

Tissue thickness measured with dielectric-based technology during radiofrequency catheter ablation

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KEYWORDS

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Radiofrequency catheter ablation of the cavotricuspid isthmus is the standard treatment for patients suffering from typical atrial flutter. The aim of this study was to test the feasibility of tissue thickness and lesion transmural measurement by a novel dielectric system. This was a retrospective multicentric non-randomized open-label, single-arm study. The atrial wall thickness was significantly higher close to the tricuspid annulus than close to the inferior vena cava and a trend towards a progressive decrease of atrial wall thickness was observed moving the mapping catheter from the tricuspid valve to the inferior vena cava. The possibility to visualize the tissue thickness could modify the way to deliver radiofrequency energy, allowing a tailored approach in cardiac ablation procedures.

Introduction

Cavotricuspid isthmus (CTI) ablation is the preferred treatment for typical atrial flutter (AFL). Bidirectional conduction block across the CTI is the endpoint for the ablation of typical AFL. However, despite the use of irrigated or large-tip ablation catheters, recurrences may occur in 10–15% of cases.^{1–4}

Cavotricuspid isthmus wall thickness is a known determinant of radiofrequency (RF) ablation lesion transmural-ity. Previous studies have demonstrated more frequent CTI reconnection in regions of increased atrial wall thickness. The KODEX-EPD is a new imaging and mapping system (EPD Solutions, a Philips company) which uses a novel technology based on dielectric imaging to determine wall-thickness measurements in real time. The Wall Viewer (WV) algorithm is a new dielectric-based method for measuring tissue thickness based on a pre-trained

algorithm model that incorporates real-time catheter position and local dielectric tissue interrogation by catheter electrodes. The aim of this study is to test whether tissue thickness and lesion transmural-ity measured by the novel dielectric system can predict the efficacy of CTI ablation in patients with typical AFL.

Methods

This is a retrospective multicentric non-randomized open-label, single-arm study. This study was approved by the institutional review committee, and all patients signed informed consents.

The Kodex version 1.5.1 used to perform this type of analysis has the tissue thickness measurement (WV) activated. It is a version not commercially available yet but used only for cases replay and research purpose, not used in clinical practice.

The study population consisted of 27 consecutive patients, suffering from symptomatic paroxysmal or persistent CTI-dependent, counterclockwise, and clockwise AFL,

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undergoing a first catheter ablation between April 2021 and November 2022.

Participants included patients who were ≥ 18 years old, with at least an episode of AFL regardless of its duration scheduled for CTI ablation.

Exclusion criteria were: inability to give informed consent, previous AFL catheter ablation, AFL attributable to a cardiac or noncardiac reversible cause, programmed heart transplant or other cardiac surgery, previous cardiac surgery in the last 3 months, known atrial myxoma, unstable angina, unstable heart failure, severe cardiac valvular defects, tricuspid valve replacement, atrial septum defect, life expectancy < 12 months, pregnancy, and breastfeeding.

The technical characteristics of the KODEX-EPD imaging system have been already described.⁵ Briefly the system creates high-resolution images of cardiac anatomy by exploiting the distinct dielectric properties of biological tissue. The system receives and analyses the subtle electrical field transmission and reflection from all catheter electrodes as they are manipulated in the cardiac chambers. Structures such as the endocardial atrial surface, cardiac veins, and heart valves cause marked gradients in the electrical field. This ‘bending of the electrical field’ is sensed by the system and used to calculate the geometric characteristics of the three-dimensional (3D) image. With this technique, the KODEX-EPD imaging system can collect anatomic information without immediate physical surface contact a few millimetres ahead of the catheter electrodes, resulting in a certain degree of ‘far-field imaging’.⁶ The WV function is measured by assessing a series of dielectric signals derived directly from

real-time local interrogation of the catheter-tissue interface. The electric-field values (e.g. the field shape in the spectrum of frequencies) based on the interaction with the dielectric tissue characteristics are acquired when the ablation catheter is stable and engaged with the endocardial wall momentarily (> 1.5 s). Extreme outliers are filtered out by regional dielectric normality distribution tables. WV is displayed in millimetres, with either high or low confidence levels per met or unmet prerequisite acquisition criteria (e.g. tissue engagement), respectively, and it is displayed as a colour code scale (Figure 1).

All procedures were performed under local anaesthesia implemented with sedation. Vitamin K antagonist treatment (with a target INR of 2.0–3.0 on the day of the procedure) or non-vitamin K anticoagulants were uninterrupted.

