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# Summary and conclusion

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The general introduction outlines the role and importance of pre-procedural evaluation of patients undergoing RFCA for AF. Novel echocardiographic techniques to estimate atrial remodelling are discussed as well as the role of MSCT and natriuretic peptides during the pre-procedural evaluation. In addition, the use of imaging and image integration during RFCA for complex atrial arrhythmias is discussed. An overview of the advantages and limitations of the most common used imaging modalities is provided and the benefit of image integration to overcome these limitations is discussed.

### Part I: Pre-procedural evaluation of patients undergoing radiofrequency catheter ablation for atrial fibrillation

The first part of this thesis discusses the role of echocardiography, MSCT and natriuretic peptides in the pre-procedural evaluation to identify patients with a high likelihood to maintain sinus rhythm after RFCA for AF.

Chapter 1 comprises an editorial comment about the limitations of left atrial size as a predictor of AF recurrence after RFCA. Left atrial size is commonly estimated by measuring the anterior-posterior left atrial diameter on two-dimensional echocardiography. However as left atrial enlargement may not be symmetrical, a 3-dimensional evaluation provides a more accurate estimate of true left atrial size. Three-dimensional measurement of left atrial size can be performed MSCT, 3-dimensional echocardiography and magnetic resonance imaging.

In Chapter 2, echocardiography derived calibrated integrated backscatter is used to estimate the extent of left atrial fibrosis and to relate this to the outcome of RFCA for AF. Calibrated integrated backscatter is an echocardiographic technique that allows tissue characterisation based on

ultrasound reflectivity. In a group of 170 patients undergoing RFCA for AF, a high extent of left atrial fibrosis was an independent predictor of AF recurrence (OR 1.217 per dB, p<0.001). Moreover, the combined assessment of left atrial fibrosis and left atrial size significantly improved the accuracy to identify patients with a high likelihood to maintain sinus rhythm.

Chapter 3 describes the impact of total atrial conduction time on the efficacy of RFCA for AF. Total atrial conduction time reflects the extent of both electrical and structural remodelling of the atria and can be assessed using tissue Doppler imaging by measuring the time delay between the onset of the P-**wave in lead II of the surface ECG and the peak A'**-wave on the tissue Doppler tracing of the left atrial lateral wall (PA-TDI duration). The PA-TDI duration demonstrated a superior accuracy to predict AF recurrence after RFCA compared to left atrial size (receiver-operator characteristics analyses: area under the curve 0.765 vs. 0.561, respectively).

In Chapter 4, the impact of coronary artery disease on the efficacy of RFCA for AF is studied. In a population of 125 consecutive patients MDCT is used to determine the presence and extent of coronary artery disease (coronary angiography and/or coronary calcium score) prior to RFCA for AF. The presence and extent of coronary artery disease had no negative impact on the efficacy of RFCA for AF.

In addition to information about the presence of coronary artery disease, multi-slice computed tomography provides information about the pulmonary veins and left atrial dimensions. Chapter 5 studies the impact of pulmonary vein anatomy and dimensions, as well as left atrial dimensions, on the efficacy of RFCA for AF. Atypical anatomy of the right-sided pulmonary veins, defined as an additional right pulmonary vein, was present in 17% of patients and was associated with a lower risk for AF recurrence after RFCA. Left sided pulmonary vein anatomy as well as pulmonary vein dimensions were not

predictive for AF recurrence after RFCA. Left atrial size measured by MSCT demonstrated a superior accuracy to predict AF recurrence compared to left atrial size on two-dimensional echocardiography.

Finally, Chapter 6 describes the role of natriuretic peptides (NT-proANP and NT-proBNP) in the pre-procedural evaluation of patients undergoing RFCA for AF. Theoretically, natriuretic peptides can provide information about the presence and severity of a previously undetected cardiac condition limiting the efficacy of RFCA for AF. In 87 patients with symptomatic drug-refractory AF, pre-procedural serum levels of natriuretic peptide levels were determined. Importantly, all samples were collected during sinus rhythm to avoid the potentially obscuring effect of AF on the natriuretic peptide levels. After a follow-up of 12 months, pre-procedural NT-proBNP was an independent predictor of AF recurrence after RFCA.

