Heart beat modelling in a water and anthropomorphic phantom

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Introduction

Atrial fibrillation represents the most common cardiac arrythmia. AV node ablation requiring an invasive procedure is the commonly used treatment choice at the moment. However, animal studies have shown that a similar result can be achieved non-invasively using ionising radiation. A method was described by Sharma et al [1] using photons to achieve AV node ablation.

As known from cancer patients using the Bragg peak characteristic of charged particles can lead to a more favorable dose deposition. In order to explore the potential of carbon ions for treatment of atrial fibrillation animal studies with swines are planned for 2014 at GSI. In this report a method for determining the dose deposition under influence of breathing and cardiac motion with the help of a phantom is described.

Figure 1: Picture of the Kuka robot holding the PMMA block with ionisation chambers inside the anthropomorphic breathing phantom.

Materials and methods

The main challenge when irradiating the AV node is the motion of the target. The target exhibits two interfering motion types: a slow motion (several seconds) with large amplitude due to breathing as well as a fast motion (around 120 beats per minute for swines) coming from the heart itself. The treatment procedure must incorporate means to mitigate the motion of the AV node.

Moving phantoms need to be used in order to experimentally study the dosimetric effects of breathing, heartbeat and motion mitigation techniques. For this purpose the target area is simulated by a PMMA block containing pinpoint ionisation chambers. The ion chamber block is mounted on an industrial robot Kuka KR5 sixx R850. The robot is capable of 6D motion and holds the target block either in water or an anthropomorphic breathing phantom. The latter phantom consists of a thorax and is actuated with a stepper motor to simulate the moving of the chest wall while breathing (Fig. 1).

The breathing functionality of the anthropomorphic phantom has been used for several years at GSI and is documented in [2]. The motion of the AV node has now been incorporated into the phantom motion mimicking patterns extracted from 4DCTs of four swines. The 4DCTs were taken by Mayo Clinic College of Medicine. The AV node displacement can be traced with sufficient accuracy (< 0.5 mm) by the robot. In order to study the effects of the different motion components, the robot control software can enable each movement type individually (Fig. 2).

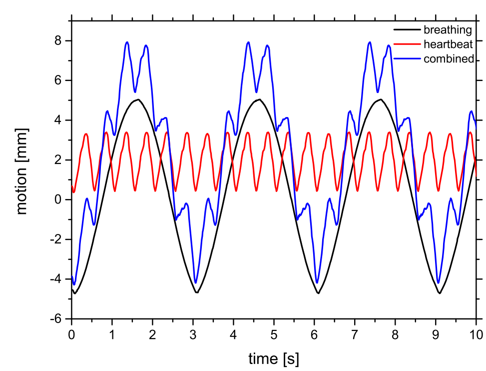

Figure 2: Motion trajectory of the target in superior-inferior direction showing breathing and heartbeat motion individually as well as the superposition.

Discussion

The robot is able to reliably reproduce a target trajectory coming from both breathing and cardiac motion in a phantom. The motion parameters can easily be manipulated in the control software to allow both quality assurance as well as research for a large variety of patients or animals.

References

[1] Sharma et al., HeartRhythm 7(6), 2010

[2] Steidl et al., Phys Med Biol 57(8), 2012

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