Through femoral venous access an open-irrigated tip catheter (Celsius ThermoCool®; EzSteer Biosense Webster, Diamond Bar, CA, USA or MAP-iT APT; Access Point Technologies, USA) and a decapolar electrode catheter were inserted, the use of a third catheter (for example a duodecapolar catheter) was also admitted according to operator’s preferences. After reconstruction of the right atrium using 3D electro-anatomic imaging and mapping system (Kodex-EPD), a decapolar electrode catheter was positioned in the coronary sinus. The anatomy of the CTI was accurately identified using the mapping catheter. Prior to ablation, WV measurements were taken with an ablation catheter (Celsius ThermoCool® or MAP-iT APT) along the CTI by blinded operators, and then examined.

The ablation was performed during ongoing AFL, or during CS pacing in patients who were in sinus rhythm. Before ablation, entrainment was used to rule out the

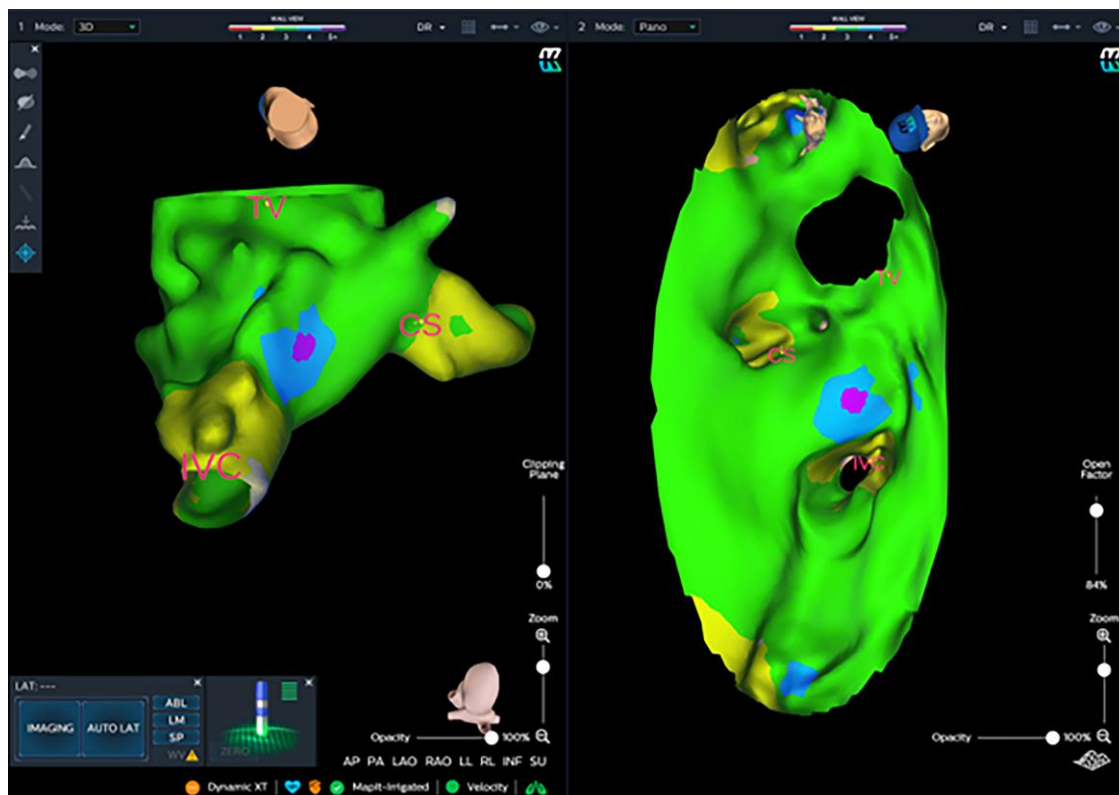


Figure 1 Views of right atrium KODEX-EPD imaging system reconstruction, inferior view on the left and PANO view on the right. A colour scale code was used to distinguish the different thickness.

Table 1 Patient population

Clinical and procedural characteristics	Total (n = 27)
Age, years	65.3 ± 8.3
Male, n (%)	19 (70.4)
Body mass index	28.3 ± 6.3
Hypertension, %	73
Coronary artery disease, %	3.7
Mean RF time, s	645 ± 318
Number of RF pulses	24 ± 8
Fluoro time, s	650 ± 332
Procedural time, min	49.06 ± 21.38
CTI length, mm	29.4 ± 4.5

independence of the arrhythmia on CTI. Patients with an atypical AFL were not included in the study.

A suitable starting point for the ablation, in the proximity of the tricuspid valve, and a final location in the junction between the inferior vena cava and the right atrium, were precisely defined based on electrograms recorded and their distance was measured.

