A comparison between multipolar mapping and conventional mapping of atrial tachycardias in the context of atrial fibrillation ablation

Comparaison entre cartographie multi-points et cartographie point-par-point des tachycardies atrales survenant après ablation de fibrillation atriale

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Summary

Background. — Activation mapping can be challenging and time-consuming in patients with multiple atrial tachycardias (ATs).
Aims. — To compare multielectrode mapping using a dedicated mapping catheter — PentaRay (Biosense Webster Inc.) — and the conventional technique for mapping ATs in the context of atrial fibrillation (AF) ablation.
Methods. — All procedures where PentaRay mapping of AT were used — after or during persistent AF ablation — were analysed. These were compared to a historical group — using conventional mapping.
Results. — A mean of 449 ± 520 points within 14 ± 6 min were acquired per AT in the PentaRay group (n = 17) versus 42 ± 18 points (P < 0.0001) within 33 ± 25 min (P = 0.04) in the conventional group (n = 17). All 25 AT isthmuses were easily identified and ablated in the PentaRay group.

KEYWORDS

Multielectrode mapping; Atrial tachycardia; Atrial fibrillation; Activation mapping

Abbreviations: AF, atrial fibrillation; AT, atrial tachycardia; ECG, electrocardiogram; LA, left atrium/atrial; MEM, multielectrode mapping; PV, pulmonary vein.
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Background

Percutaneous radiofrequency catheter ablation is a validated technique for the treatment of patients with symptomatic paroxysmal/persistent atrial fibrillation (AF) according to recent guidelines [1]. The strategy for persistent AF ablation is still a subject of debate, Scherr et al. have reported the importance of periprocedural AF termination into sinus rhythm with or without an intermediate transformation into atrial tachycardias (ATs) [2]. The incidence of ATs after AF ablation ranges from 3 to 29%, according to different studies [3–5]. AT can be more symptomatic than the initial underlying AF, leading — in most cases — to a repeat radiofrequency catheter ablation procedure. Post-AF ablation ATs can manifest themselves with an electrocardiogram (ECG) suggesting atrial flutter [6], with different possible mechanisms: either macroreentrant or focal (localized microreentry or automaticity) [7]. Electrophysiological tools for AT ablation include entrainment and activation mapping using three-dimensional electroanatomical mapping systems. The conventional method consists of an operator-dependent acquisition of electrogams by a single pair of electrodes (using an ablation catheter) according to a chosen and predefined intracardiac reference. However, this method can be challenging and time-consuming in case of multiple successive AT circuits. Recently, a multipolar mapping catheter has been developed for multi-electrogram acquisition (PentaRay, Biosense Webster Inc., Diamond Bar, CA, USA). A recent study has reported the superiority of multielectrode mapping (MEM) — in terms of acute procedural success — in comparison with the conventional point-by-point strategy [8]. However, whether the long-term outcome of this strategy is superior to the conventional method is not yet known.

We aimed to compare MEM using a PentaRay catheter with the conventional ablation catheter technique for mapping AT, and assessed the long-term outcome of this strategy.

(100%) versus 20/23 (87%) in the conventional group ($P=0.056$). The ablation time was shorter in the PentaRay group (760 ± 540 vs 1347 ± 962 s; $P=0.037$). However, procedure and fluoroscopy times were not significantly different between the PentaRay and conventional groups: 253 ± 77 vs 267 ± 73 min ($P=0.80$) and 13.1 ± 8.0 min vs 15.1 ± 10.0 min ($P=0.98$), respectively. Recurrence occurred in less patients in the PentaRay group (0 vs 23.5%; $P=0.033$) during a mean follow-up of nearly 1 year.

Conclusion. — In patients with multiple ATs, multielectrode PentaRay mapping was faster than the conventional technique, with less radiofrequency delivery and a better mid-term outcome.

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Methods

Patient selection

Consecutive patients were included if they underwent radiofrequency ablation for persistent AF and converted to AT during the same procedure, or if AT ablation occurred after an initial AF ablation index procedure. Patients were recruited between June 2014 and June 2015 (in the PentaRay group) at the Princess Grace Hospital (Monaco). Before June 2014, all mapping procedures were performed conventionally (patients recruited from June 2013 to June 2014); after June 2015, when the PentaRay catheter became commercially available, all procedures were performed with the PentaRay catheter. No randomization was performed between the PentaRay and conventional groups. Patients had conventional indications for ablation with symptomatic AT/AF and a failed attempt to maintain sinus rhythm with an antiarrhythmic drug. Exclusion criteria were hyperthyroidism, left atrial (LA) thrombus, decompenated heart failure, stroke, myocardial infarction or gastrointestinal bleeding within 4 weeks prior to the intervention, and life expectancy < 6 months. Written informed consent was obtained from all patients.

