Epicardial Atrial Mapping during Minimally Invasive Cardiothoracic Surgery

Lisette van der Does
Frans Oei
Paul Knops
Ad Bogers
Natasja de Groot

ABSTRACT

Mapping of the unorganized activation patterns of atrial fibrillation requires a high-resolution mapping approach in order to diagnose substrate-mediated pathophysiological mechanisms. Epicardial mapping is for now the only approach able to acquire electrograms of >200 high-density sites simultaneously. This study introduces a technique to perform high-resolution mapping in minimally invasive surgery. In three patients with mitral valve disease epicardial mapping of the right atrium, Bachmann's bundle and parts of the left atrium was safely performed via minimal right thoracotomy.

INTRODUCTION

Atrial fibrillation is often triggered by impulses from the pulmonary veins, and isolation of the pulmonary veins is the standard ablative approach. However, recurrences occur frequently and can be due to recovery of pulmonary-atrial conduction or due to remodeling of atrial tissue serving as a substrate for persistence of atrial fibrillation.[1] To improve the success of ablative therapy, patients would benefit from an individualized approach. Analyzing the electrical activation patterns of atrial fibrillation, or so-called mapping, could not only guide treatment strategies but also determine the effect of the applied scars and evaluate the need for additional treatment. Minimally invasive surgical approaches are gaining ground and are currently widely employed in patients with mitral valve disease, in whom a high incidence of atrial fibrillation is observed.[2] Therefore, we developed a technique to map atrial activation patterns at high resolution during minimally invasive surgical procedures. Here, we present our first evaluation in three patients without a history of arrhythmia to assess the usability of the mapping approach.

Three patients, aged 67, 59 and 62 years, scheduled for mitral valve repair using a minimally invasive approach were informed and gave consent to participate in the study protocol approved by the local ethics committee (Halt & Reverse, MEC2014-393). All patients had severe mitral valve insufficiency and normal left ventricular function and underwent mitral valve surgery alone.

SURGICAL TECHNIQUE

Preparation

General anesthesia was applied, and patients were intubated with a double-lumen respiration tube and received a transoesophageal echo probe and a central and arterial line, with electrocardiogram (ECG) monitoring. The patients were positioned supine and turned 30˚ to their left side on the operation table with an inflatable cushion supporting the right scapula. Minimal right thoracotomy of 4-5 cm was performed at the 4th intercostal space, and the videoscope was introduced via a port in the 3rd intercostal space. The pericardium was opened with a reversed L-incision exposing the heart. Cannulas for cardiopulmonary bypass were placed in the femoral vein and femoral artery and advanced towards the superior vena cava and aortic arch, respectively. The critical position of the tip of the venous cannula in the superior vena cava was confirmed by transoesophageal echocardiography.

Mapping procedure

A reference signal during mapping was obtained by a bipolar pacemaker wire stitched on the terminal crest of the right atrium. A steel wire was fixed to subcutaneous tissue at the femoral access site of the cannulas and served as an indifferent electrode. A rectangular flexible 192-electrode array (1.4x4.6 cm), fixed on a similar shaped spatula made from bendable steel for stability (Figure 1), was connected via 3 meter shielded cables wrapped in a sterile sack to a custom computerized mapping system.

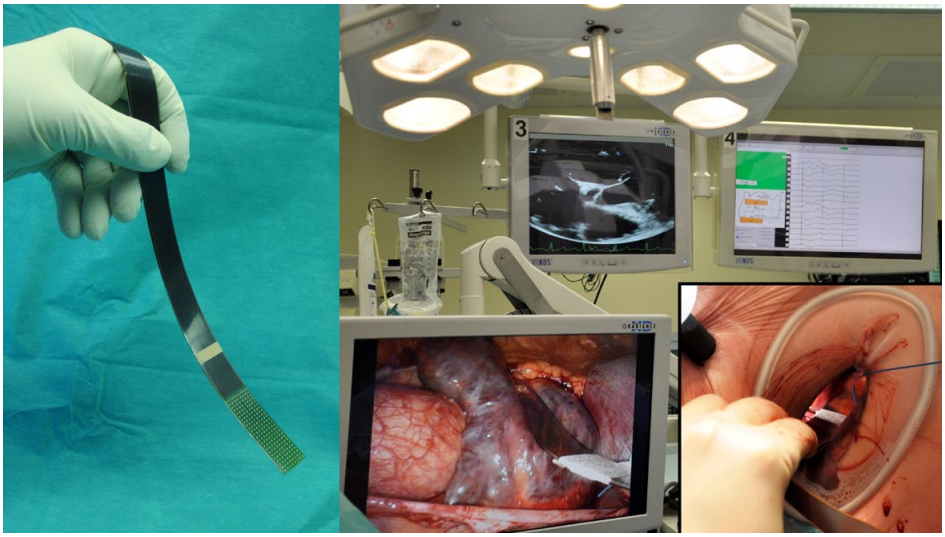

Figure 1. Epicardial mapping during minimally invasive surgery.
Left: The flexible 192-electrode mapping array fixed on a bendable steel spatula. Right: Epicardial mapping during a minimally invasive surgical procedure.

