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Spatial distribution of conduction disorders during sinus rhythm☆,☆☆

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ABSTRACT

Background: Length of lines of conduction block (CB) during sinus rhythm (SR) at Bachmann's bundle (BB) is associated with atrial fibrillation (AF). However, it is unknown whether extensiveness of CB at BB represents CB elsewhere in the atria. We aim to investigate during SR 1) the spatial distribution and extensiveness of CB 2) whether there is a predilection site for CB and 3) the association between CB and incidence of post-operative AF.
Methods: During SR, epicardial mapping of the right atrium (RA), BB and left atrium was performed in 209 patients with coronary artery disease. The amount of conduction delay (CD, Δlocal activation time ≥ 7 ms) and CB (Δ ≥ 12 ms) was quantified as % of the mapping area. Atrial regions were compared to identify potential predilection sites for CD/CB. Correlations between CD/CB and clinical characteristics were tested.
Results: Areas with CD or CB were present in all patients, overall prevalence was respectively 1.4(0.2–4.0) % and 1.3(0.1–4.3) %. Extensiveness and spatial distribution of CD/CB varied considerably, however occurred mainly at the superior intercaval RA. Of all clinicalcharacteristics, CD/CB only correlated weakly with age and diabetes ($P < 0.05$). A 1% increase in CD or CB caused a 1.1–1.5ms prolongation of the activation time ($P < 0.001$). There was no correlation between CD/CB and post-operative AF.
Conclusion: CD/CB during SR in CABG patients with electrically non-remodeled atria show considerable intra-atrial, but also inter-individual variation. Despite these differences, a predilection site is present at the superior intercaval RA. Extensiveness of CB at the superior intercaval RA or BB does not reflect CB elsewhere in the atria and is not associated with post-operative AF.

1. Introduction

Conduction block (CB) is associated with genesis and perpetuation of cardiac arrhythmias [1]. Previous studies have demonstrated that longitudinal dissociation in conduction is one of the key elements of the substrate underlying longstanding persistent atrial fibrillation (AF) in humans [2]. Since atrial CB on a high resolution scale is mainly studied during AF, data on CB during sinus rhythm (SR) are scarce. If CB is already present during SR, it is most likely structural in nature. Some studies suggest an association between CB during SR and (development of) AF [3,4].

Zaman [4] demonstrated the relevance of CB at the right atrium (RA) for intra-operative AF inducibility, although indirectly. Epicardial mapping was performed in 34 patients without a history of AF, undergoing coronary artery bypass grafting (CABG). The degree of fractionation of SR electrograms, most likely due to local CB, was higher in patients in whom AF was inducible than in non-inducible patients (96.2 vs. 74.9 Hz) [4]. During SR, the length of lines of CB at Bachmann's Bundle (BB) was associated with (development of) AF [3]. For this study, epicardial mapping studies of BB were performed in 185 patients with various underlying cardiac diseases. However, CB at the remainder of the right and left atria was not investigated and it is unknown whether CB at BB or RA is representative for CB elsewhere in the atria.

Hence, although the relevance of CB during SR for AF has been investigated at BB and RA, data on the physiological variation of CB at the entire atria are absent. We therefore aim to investigate 1) the spatial distribution and extensiveness of CB during SR and 2) whether there is a predilection site for CB during SR. This is evaluated by intra-operative, high-resolution

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epicardial mapping of the entire (electrically non-remodeled) atria in CABG patients without a history of AF. In addition, we examined if CB during SR is associated with development of early-post operative AF (PoAF).

2. Methods

2.1. Study population

The study population consisted of patients without a history of AF undergoing elective CABG for coronary artery disease. This study is part of the QUASAR [5] project and HALT&REVERSE [6] project. Both studies are approved by the institutional Medical Ethical Committee (MEC-2010-054/MEC-2014-393) and all patients provided written informed consent. The study was carried out according to the principles of the Declaration of Helsinki. Patient characteristics were obtained from electronic patients files.