AF catheter ablation

Procedures were performed with vitamin K antagonist continuation (with a target international normalized ratio of 2.0–3.0) or uninterrupted direct oral anticoagulant (dabigatran, rivaroxaban or apixaban) under conscious sedation or general anaesthesia in a fasting state. All catheters were advanced via the femoral vein using ultrasound-guided puncture [9]. A 6F steerable decapolar catheter (Irvine Bio Inc., St. Jude Medical, Inc., St. Paul, MN, USA) was positioned in the coronary sinus. After LA thrombus exclusion and trans-oesophageal guided double transseptal puncture, a multipolar catheter (PentaRay, 2.6-2.2 mm interelectrode spacing, 1 mm electrodes) was advanced within a sheath into the LA (Preface, Biosense Webster Inc.). Intravenous heparin was administered immediately after the insertion of the femoral sheaths, and continuously given to maintain an activated clotting time of 300–350 s throughout the procedure. A 3.5 mm open-irrigated magnetic ablation catheter (Navistar Thermocool RMT, Biosense Webster Inc.) or contact-force sensing catheter (Smart Touch, Biosense Webster Inc.) was then advanced through an SL1 sheath (St. Jude Medical, Inc.) into the LA in both groups.

Circumferential pulmonary vein (PV) isolation was performed using a three-dimensional mapping system (Carto 3, Biosense Webster Inc.) in conjunction with the integrated computed tomography image of the LA and real-time fluoroscopy. The radiofrequency generator (Stockert, Biosense Webster Inc.) was set to temperature-controlled radiofrequency delivery with a target temperature of 42 °C and nominal power limits of 40 W (flow 30 mL/min) and 30 W (flow 17 mL/min) at the posterior LA wall. Electrical isolation of all PVs defined as bidirectional conduction block was proven by the PentaRay catheter. During procedures performed under general anaesthesia, an oesophageal probe was inserted for luminal oesophageal temperature monitor-

ing and its height was constantly adjusted under fluoroscopy to be as close as possible to the position of the catheter tip. Complex fractionated atrial electrograms ablation and other lines (i.e. mitral isthmus, roof and/or cavitricuspid isthmus lines) aiming at block completion were performed in case of persistent AF.

Mapping and ablation of AT

During AT, based on analysis of surface ECG atrial wave morphology and activation sequence on the coronary sinus catheter, the strategy consisted of activation mapping using the PentaRay or the conventional technique with an electroanatomical system, in the right atrium and/or LA. Sites including fractionated electrograms, double potentials (≥ 50 ms), and very low amplitude electrograms (< 0.05 mV), as well as atrial scars, were systematically labelled on the map. All acquired points were manually checked and annotated in both groups. Care was taken to annotate — for each acquired point — the local activation time according to the steepest negative deflection on the unipolar signals with the conventional catheter. After obtaining a region of interest, entrainment manoeuvres were performed at a cycle length 20 ms shorter than of the tachycardia to identify sites located within the reentry circuit (after confirming the chamber of origin). In the PentaRay group, annotation was made based on the peak of the positive deflection of the bipolar signals on the multipolar catheter. The critical isthmus or focal origin were specifically targeted, the final endpoint of each procedure being sinus rhythm. The mechanism of AT was considered as a macroreentry if activation mapping accounted for at least 90% of the tachycardia cycle length and if the diameter of the reentry circuit was ≥ 3 cm [10]. The mechanism was considered to be caused by a small reentry circuit if the circuit accounted for 75–90% of the AT cycle length and the diameter of the circuit was < 3 cm. A focal mechanism was confirmed if mapping showed centrifugal activation from a central source [11]. All procedures were performed by two experienced electrophysiologists.

Acute success was defined as termination of any inducible AT with sinus rhythm resumption. Reinduction manoeuvres were systematically performed until non-inducibility. An ablation-induced transformation to another AT was presumed if a sustained change in cycle length (> 20 ms), intracardiac activation pattern (on the coronary sinus catheter) and surface ECG occurred. The endpoint also included the demonstration of isthmus block in patients who benefited from a mitral isthmus line and/or roof line.