Subsequently, a ‘point-by-point’ CTI ablation was performed and interlesion distance measurement ≤6 mm was monitored with the imaging system. Radiofrequency power was set between 30 and 40 W. Real-time automated display of RF applications was used with predefined settings of catheter stability (3 mm for 3 s) for every single point, points were coloured in dark red when an impedance drop of >8 Ohms was achieved.

Once the CTI linear ablation was concluded, conduction block (first pass block) was assessed immediately. In the absence of bidirectional CTI block, touch-up ablations were delivered until CTI block was achieved. Resumption of CTI conduction was evaluated at 20 min after the ablation. In case of conduction recovery, CTI was newly ablated targeting the points of electrical breakthrough. Bidirectional conduction block after CTI ablation was confirmed by demonstrating counterclockwise activation sequence over the lateral right atrium during pacing from the ostium of the coronary sinus, and a cranial to caudal sequence over the right atrial septum during pacing from the lateral edge of the ablation line or the low lateral right atrium.

A 12-lead electrocardiogram (ECG) documenting heart rhythm was obtained at hospital discharge. Patients were instructed to contact immediately the site in case of symptoms suggestive of recurrences. A 6-month ambulatory visit was scheduled to evaluate: 12-lead ECG, symptoms, recurrence of Afl and atrial fibrillation (AF), and all-cause hospitalizations.

Study endpoints

Primary endpoint of the study was evaluation of impact of transmuralty on:

- CTI conduction block after ablation
- Durable CTI block after 20 min waiting time
- Global acute success of the procedure (rate of persistent CTI block)

Secondary endpoint was impact of transmuralty on:

- Overall procedural time
- Overall RF time
- Overall fluoroscopy time

Table 2 Cavotricuspid isthmus wall-thickness pattern for each patient

Patient:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Mean	STDEV
TV	3.3	4.3	4.2	3.7	3.2	3.4	4.1	3.5	3.1	3.2	3.5	2.7	4	3.7	3.5	4.3	3.5	4.1	3.8	3.5	3.5	3.9	4.3	3.8	3.3	3.5	3.3	3.6	0.4
	3.0	4.2	3.6	3.2	3.3	3.3	3.7	2.6	3.1	3.3	3.4	2.5	4.1	3.6	3.5	4	3.3	3.9	3.5	3.3	3.4	3.7	3.9	3.1	3.5	3.8	3.1	3.4	0.4
	2.8	4	2.5	4	3.4	3	2.4	3	3.4	2.7	3.1	2.5	4	3.4	3.6	3.8	2.5	3.8	2.8	3.8	2.8	3.3	3.1	3.3	3.7	3.3	2.8	3.2	0.5
	2.5	4	2.3	3.6	3.2	3.3	2.7	3	3.1	3.2	3.2	2.5	3.6	3.6	3.5	3.6	2.6	3.7	2.5	3.3	3.1	3.2	2.9	3.1	3.3	2.8	2.6	3.1	0.4
	2.5	3.2	3.3	3.4	3	2.3	3	3.2	3.3	3.1	2.7	2.6	3.2	3.5	3.5	3.7	2.3	3.3	3.2	3.1	2.7	2.1	2.7	3.5	2.8	2.7	2.5	3.0	0.4
	3.4	4.2	3.3	3	3.1	3.5	3.1	2.7	2.9	3.5	2.6	2.4	3.5	3	3.9	3.6	2.9	3.5	3.4	3.3	3.3	2.8	2.8	2.6	2.7	2.6	2.3	3.1	0.5
	3.0	3.5	2.6	2.6	2.9	2.9	3.1	3.5	3.1	4.3	3.1	2.6	2.4	2.8	3.8	3	2.8	3.6	2.7	2.8	2.7	3.3	2.9	2.9	2.6	3.1	2.2	3.0	0.5
	2.5	3.7	3.3	3.2	2.9	2.9	2.5	3.3	3	3.6	3.1	2.7	2	3	3.7	2.6	2.6	3.5	3.1	2.9	3.2	3.2	2.7	2.8	2.8	3.3	2.8	3.0	0.4
	2.4	3.2	2.2	2.9	3.1	3	2.7	2.5	2.9	2.9	2.5	2.6	2.3	2.6	3.3	3	2.5	3.3	2	2.8	3	3.1	3.1	2.7	2.7	3.4	3.1	2.8	0.4
	2.2	3.6	2.2	2.6	3	3	2.6	2.8	2.3	2.3	2.3	2.4	2.5	3.1	3.2	2.9	2.4	3.5	2.3	2.7	2.7	3.3	2.9	3.1	2.8	3.6	3.3	2.8	0.4
	2.7	3.5	2.3	2.6	2.8	3.1	2.4	2.9	2.1	2.9	2.3	2.4	2.2	2.9	3.1	2.7	3.5	3.6	2.1	2.8	2.9	3.2	2.6	3.3	2.9	3.1	3.2	2.8	0.4
IVC	1.9	3.1	2.5	2.5	2.6	2.3	2.1	2.3	2	2.6	2.1	2.3	2.3	2.7	2.9	2.4	3.1	3.4	2.8	2.7	2.8	3.3	2.8	2.8	2.5	2.9	2.9	2.6	0.4