The first part of this thesis suggests that comprehensive evaluation of left atrial substrate, taking into consideration the extent of atrial fibrosis and electromechanical properties, may provide a better identification of patients who will benefit from RFCA for AF than measurement of left atrial dimensions. Furthermore, measurement of natriuretic peptides levels may provide a more sensitive marker for the presence of non-pulmonary vein related arrhythmogenic substrate to develop AF.


Part II: Imaging to facilitate radiofrequency catheter ablation of complex atrial arrhythmias

The second part of this thesis describes the role of imaging and image integration to facilitate RFCA of complex atrial arrhythmias. To perform these procedures, accurate visualization of the intracardiac catheters in relation to the cardiac anatomy is crucial. Furthermore, as these procedures are associated

with a high radiation exposure to both patient and operator, the need for non-fluoroscopic imaging modalities has increased.

Chapter 7 comprises an overview of the use of intracardiac echocardiography during interventional and electrophysiological procedures. Intracardiac echocardiography is performed using a catheter with an ultrasound transducer at its tip which is typically positioned inside the right atrium or right ventricle. Intracardiac echocardiography provides real-time information about the cardiac anatomy without radiation exposure and can be used to guide RFCA procedures. However, currently intracardiac echocardiography is a 2-dimensional imaging modality and does not provide the highly detailed anatomical information that multi-slice computed tomography does.

In Chapter 8 the integration of intracardiac echocardiography, electroanatomical mapping and MSCT to guide RFCA for AF is described. A novel electroanatomical mapping system was used that allows tracking of a specifically designed ultrasound catheter thereby allowing to project the 2-dimensional ultrasound image into its 3-dimensional mapping environment. By tracing the endocardial contours of the left atrium and pulmonary veins on these ultrasound images a 3-dimensional map was created on the electroanatomical mapping system. Finally, a pre-procedurally acquire MSCT image of the left atrium was uploaded to the mapping system and integrated with the 3-dimensional map. In a group of 17 patients, 3-dimensional mapping of the left atrium using intracardiac echocardiography was feasible with a mean of $31.1 \pm 8.5$ contours. Integration with multi-slice computed tomography resulted in a mean distance of $2.2 \pm 0.3$ mm between the map and the multi-slice computed tomography image. Three-dimensional mapping using intracardiac echocardiography demonstrated a high sensitivity to detect and visualize the pulmonary veins.

Chapter 9 comprises a case-report about the integration of intracardiac echocardiography and electroanatomical mapping to facilitate ablation of an atrial tachycardia in a young patient who previously underwent a Senning operation for transposition of the great arteries. The arrhythmia caused hemodynamic instability thereby limiting activation mapping of the presumed macro-reentrant circuit during on-going tachycardia. However, the anatomic information acquired with intracardiac anatomy in combination with rough voltage mapping enabled the identification and confirmation of the critical isthmus by limited entrainment mapping at selected sites during only brief episodes of tachycardia.

Finally, Chapter 10 describes the case of a 24-year-old male who previously underwent a Mustard operation for transposition of the great arteries and suffered from recurrent episodes of tachycardia. The electrophysiological examination revealed an atrioventricular nodal re-entry tachycardia. Subsequently, electroanatomical mapping was performed to visualize the complex cardiac anatomy and successfully guide RFCA of the slow-pathway. In addition, an anatomical perspective is provided about the cardiac anatomy following a Mustard operation.

## Conclusions

Implementation of novel echocardiographic techniques to measure atrial remodelling as well as natriuretic peptide levels in the assessment of patient undergoing RFCA for AF improves the identification of those with a high likelihood to maintain sinus rhythm after the procedure. Moreover, integration of multiple imaging modalities during RFCA of complex atrial arrhythmias allows for an improved identification of important cardiac structures, reduced radiation exposure and potentially an improved outcome.