2.2. Mapping procedure

Epicardial mapping was performed prior to commencement to extra-corporal circulation [7]. A pacemaker wire attached to the terminal crest served as a temporal, bipolar reference electrode and a steel wire fixed to the subcutaneous tissue was used as an indifferent electrode. The mapping procedure was performed with electrode arrays consisting of 128 (diameter 0.65 mm) or 192 unipolar electrodes (diameter 0.45 mm). Inter-electrode distances of both devices are 2.0 mm. Epicardial mapping during SR was conducted following a predefined mapping scheme as demonstrated in the left upper panel in Fig. 1, covering the entire epicardial surface of the RA, BB and left atrium (LA). The electrode array is shifted along imaginary lines with a fixed orientation at each position. We tried to avoid omission of areas at the expense of possible overlap between adjacent mapping sites. Mapping of the RA started at the cavo-tricuspid isthmus and continued perpendicular to the caval veins towards the right atrial appendage. BB is mapped from the tip of the left atrial appendage across the roof of the LA, behind the aorta towards the superior cavo-atrial junction. Mapping of the LA is performed from the lower border of the left inferior pulmonary vein (PV) along the left atrioventricular groove (LAVG) towards the left atrial appendage. The PV area (PVA) is mapped from the sinus transversus fold in between the right and left PV towards the LAVG [3]. Five seconds of SR were recorded from every mapping site, including unipolar epicardial electrograms, a bipolar reference electrogram, a surface ECG lead and a calibration signal of 2 mV and 1000 ms. Data was stored on hard disk after amplification (gain 1000), filtering (bandwidth 0.5–400 Hz), sampling (1 KHz) and analogue to digital conversion (16 bits).

2.3. Mapping data analysis

The center upper panel of Fig. 1 shows a color-coded activation map of the RA free wall. Activation maps were constructed by annotating the steepest negative deflection of each extracellular potential, in case of a fractionated electrogram the steepest deflection is marked. Premature atrial complexes and aberrant beats were excluded. The averaged SR beat was used to quantify prevalence and amount of conduction delay (CD) and CB. For this purpose, differences in local activation times between neighboring electrodes were calculated. CD is defined as differences in local activation time of ≥7 ms and differences in local ≥12 ms as CB. In literature, the slowest conduction velocity during longitudinal propagation was measured around 20 cm/s [8]. A somewhat lower value of <18 cm/s was chosen in order to be consistent with previous mapping studies in which we observed fractionated electrograms and activation from another direction at the other site of the line of CB [9,10].

CD and CB are expressed as a percentage of the total available number of interelectrode connections. A more detailed description of the mapping data analysis is included in the supplemental materials.

To evaluate the spatial distribution of CD and CB, the atrial epicardial surface is subdivided in the following areas, which are also indicated in the right upper panel of Fig. 1: 1) superior intercaval RA, 2) superolateral RA, 3) inferior intercaval RA, 4) inferolateral RA, 5) BB, 6) PVAand 7) LAVG. Within these areas, CD and CB were quantified per quadrants of 1cm^2. Quadrants were excluded for analysis when ≥50% of the recorded electrograms had a slope threshold ≤80 mV/s and a signal-noise ratio < 4.

The lower panels of Fig. 1 show an example of the reconstruction of CB maps. The left lower panel demonstrates isochronal maps; arrows indicate main trajectories of the SR wavefront. Combined CB and CD maps (center lower panel) were derived from the isochronal map and depict the spatial distribution of CD (blue lines) and CB (red lines). The median incidences (P50) of CD and CB in the entire atria were respectively 0.4% and 0.3%. The right lower panel indicates the amount of CB/cm^2 within the predefined atrial areas. Although rarely occurring in this patient, areas of CD or CB were found at various sites within the superior intercaval RA, BB and PVA.

2.4. Intra-operative inducibility of atrial fibrillation

Intra-operative AF induction was attempted in every patient, see supplemental materials.