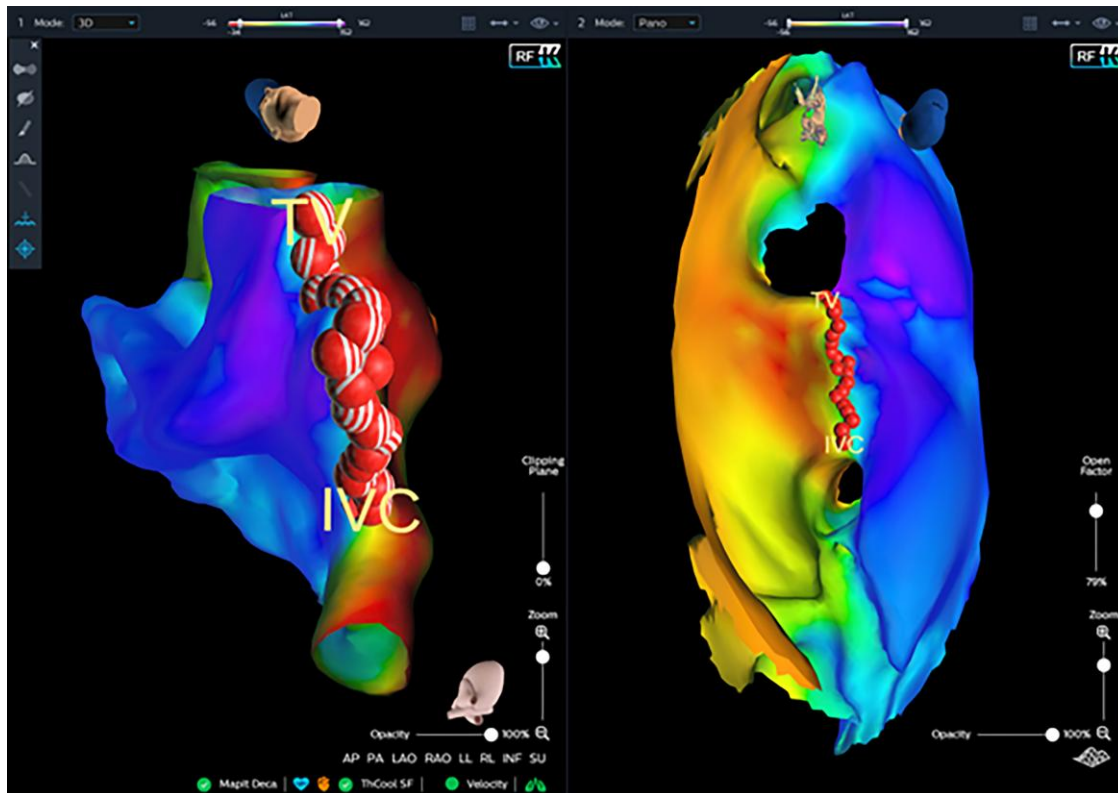


Figure 2 Views of right atrium KODEX-EPD imaging system reconstruction, inferior view on the left and PANO view on the right, ablation tags displayed in red colour if impedance drop was >8 Ohms. A colour scale code was used for local activation times (LAT) with purple for higher delays and red for lower delays in time.

