (skin) depths in aluminum and copper are 18 µm and 14 µm respectively. All coils were 15 × 15 cm² square loops of 6-mm-wide strips with 12-cm-long connections to a board containing low-loss tuning and matching capacitors (Voltronics, ATC). Loaded and unloaded quality factors (Q) were measured by driving the matched coil and receiving with a small loop ($S_{21}$ measurement on a network analyzer); efficiency is calculated as $\eta = 1 - \frac{Q_{\text{loaded}}}{Q_{\text{unloaded}}}$, and SNR $\propto \sqrt{\eta}$ [3]. Coils were matched to 50 Ω, and Q measurements were corrected for loading at the coil port [4].

Coil SNR was measured by acquiring gradient echo images of a uniform phantom (Figure 1).
Slice thickness = 10 mm, TE = 12 ms, TR = 333 ms, and bandwidth = 62 kHz.

RESULTS

The surface dose without coil material on the phantom surface is 22% of $D_{\text{max}}$ and higher (32% of $D_{\text{max}}$) in a 0.2 T parallel magnetic field because the field traps contaminant electrons. The surface dose increases approximately linearly with the investigated thicknesses (Figure 2). The slope of the increase is lower in a magnetic field than without magnetic field because the coil material, in addition to acting as build-up, also attenuates contaminant electrons [1].

Coil efficiency measurements are consistent with the image SNRs (Figure 3). For the thicknesses investigated there was not a clear trend between thickness and SNR, but the thinnest conductor did yield the worst SNR as is expected from its higher resistance.

CONCLUSIONS

Aluminum coils can achieve ~85–90% of the SNR of copper coils of the same conductor thickness. Differences in efficiency (SNR) between copper and aluminum are due to their different conductivities.

Surface doses lower than those beneath a patient’s gown can be achieved by practical aluminum or copper foil thickness. The SNR of these low surface dose coils is comparable to that of thick copper coils. With thicknesses that achieve the same efficiencies (SNR), aluminum coils will increase surface dose by a factor of two less than copper coils.

REFERENCES