Follow-up

All patients were monitored in the hospital for ≥ 12 hours. On the day after the procedure, a 12-lead surface ECG was acquired to confirm normal sinus rhythm. Previous antiarrhythmic drugs were usually continued for ≥ 1 month after ablation. Oral anticoagulation was continued after the procedure. After hospital discharge, all patients were followed in an outpatient clinic every 3 months for ≥ 1 year. At each visit, patients were questioned for symptoms and documented arrhythmia recurrences, and current medication was assessed. Twenty-four-hour Holter recordings were performed at 1, 6 and 12 months after the last procedure. A
documented AF or left AT episode lasting > 30 s outside a blanking period of 3 months after the index or repeat procedure were considered as recurrent AF/AT.

Study endpoints

Clinical and procedural data were analysed in each group. The primary endpoint of this observational study was acute procedural success, defined as successful inducible AT ablation with sinus rhythm resumption. Secondary endpoints were long-term procedural success, defined as long-term freedom from any AT/AF episodes irrespective of symptoms after the index procedure during 12 months of follow-up without antiarrhythmic drugs. Further secondary endpoints were procedure duration, radiofrequency current application duration, fluoroscopy time and procedure-related complications (death, atrio-oesophageal fistulae, PV stenosis requiring intervention, pericardial tamponade, systemic embolic events, phrenic nerve paralysis, femoral vessel damage requiring surgery, blood transfusion or prolongation of hospitalization).

Statistical analysis

Statistical analysis was performed with GraphPad Prism 5 (San Diego, CA, USA) and STATA 12 (STATA Corp, College Station, TX, USA). Quantitative variables are expressed as mean ± standard deviation (SD). Continuous variables were compared between groups using an unpaired Student’s t test for normally distributed interval variables and Wilcoxon-Mann-Whitney test for variables without a normal distribution. Categorical data were compared by the χ² test. A two-tailed P value < 0.05 was considered statistically significant.

Results

Patient population

A total of 34 patients were analysed (17 in each group). Patient characteristics are summarized in Table 1. There were no significant differences between the two groups concerning clinical characteristics or LA echographic parameters.

Comparison between the PentaRay and conventional techniques

A mean ± SD number of 449 ± 520 points within 14 ± 6 min were acquired per AT in the PentaRay group compared with 42 ± 18 points (P < 0.0001) within 33 ± 25 min (P = 0.04) in the conventional group (Table 2). A mean of 1.47 ATs per patient were analysed in the PentaRay group, versus 1.35 ATs per patient in the conventional group. Owing to far better mapping resolution, all AT isthmuses (n = 25) were easily identified and ablated in the PentaRay group (100%) versus 20/23 (87.0%) in the NAV group (P = 0.056) (Table 2) (Fig. 1A and1B). Another example of a microreentrant circuit mapped with the PentaRay is depicted in a 37-year-old patient (Fig. 2).

Procedure and fluoroscopy times were not significantly different between the two groups (Table 2). In contrast, radiofrequency delivery time was significantly lower in the PentaRay versus to conventional group (760 ± 540 vs 1347 ± 962 s; P = 0.037).

A higher number of macroreentrant circuits were mapped in the PentaRay group versus the conventional group (20 vs 11; P = 0.019; Table 2). Mitral isthmus-dependent circuits were significantly increased in the PentaRay group (12 vs 6; P = 0.039), but the other circuit locations were not significantly different between the two groups.

During the index procedure, three patients in each group underwent a PV isolation as the first step of a persistent AF ablation procedure, before conversion into AT. The repeat procedure also included a PV re-isolation in seven patients of the PentaRay group versus four patients in the conventional group (P = 0.27).

Outcomes

Four patients (23.5%) had a recurrence in the conventional group (mean follow-up 351 ± 321 days) versus none in the PentaRay group (mean follow-up 351 ± 321 days) (P = 0.033) (Table 2). One patient had a successful repeat ablation 13 months after a LA macroreentry using a newly released electroanatomical system (Rhythmia, Boston Scientific, Natick, MA, USA). Two patients refused a repeat ablation and underwent a biventricular pacemaker implantation with atrioventricular node ablation. The fourth patient underwent another procedure 8 months later with PV re-isolation and three ATs (mapped with the conventional technique) including one circuit that could not be targeted because it was unstable and non-sustained. There were no complications in any of the patients undergoing AT/AF ablation.

Discussion

In the present study, MEM was faster and more accurate for AT ablation than the conventional technique.

AT occurring after AF ablation

The development of radiofrequency catheter ablation techniques for AF has led to the emergence of a very large number of regular ATs, which have to be managed by the electrophysiological community. Many of these tachycardias occurring after circumferential PV isolation are reentrant, and related to gaps in prior ablation lines. Perimital, roof-dependent and septal circuits are the most frequent mechanisms of LA macroreentrant ATs [4,5]. Radiofrequency ablation of these tachycardias can be challenging for many reasons. Perimital flutters, for instance, are difficult to treat, as mitral isthmus block completion has limited impact on arrhythmia recurrence [12].

