Influence of cardiac motion on pulmonary veins for the non-invasive treatment of atrial fibrillation with a scanned cabon ion beam*

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Introduction

Arrhythmias describe a wide range of caridac conditions associated with abnormal heart beats. The most common arrhythmia is atrial fibrillation (AF), describing an irregular and often rapid heart beat. Although not considered life treathening, it causes a range of complications and significantly increases the risk of suffering a stroke. AF is often treated by radiofrequency ablation aiming for an electrical isolation of the pulmonary veins (PVs). This is a complicated and time consuming procedure with varying success rates [1]. Recently, animals studies showed that a non-invasive albation with photons is feasible [2]. Based on the experience gained in cancer treatment lesion creation with ions seems promising. In order to study the treatment delivery for such an irradiation, the cardiac motion due to respiration and heart beat was studied. The resulting motion volume histograms (MVHs) of the PVs will be presented for one patient case.

Material and Methods

A time resolved Computed Tomography scan of an AF patient, gated on the respiration as well as on heart beat (5DCT) was acquired. Forty quasi-stationary sections (motion phases) resulted as each of the two respiratory phases (exhale, inhale) included twenty cardiac phases (5% intervals of the cardiac cycle). PV ablation lines for the left PV (LPV) and right PV (RPV) were contoured (x≈5 mm, y≈20 mm, z≈35 mm, respectively for LPV and RPV). 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 PVs due to the influence of the heart beat was investigated by studying the difference between the minimal and maximal phase of the cardiac cycle at the exhale position of the patient. The influence of the respiration was studied by keeping the cardiac phase constant and looking at the displacement vectors between inhale and exhale.

Results

In fig.1 the MVH for the motion of the PVs due to the heart beat is shown (left column) and under respiratory influence (right column) for the different motion directions as well as the LPV and RPV, respectively.

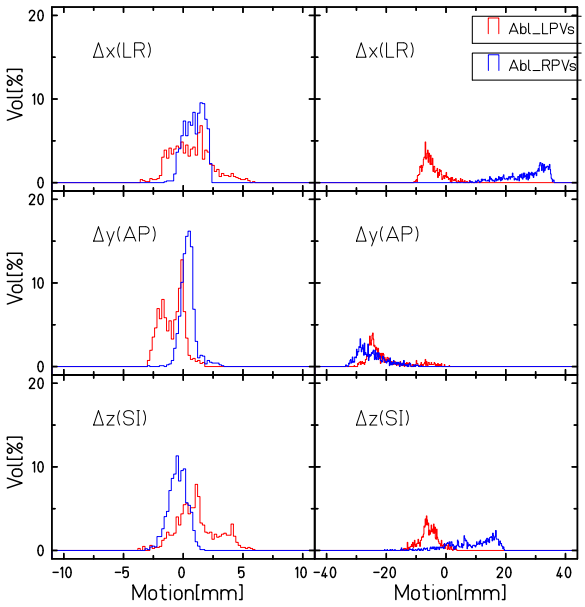

Figure 1: MVHs of PV motion. The left column shows the displacement due to the cardiac cycle, the right column due to respiration. The top row shows the motion in the left-right (LR) direction, the second row in the anterior-posterior (AP) direction and the third row in the superior-inferior (SI) direction.

As expected, the motion of the PVs due to respiration is big (∼ 20 mm), while the motion due to heart beat alone is relatively small (∼ 5 mm). Nevertheless, taking into account the small size of the target as well as the planned beam spot size (x=1 mm, y=1 mm), the motion due to heart beat can not be neglected.

Conclusion

From the investigation of one single patient CT it seems as if the irradiation of the PVs for a non-invasive treatment of AF motion mitigation technqiues need to be applied not only on the respiration of the patient but also on the heart beat itself.

References

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