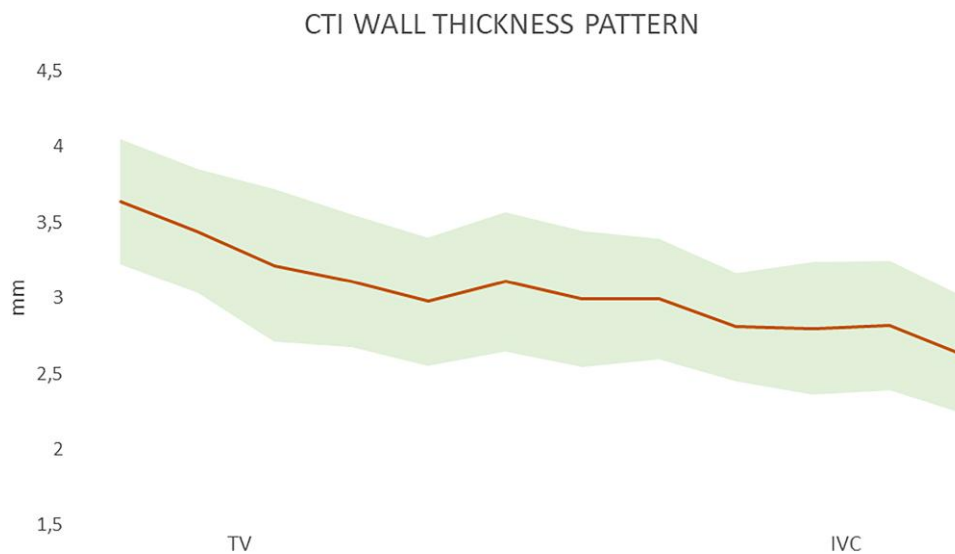


Figure 3 Atrial wall thickness measured by the ablation catheter. The position on the cavotricuspid isthmus is reported on the horizontal axis starting from the tricuspid valve (TV) ending to the inferior vena cava junction (IVC).

Statistical methods

All continuous data were expressed in terms of mean and the standard deviation, and the categorical data were expressed as frequency and percentages. For all tests, $P < 0.05$ was considered significant. All statistical analysis was performed using SPSS v.19.0 (IBM Corp., Armonk, NY, USA).

Results

Twenty-seven patients have been enrolled, the mean age was 65.3 ± 8.3 years, 19 (70.4%) were males. The mean body mass index was 28 ± 6.3 , 73% of the patients had hypertension, and 1 (3.7%) had coronary artery disease.

The mean procedure time was 49.06 ± 21.38 min, the mean fluoroscopic time was 650 ± 332 s, the mean RF time 645 ± 318 s, with a mean number of RF pulses of 24 ± 8 . The mean CTI length was 29.4 ± 4.5 mm (Table 1). The atrial wall thickness (Table 2) was significantly higher close to the tricuspid annulus than close to the inferior vena cava (3.64 ± 0.41 vs. 2.61 ± 0.39 mm, $P < 0.05$) and a trend towards a progressive decrease of atrial wall thickness was observed moving the mapping catheter from the tricuspid valve to the inferior vena cava (Figure 2). Acute bidirectional CTI block was achieved in all patients without any complications (Figure 3).

Discussion

In our series, we first describe a new mapping technology that allows atrial wall-thickness measurement. As expected, the wall thickness was higher close the tricuspid annulus and lower towards the inferior vena cava.⁷ Similar data have been reported in two small series on terminally anaesthetized swine,⁸ in a preliminary study with 8 patients,⁹ and in a clinical study with 16 patients¹⁰ undergoing CTI ablation, in which KODEX-EPD imaging system wall-thickness measures were comparable with computed tomography and intracardiac echocardiography.

Besides tissue thickness, the atrial wall composition seems to be an important modulator, since there is considerable variability in the connective tissue amount, and it can influence the total RF energy needed to create a bidirectional block. Moreover, in the posterior third of the CTI catheter contact can be poor if a prominent Eustachian ridge is present.

Thus, despite significant anatomic variability between patients, the tricuspid aspect of the CTI is thicker and has the highest muscle content. Consequently, the amount of RF energy that should be delivered in the tricuspid aspect should be also higher resulting in higher impedance drop when compared with middle and caval portions. In most of the cases, the total energy delivery during a single lesion application is due to operator's decision (even when a quality lesion assessment index is adopted) and it is not based on wall thickness. This is done to prevent complications like 'steam pop', especially when steep impedance drop is observed, but sometimes multiple lesions are needed to achieve bidirectional block in CTI ablation. It has been argued that a non-transmural lesion may be sufficient to create conduction delay across the CTI to prevent typical AFL recurrences, but future studies including histological examination of the ablated CTI are needed to address this question.¹¹

Conclusions

In this multicentre and prospective registry, we observed a progressive decrease of atrial wall thickness from tricuspid aspect to inferior vena cava. The possibility to calculate the

tissue thickness could modify the way to deliver RF energy, allowing a tailored approach by increasing the efficiency and reducing the risks of ablation procedures.

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Conflict of interest: None declared.

Data availability

No new data were generated or analysed in support of this research.

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