Another difficulty can be encountered when managing unstable ATs (AT cessation with entrainment manoeuvres) or non-sustained ATs [13]. The presence of significant scarring coupled with fractionated and split electrograms may complicate the realization of activation and entrainment mapping. Finally, successive multiple AT circuits within the same patient can be difficult to target because mapping
Multipolar or conventional mapping of atrial tachycardias in AF ablation becomes very time-consuming (activation mapping and verification of conduction block after AT interruption). In this case, MEM can be advantageous in comparison with the conventional technique, independently from the mechanism of the arrhythmia considered, as it was also used for focal ATs and localized re-entries [13].

**Multielectrode technology**

The multielectrode catheters (PentaRay or Lasso, Biosense Webster Inc.; AFocus II HD, St. Jude Medical) are now widely used during AF ablation procedures at different levels — either during tachycardia or sinus rhythm — for:

- fast anatomical mapping and geometry creation of the LA shell [14];
- PV mapping and confirmation of persistent isolation;
- voltage mapping to identify reconnected or atrial fibrotic regions [8,15];
- complex fractionated atrial electrogram mapping using dedicated software during ongoing AF [16,17];
- activation mapping when AF terminates and converts into AT or voltage mapping during sinus rhythm to identify putative channels of activation [18];

### Table 1 Baseline characteristics.

<table>
<thead>
<tr>
<th></th>
<th>PentaRay group (n = 17)</th>
<th>Conventional group (n = 17)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>64.1 ± 11.4</td>
<td>62.9 ± 13.9</td>
<td>0.78</td>
</tr>
<tr>
<td>Men</td>
<td>12 (70.6)</td>
<td>11 (64.7)</td>
<td>0.71</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>4 (23.5)</td>
<td>1 (5.9)</td>
<td>0.15</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1 (5.9)</td>
<td>0</td>
<td>0.31</td>
</tr>
<tr>
<td>Stroke</td>
<td>1 (5.9)</td>
<td>1 (5.9)</td>
<td>1.00</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>4 (23.5)</td>
<td>2 (11.8)</td>
<td>0.37</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>0</td>
<td>3 (17.6)</td>
<td>0.07</td>
</tr>
<tr>
<td>CHA2DS2-VASc score</td>
<td>1.9 ± 1.6</td>
<td>1.4 ± 1.2</td>
<td>0.30</td>
</tr>
<tr>
<td>Left atrial diameter (mm)</td>
<td>43 ± 9.1</td>
<td>41 ± 7.0</td>
<td>0.41</td>
</tr>
<tr>
<td>Left atrial surface (cm²)</td>
<td>22.5 ± 4.1</td>
<td>20.8 ± 4.2</td>
<td>0.26</td>
</tr>
<tr>
<td>Persistent atrial fibrillation</td>
<td>7 (41.2)</td>
<td>3 (17.6)</td>
<td>0.13</td>
</tr>
<tr>
<td>Previous left atrial ablation procedure</td>
<td>12 (70.6)</td>
<td>11 (64.7)</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± standard deviation or number (%).