For mapping, the electrode array is moved along imaginary lines to directly record electric potentials on the atrial surface. At the right atrium, the array is positioned perpendicular to the caval veins and recording starts at the top of the right atrial appendage, near the superior caval vein (Figure 2). After each 5 to 10-second recording, the array is moved further downwards over the right atrial appendage until the cavotricuspid isthmus is reached. The intercaval area including the terminal crest is mapped from Waterston's groove, with the array positioned in the longitudinal direction of the caval veins. The posterior left atrium is mapped below the inferior pulmonary veins along the atrioventricular groove from the left inferior pulmonary vein towards the right inferior pulmonary vein. Mapping of Bachmann's bundle was performed from the roof of the left atrium towards the superior cava-atrial junction. Then, by advancing the array past Bachmann's bundle, the left atrial appendage was reached and mapped from the tip to its base.

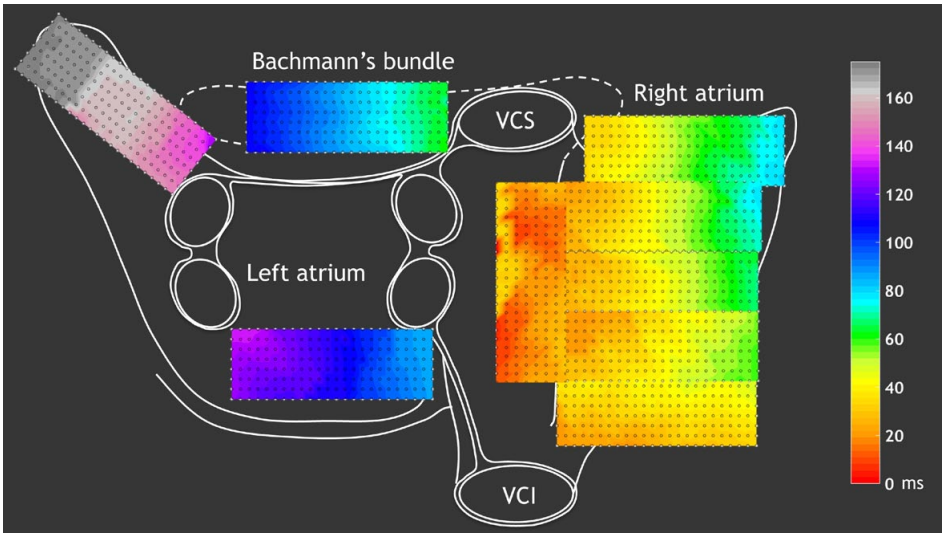

Figure 2. An overview of the high-resolution atrial activation pattern.
The color-coded activation map demonstrates the overall atrial activation pattern during sinus rhythm in high resolution.

Fixed high-rate pacing was performed at the right atrial appendage with the aim to induce atrial fibrillation and map atrial fibrillation patterns using the same protocol. If there was no spontaneous return of sinus rhythm after mapping of induced atrial fibrillation, sinus rhythm was restored with electrical cardioversion or atrial fibrillation stopped when cardioplegia was applied. The pacemaker wire and steel wire were removed and the operation proceeded as scheduled.

Postoperative course

Two patients did not have any arrhythmias or complications in the postoperative period, and the other patient had multiple episodes of postoperative atrial fibrillation, which converted spontaneously with amiodarone. Two weeks after surgery, this patient also developed Dressler syndrome which was successfully treated with medications. His atrial fibrillation episodes progressed to persistent atrial fibrillation 4 months after surgery and sinus rhythm was restored with electrical cardioversion .

DISCUSSION

Clinical results

The reported cases are the first experience with this technique performed using a minimally invasive surgical approach. However, our experience in a large study cohort of, now,

>500 patients with an open-heart surgical approach has demonstrated this mapping procedure to be safe, and it can be performed within 10 minutes with experienced personnel.[3]

Epicardial mapping

Epicardial mapping and ablation are being utilized nowadays for ventricular tachyarrhythmias to treat origin sites that cannot be reached endocardially. Recently, we demonstrated that asynchrony of the epicardial and endocardial atrial wall occurs during atrial fibrillation, and epicardial activation can remain undetected recording from the endocardial side alone.[4,5] Therefore, epicardial atrial mapping may be getting a more important role in the treatment of atrial fibrillation as well. Previous studies mapping atrial fibrillation epicardially were all performed during open-heart surgery and those arrays seem unsuitable for minimal invasive procedures.[6,7] The large and specifically shaped arrays of Lee et al. for simultaneous biatrial mapping seem difficult and time consuming to position with retractors.[6] The triangular shaped electrode with sides of approximately 4 cm in the study of Walters et al. will not be able to reach areas behind tight spaces such as the pulmonary vein area and Bachmann's bundle.[7] However, for clinical purposes, a minimally invasive approach would be preferred.

