The aim of this study is to incorporate a physically correct description of the bladder properties in treatment planning, most notably the presence of convection and the absence of perfusion, and to assess the differences with the conventional model.

**Material and Methods:** We created a convective thermophysical fluid model based on the Boussinesq approximation to the Navier-Stokes equations; this means we assumed all parameters to be temperature independent except for the mass density in the gravitational term. We implemented this using the (finite element) OpenFOAM toolkit, and coupled it to our (finite difference) in-house developed treatment planning system, based on Pennes’ bio-heat equation.

A CT scan was obtained from a bladder cancer patient and an experienced clinician delineated the bladder as part of the standard clinical work-flow. Based on this input, we first performed the treatment planning the conventional way with a muscle-like solid bladder, and calculated the optimal phase and amplitude settings for all four antennae. Next, we redid the temperature calculation with the expanded treatment planning system with a fluid-filled bladder, using the same settings. We subsequently calculated the differences between the two temperature distributions.

**Results:** The temperature in the bladder with realistic fluid modelling is much higher than without, as the absence of perfusion in the bladder filling leads to a much lower heat removal. The maximum temperature difference was 3.6 °C. Clinically relevant tissue temperature differences of more than 0.5 °C extended to 1.75 cm around the bladder. The temperature distribution according to the convective model and the difference with the solid only model are shown in Figure 1. The difference reflects the homogenizing effect of convection within the bladder and the nett heat transport in the upward direction.

Figure 1.

*Left:* Temperature distribution at equilibrium according to the expanded treatment planning system with fluid dynamics. Note the homogeneous temperature distribution inside the bladder (top: axial view, bottom: coronal view).

*Right:* Temperature difference at equilibrium between the expanded treatment planning system with fluid dynamics and the traditional planning system without fluid dynamics. Note that the entire bladder, but especially the top half, is much warmer when fluid dynamics are accounted for. Clinically relevant effects extend to 1.75 cm around the bladder (top: axial view, bottom: coronal view).

**Conclusion:** The addition of the new convective model to the hyperthermia treatment planning system leads to clinically highly relevant temperature changes. Explicit modelling of fluids is particularly important when the bladder or its direct surroundings are part of the treatment target area.

**Purpose or Objective:** There have been concerns that the quality of highly conformal dose distributions, delivered under active MRI guidance, may be degraded by the influence of the magnetic field on secondary electrons. This planning study quantifies this effect for stereotactic body radiotherapy (SBRT) of lung tumors, conducted either with or without real-time multileaf collimator (MLC) tumor tracking.

**Material and Methods:** The Elekta Monaco treatment planning software, research version 5.09.07, was used to design treatment plans on the peak-exhale 4DCT phase of nine patients undergoing lung SBRT. The software features a machine model of the Atlantic MR-linac system and allows dose calculation and plan optimization under consideration of a magnetic field.

For each patient, we prepared four different 9-beam step-and-shoot IMRT plans: two for conventional, non-traacked treatment and two for delivery with real-time MLC tumor tracking, each delivered either with or without a 1.5T magnetic field oriented in the superior-inferior patient direction. For the conventional delivery, the internal target volume was defined as the union of the gross tumour volumes (GTV), delineated on each 4DCT phase. For the tracked delivery, the moving target volume was defined as union of all GTVs, each corrected for the center-of-volume shift thus accounting for target deformations. Dose was prescribed according to the RTOG 1021 guideline. Delivery of the respective plans was simulated to all 4DCT phases and the doses were then deformably accumulated onto the peak-exhale phase.

In order to evaluate the effect of the magnetic field and real-time tumor tracking, several dose-volume metrics and the integral deposited energy in the body were compared. Statistical significance of the differences was evaluated using a two-sided paired t-test after verifying normal distribution of them, while correcting for multiple testing for the four primary endpoints.

**Results:** The table presents the differences in the investigated dose-volume metrics due to either the presence of a magnetic field or real-time MLC tumor tracking. Most prominently, the magnetic field caused an increase in dose to the skin and a decrease of dose to the GTV (see figure). While statistically significant, the magnitude of these differences is small. In all 36 simulated dose deliveries, the dose prescription to the target was fulfilled and there were only minor violations of normal tissue constraints. Real-time MLC tumor tracking was able to maintain dose coverage of the GTV while reducing the integral deposited energy. This results in a decrease in dose to the skin and normal lung tissue, both with and without a magnetic field.
Conclusion: This study has shown that accounting for the effects of the magnetic field during treatment planning allows for design of clinically acceptable lung SBRT treatments with a MR-linac. Furthermore, it was found that the ability of real-time tumor tracking to decrease dose exposure to healthy tissue was not degraded by a magnetic field.

