Influence of cardiac motion on porcine AV node for the non-invasive treatment of atrial fibrillation with a scanned carbon ion beam*

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Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia and occurs in ∼2 % of the western population older than eighty [1]. Since age is an important risk factor for this disease, the prevalence is estimated to double in the next fifty years. One treatment strategy for reducing the ventricular rate in AF patients is atrioventricular (AV) node ablation, requiring the implantation of a pacemaker. It has recently be shown in animal studies that a non-invasive ablation on this target site is feasible with photons [2]. Similar experiments with carbon ions are planned for 2014 at GSI, where the AV node of swines will be irradiated. In order to assess the target displacement due to heart beat motion volume histograms (MVHs) were analyzed.

Material and Methods

In order to study the displacement of the AV node during the cardiac cycle time resolved Computed Tomography (CT) scans of a swine, gated on heart beat were acquired. Treatment planning is usually based on native CT scans where the density information can be directly used as range information for the particle beam. As the heart muscle is a very dense structure a contrast enhanced CT scan of the swine was also acquired, enabling a comparison of the AV node motion based on the two different scans. In both cases the cardiac cycle was divided into twenty quasi-stationary sections (motion phases) (5% intervals of the cardiac cycle). Ablation lines for AV node were contoured (x≈2 mm, y≈5 mm, z≈3 mm). A non-rigid registration of the motion phases was carried out with the open source software Plastimatch. The MVHs were calculated with the in-house treatment planning software TRiP4D [3]. The motion of the AV node due to the influence of the heart beat was investigated by studying the displacement of the target in all nineteen motion phases compared to the reference phase (0%).

Results

In fig.1 the mean displacement and standard deviation of the AV node due to heart beat are shown for the different motion directions resulting from the native CT (in black) and the contrast enhanced CT (in red), respectively. While the native scan yields no significant displacement of the AV node, the contrast enhanced CT scan allows for a motion assessment.

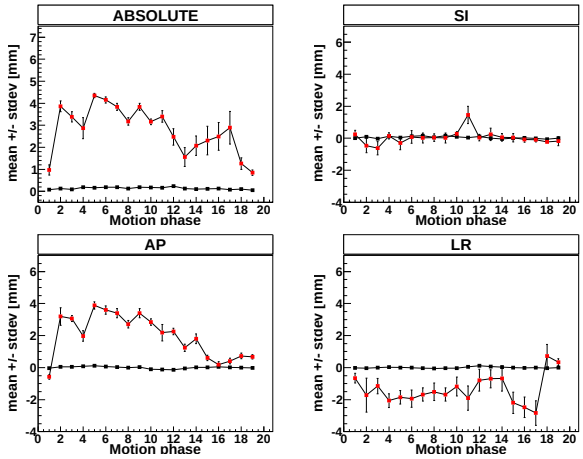

Figure 1: Displacement of AV node in superior-inferior (SI) direction, anterior-posterior (AP) direction and left-right (LR) direction. The absolute displacement is also plotted. Comparison between native CT data (black) and contrast enhanced CT (red) for one swine data set.

The mean absolute displacement of the AV node resulting from the contrast enhanced CT scans results to (2.78 ± 1.04) mm. It can be concluded that the motion is smallest in SI direction with a mean displacement of (0.04 ± 0.41) mm, while AP is the biggest motion direction with a mean displacement of (1.98 ± 1.30) mm.

Conclusion

Resulting from a contrast enhanced CT scan of a swine, the AV node seems to move significantly with an absolute displacement of up to 4 mm. The motion due to heart beat is hence not negligible when irradiating this cardiac target volume. This needs to be considered in the upcoming beam time at GSI where a non-invasive AV node ablation with scanned carbon ions will be carried out in swines.

References

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