RADIATION INDUCED RF COIL DEGRADATION IN HYBRID MRI-ACCELERATOR SYSTEMS

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Purpose

Recent developments in radiotherapy show that image guidance decreases the geometrical uncertainties associated with tumour position and shape [1]. Lagendijk et al. [2] presented the benefit of using MR imaging, not only as a position verification system, but as a treatment guidance modality. On-line MR images provide superior soft-tissue contrast and enable development of new treatment strategies, even for patient groups that were not eligible for radiotherapy so far (e.g., renal cancer patients [3]). Recently, we have reported on a prototype integrated MRI-accelerator and demonstrated good image quality even with the radiation beam on [4]. Before clinical introduction, accelerator parts must be shown to operate undisturbedly near the MRI scanner and vice versa. Radiofrequency (RF) coils used in MR imaging during irradiation are likely to be exposed to the treatment beam. Since these receiver coils are at the beginning of the MR signal processing chain that ultimately leads to images, the effect of radiation on the coils' functioning must be studied. In the present work the cumulative effect of a large radiation dose on the coil electronics is examined; we carry out a prolonged radiation resistance test to determine radiation damage to the coil hardware. The results are interpreted to give an estimate of the expected coil life-time in worst and usual case clinical scenarios when used in intensity modulated radiotherapy (IMRT) treatment of prostate cancer patients.

Methods

In this study, electronics (such as pre-amplifier and (de-)tuning circuitry) in an MRI surface receive coil are exposed to radiation in a set-up as depicted in Figure 1. The coil is a C1 circular coil (Philips Medical Systems, Best, The Netherlands). The accelerator is a 6 MV compact linear accelerator (Elekta, Crawley, UK). The coil hardware is positioned between the ionization chambers and the secondary collimator, yielding a source-to-surface distance of approximately 18 cm. At this distance, the dose rate as determined by the law of squares is thirty times larger compared to that at the standard distance of 1 m. A 1 cm thick water equivalent build-up layer is used to increase the dose deposition (i.e., the dose-maximum is reached approximately at the surface of the coil).
Dose-rate calibrations are carried out using gafchromic EBT2 dosimetry film (ISP, Wayne, USA). The dose-response of a batch of film is calibrated in the range of 0 -15 Gy on a clinically used linear accelerator. The dose-rate in our set-up is established using film positioned between the build-up material and the coil electronics. We find our accelerator is capable of delivering approximately 30 cGy/MU to the coil hardware in this set-up. Coil performance is measured in a standardized set-up using a quality assurance tool available on Achieva scanners (Philips Medical Systems, Best). The coil electronics are subjected to 7200 Gy of radiation in steps of 600 Gy at a time and a quality measurement is performed after each irradiation step.

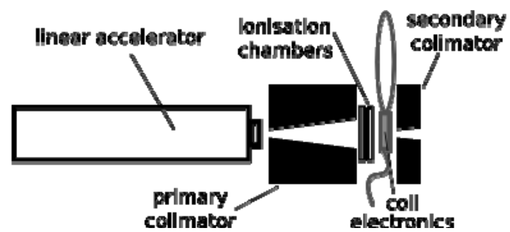

Figure 1: irradiation set-up

Results and discussion

In Figure 2 the measured coil signal to noise ratio as a function of radiation dose is shown. An SNR baseline value of 128 was found. A linear decrease of SNR with the accumulated dose is observed (0.0054 Gy). All other measured quantities, e.g. coil quality-factors, remain constant. The specified minimum SNR for appropriate functioning (111) is reached after approximately 2500 Gy.
To put our findings in a more clinical perspective, a series of 112 prostate IMRT plans, as they are made in our department, is considered. A typical plan consists of five coplanar beams which together deliver a prescribed dose of 75 Gy in the target. We assume that, in a *worst case* scenario, electronics in a surface coil are subjected to same dose that is delivered at the skin of the patient. The skin dose in a plan is estimated by averaging the dose at the body contour for all positions along the cranio-caudal axis of the patient. A average maximum skin dose of 8.54 Gy is then obtained. If we adopt 2500 Gy as the maximum dose allowable for coil electronics, the coil would thus have to be changed roughly every 300 patients. However, in the usual cases it is possible to position a coil such that its electronics lie outside the main radiation field, reducing the dose to electronics to only that produced by scatter. This amounts to a few percent of the maximum skin dose, resulting in over 5000 treated patients before the coil would have to be changed which corresponds roughly to the total number of patients treated yearly in our department.

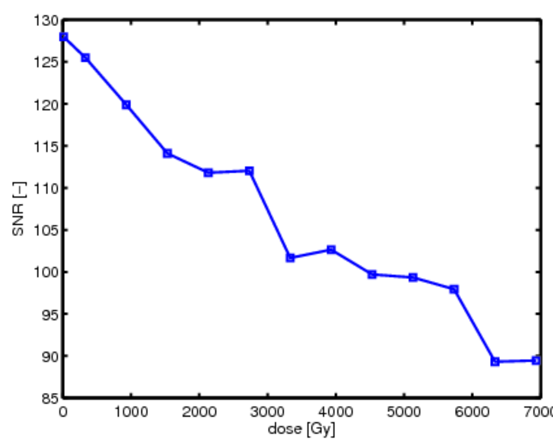

Figure 2: coil SNR as a function of absorbed dose.

Conclusion

We have presented measurements of MRI surface receiver coil performance in an integrated MRI-accelerator as a function of the radiation dose it has received. We conclude that the accumulative effect is small, in that the coil hardly deteriorates from the dose it receives during treatment of one patient. Nevertheless, we advise to establish strict quality assurance procedures for coil functioning in MR guided radiotherapy and to guarantee that hardware can be positioned outside the treatment beam.

References

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