OC-0550
Investigation of magnetic field effects for the treatment planning of lung cancer
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Purpose or Objective: Combining the capabilities of high resolution soft tissue MR imaging and intensity modulated radiation therapy into a hybrid device has the potential to increase the accuracy of radiotherapy. However, it is known that the magnetic field of the MR manipulates the trajectory of the secondary electrons and leads to a deviation of dose especially at the interfaces between high and low density materials. This study aims to introduce a routine for the evaluation of magnetic field effects to dose delivery and plan optimization using Monte Carlo simulations.

Material and Methods: An EGSnrc Monte Carlo environment, based on the egs++ class library, was developed which can be used for the simulation of IMRT plans in the presence of a 1.5 T magnetic field or real-time MR tumor tracking, averaged over the entire patient contour. Statistically significant differences are denoted by red tint. The changes of the four primary endpoints are shown at the top of this table and were evaluated at a significance level of p < 0.05. The differences in the dose-volume metrics investigated in an exploratory analysis are presented in the bottom and were evaluated at p < 0.05.

Results: Comparison showed that the Monte Carlo simulations of IMRT plans at 0 T are in good agreement with RayStation dose calculations. The effect of a 1.5 T lateral magnetic field on the dose distribution showed distinct alteration in tumor dose. Differences appear to be less when an opposing field technique is used. It could further be proven that the routine is capable of performing plan optimization based on Monte Carlo simulated beamlets in the presence of a magnetic field.

Conclusion: A routine for dose calculation of IMRT plans with EGSnrc and for plan optimization based on Monte Carlo simulated beamlets using the in-house planning system matRad was developed. This implementation provides the possibility to analyze the effects of a magnetic field during radiotherapy in detail. Additionally it enables the investigation of optimization strategies for an MRI-LINAC system.

Acknowledgments: We thank Dr. Iwan Kawrakow for providing the egs++ magnetic field macro for the EGSnrc code system.

OC-0551
Advantage of IMPT over IMRT in treatment of gynaecological cancer with para-aortic nodal involvement
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Purpose or Objective: High costs and limited capacity in proton therapy requires prioritizing according to expected benefit. The aim of this work is to quantify the clinical advantage of robust intensity-modulated proton therapy (IMPT) in terms of sparing of organs at risk (OARs) for three target volumes in treatment of gynaecological cancers compared with state-of-the-art intensity-modulated photon therapy (IMRT), and to evaluate for which target volume the benefit would justify the use of IMPT.

Material and Methods: An in-house open source treatment planning system matRad. In order to basically validate the implementation, dose distributions at 0 T were compared against collapsed cone calculations by the treatment planning system RayStation. The effect of a magnetic field to the dose distribution was investigated for simulations in a porcine lung phantom. Based on Monte Carlo simulations of patient specific beamlets, plan optimization was performed and analyzed.

Results: Comparison showed that the Monte Carlo simulations of IMRT plans at 0 T are in good agreement with RayStation dose calculations. The effect of a 1.5 T lateral magnetic field on the dose distribution showed distinct alteration in tumor dose. Differences appear to be less when an opposing field technique is used. It could further be proven that the routine is capable of performing plan optimization based on Monte Carlo simulated beamlets in the presence of a magnetic field (see figure 1).

Conclusion: A routine for dose calculation of IMRT plans with EGSnrc and for plan optimization based on Monte Carlo simulated beamlets using the in-house planning system matRad was developed. This implementation provides the possibility to analyze the effects of a magnetic field during radiotherapy in detail. Additionally it enables the investigation of optimization strategies for an MRI-LINAC system.

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Purpose or Objective: High costs and limited capacity in proton therapy requires prioritizing according to expected benefit. The aim of this work is to quantify the clinical advantage of robust intensity-modulated proton therapy (IMPT) in terms of sparing of organs at risk (OARs) for three target volumes in treatment of gynaecological cancers compared with state-of-the-art intensity-modulated photon therapy (IMRT), and to evaluate for which target volume the benefit would justify the use of IMPT.

Material and Methods: Three target volumes were included: pelvic region (primary or postoperative treatment; N=10, 6 with boost dose), pelvic and para-aortic region (N=6, all with