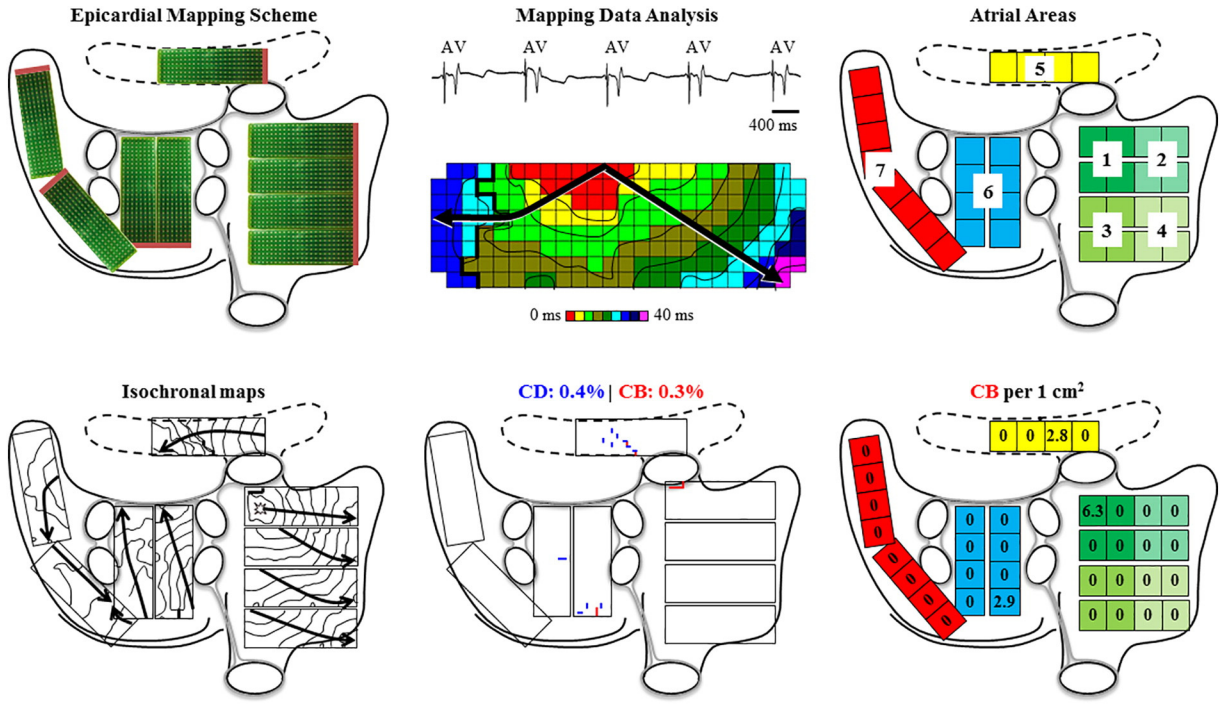

Fig. 1. Epicardial mapping during sinus rhythm. Upper left panel: projection of the 192-unipolar electrode array on a schematic posterior view of the atria. Upper center panel: epicardial, unipolar sinus rhythm potentials recorded during 5 s of sinus rhythm (A = atrial potential, V = farfield ventricular signal) and corresponding color-coded activation map. Isochrones are drawn at 5 ms intervals, arrow indicates the main trajectory of the wavefront, thick black lines represent areas of CB. Right upper panel: predefined atrial areas indicated by separate colors, see text for detailed explanation. 1) superior intercaval RA, 2) superolateral RA, 3) inferior intercaval RA, 4) inferolateral RA, 5) BB, 6) PVA and 7) LAVG. Lower left panel: local activation pattern with isochronal maps. Isochrones are drawn at 5 ms. Lower center panel: combined CD map and CB map demonstrating the lengths, orientations and spatial distributionof CD (blue lines, median prevalence 0.4%) and CB (red lines, median prevalence 0.3%). Lower right panel: spatial distribution of CB per 1cm^2. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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