Advantages

One of the most important advantages of epicardial atrial mapping is that it has a higher resolution than endocardial atrial mapping. This feature is of great significance in the mapping of the complex patterns of electric activity during atrial fibrillation. The unorganized activation patterns of atrial fibrillation differ beat-to-beat, and waves decrease in size with persistence of atrial fibrillation.[8] Therefore, a high number of simultaneously acquired electrograms with small interelectrode spacing are required to map atrial fibrillation waves. Another advantage is that mapping can precisely evaluate the continuity of ablative lesions to pinpoint the exact location in case of a gap. If this technique is combined with an electroanatomical mapping system that can store the location of the site and guide the ablation tool[9], a gap can be located and treated accordingly. The minimally invasive approach makes high-resolution mapping potentially suitable for a much wider public of patients experiencing atrial fibrillation and not only patients needing cardiac surgery. A individually tailored approach could improve the success of atrial fibrillation therapy, which mapping of atrial fibrillation could provide by identifying for each patient, the remodeled atrial sites critical in supporting the persistence of atrial fibrillation and deliver targeted ablation therapy to those sites.[10] In this study, we demonstrated that qualitative high-resolution epicardial mapping during sinus rhythm and (induced) atrial fibrillation is feasible during minimally invasive cardiothoracic surgery.

Limitations

The standard incisions for minimally invasive mitral valve surgery do not provide access for epicardial mapping of the entire left atrium. The posterior left atrium below the pulmonary veins could only be reached in one of the three patients. The left atrium could possibly be reached (better) with an additional incision site at the left side. The atrial septum cannot be mapped with an epicardial approach.

Future directions

To implement high-resolution mapping guided ablation during surgery, electroanatomical mapping systems that can guide ablation tools as set-up in electrophysiology laboratories should be made available for high-resolution mapping arrays.[9] In addition, more research on atrial fibrillation mapping is required to find mechanisms sustaining atrial fibrillation and possible target sites to stop it. This may also result in the decision to not ablate a patient if mapping demonstrates the atria are too electrically diseased for intervention to be successful.

REFERENCES

1. Iwasaki YK, Nishida K, Kato T, Nattel S. Atrial fibrillation pathophysiology: implications for management. Circulation. 2011;124:2264-74.
2. Grigioni F, Avierinos JF, Ling LH, Scott CG, Bailey KR, Tajik AJ, Frye RL, Enriquez-Sarano M. Atrial fibrillation complicating the course of degenerative mitral regurgitation: determinants and long-term outcome. J Am Coll Cardiol. 2002;40:84-92.
3. Yaksh A, van der Does LJ, Kik C, Knops P, Oei FB, van de Woestijne PC, Bekkers JA, Bogers AJ, Allessie MA, de Groot NM. A novel intra-operative, high-resolution atrial mapping approach. J Interv Card Electrophysiol. 2015;44:221-5.
4. de Groot N, van der Does L, Yaksh A, Lanters E, Teuwen C, Knops P, van de Woestijne P, Bekkers J, Kik C, Bogers A, Allessie M. Direct Proof of Endo-Epicardial Asynchrony of the Atrial Wall During Atrial Fibrillation in Humans. Circ Arrhythmia Electrophysiol. 2016;9:e003648.
5. van der Does LJ, Knops P, Teuwen CP, Serban C, Starreveld R, Lanters EA, Mouws EM, Kik C, Bogers AJ, de Groot NM. Unipolar atrial electrogram morphology from an epicardial and endocardial perspective. Heart Rhythm. 2018;15:879-887.
6. Lee S, Sahadevan J, Khrestian CM, Markowitz A, Waldo AL. Characterization of Foci and Breakthrough Sites During Persistent and Long-Standing Persistent Atrial Fibrillation in Patients: Studies Using High-Density (510-512 Electrodes) Biatrial Epicardial Mapping. J Am Heart Assoc. 2017;6:e005274.
7. Walters TE, Lee G, Spence S, Kalman JM. The effect of electrode density on the interpretation of atrial activation patterns in epicardial mapping of human persistent atrial fibrillation. Heart Rhythm. 2016;13:1215-20.
8. Allessie MA, de Groot NM, Houben RP, Schotten U, Boersma E, Smeets JL, Crijns HJ. Electropathological substrate of long-standing persistent atrial fibrillation in patients with structural heart disease: longitudinal dissociation. Circ Arrhythm Electrophysiol. 2010;3:606-15.
9. Knackstedt C, Schauerte P, Kirchhof P. Electro-anatomic mapping systems in arrhythmias. Europace. 2008;10:iii28-34.
10. van der Does LJ, Yaksh A, Kik C, Knops P, Lanters EA, Teuwen CP, Oei FB, van de Woestijne PC, Bekkers JA, Bogers AJ, Allessie MA, de Groot NM. QUest for the Arrhythmogenic Substrate of Atrial fibRillation in Patients Undergoing Cardiac Surgery (QUASAR Study): Rationale and Design. J Cardiovasc Transl Res. 2016;9:194-201.