### Table 2 Procedural data and outcome.

<table>
<thead>
<tr>
<th></th>
<th>PentaRay group (n = 17)</th>
<th>Conventional group (n = 17)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of circuits</td>
<td>25</td>
<td>23</td>
<td>—</td>
</tr>
<tr>
<td>Macroreentry circuits mapped</td>
<td>20</td>
<td>11</td>
<td>0.019</td>
</tr>
<tr>
<td>Mitral isthmus</td>
<td>12</td>
<td>6</td>
<td>0.04</td>
</tr>
<tr>
<td>Roof</td>
<td>5</td>
<td>4</td>
<td>0.69</td>
</tr>
<tr>
<td>Cavitricuspid isthmus</td>
<td>2</td>
<td>0</td>
<td>0.14</td>
</tr>
<tr>
<td>Periatriotomy</td>
<td>1</td>
<td>0</td>
<td>0.31</td>
</tr>
<tr>
<td>Left atrial anterior wall</td>
<td>0</td>
<td>1</td>
<td>0.31</td>
</tr>
<tr>
<td>Focal circuits mapped</td>
<td>5</td>
<td>12</td>
<td>0.01</td>
</tr>
<tr>
<td>Left appendage base</td>
<td>1</td>
<td>2</td>
<td>0.54</td>
</tr>
<tr>
<td>Ridge</td>
<td>1</td>
<td>3</td>
<td>0.29</td>
</tr>
<tr>
<td>Left septum</td>
<td>1</td>
<td>2</td>
<td>0.54</td>
</tr>
<tr>
<td>Coronary sinus ostium</td>
<td>1</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>Peri-sinus node</td>
<td>1</td>
<td>0</td>
<td>0.31</td>
</tr>
<tr>
<td>Around pulmonary veins</td>
<td>0</td>
<td>4</td>
<td>0.33</td>
</tr>
<tr>
<td>Procedure time (min)</td>
<td>253 ± 77</td>
<td>267 ± 73</td>
<td>0.80</td>
</tr>
<tr>
<td>Fluoroscopy time (min)</td>
<td>13.1 ± 8.0</td>
<td>15.1 ± 10.0</td>
<td>0.98</td>
</tr>
<tr>
<td>Ablation (radiofrequency delivery) time (s)</td>
<td>760 ± 540</td>
<td>1347 ± 962</td>
<td>0.037</td>
</tr>
<tr>
<td>Number of points per AT</td>
<td>449 ± 520</td>
<td>42 ± 18</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Mapping time per AT (min)</td>
<td>14 ± 6.0</td>
<td>33 ± 25</td>
<td>0.04</td>
</tr>
<tr>
<td>Number of circuits successfully ablated</td>
<td>25/25 (100)</td>
<td>20/23 (87.0)</td>
<td>0.056</td>
</tr>
<tr>
<td>Follow-up (days)</td>
<td>351 ± 321</td>
<td>323 ± 181</td>
<td>0.24</td>
</tr>
<tr>
<td>Recurrences</td>
<td>0 (0)</td>
<td>4 (23.5)</td>
<td>0.033</td>
</tr>
</tbody>
</table>

Data are expressed as number, mean ± standard deviation or number/number (%). AT: atrial tachycardia.
Figure 1.  A. Electroanatomical activation map in an anteroposterior projection of a figure-of-eight reentry around left atriotomy (PentaRay group). B. Electroanatomical activation map in an anteroposterior projection of a microreentry successfully ablated at the ridge between the left upper pulmonary vein and the appendage (conventional group).

Figure 2.  Electroanatomical map of a microreentry from the septal part of the mitral annulus in anteroposterior (AP) and posteroanterior (PA) views. Electrograms recorded on the PentaRay catheter are displayed in the left panel, showing fragmented signals at the critical site (red area). Twelve-lead surface electrocardiogram results are displayed on the right.
• delivery of radiofrequency itself [19].

Our results are in line with a previous study that showed the efficacy of MEM using the PentaRay catheter in conjunction with the Ensite NavX (St Jude Medical, Saint Paul, MN, USA) mapping system for AT occurring after AF ablation. In this study, 33 ATs were mapped with a mean of 365 ± 108 points acquired per map within 8 ± 3 min, and an acute success rate of 96% [20]. In this study, no comparison was performed with the point-by-point technique. Anter et al. [8] nicely validated the normal voltage amplitude cut-offs in patients with structurally normal atria by comparing the PentaRay with a conventional 3.5 mm electrode tip catheter. The PentaRay catheter also allowed more constant capture of the tachycardia because of the higher current density. The authors mapped 18 scar-related atrial circuits (including 13 maps performed sequentially with both catheters), and successfully ablated 17/18 ATs [8]. However, no data concerning mid-term outcomes were available.

Our study confirmed that, not only was the mapping time reduced using MEM (14 vs 33 min with the conventional technique; \( P = 0.04 \)), but it was also associated with an increase in the resolution (449 ± 520 vs 42 ± 18 electrograms; \( P < 0.0001 \)), allowing a more precise definition of the circuits. The ablation time was also significantly reduced in the PentaRay group, and the mid-term outcome was better. Surprisingly, the procedure times were not significantly different between the two groups. Possible explanations could include the lack of randomization and a selection bias of a higher proportion of PV re-isolations (included in the total procedure time) in the PentaRay group (7 vs 4 in the conventional group); and a higher number of AT circuits. Using MEM in conjunction with an electroanatomical system, there was a numerically lower fluoroscopy time in the PentaRay group, but this did not reach statistical significance in our study.

Clinical implications

There is widespread use of multipolar catheters in daily practice during radiofrequency ablation procedures for AF/AT. Whenever available (circular mapping catheters or PentaRay), MEM should be used in preference to the conventional technique, because they allow time savings and a more precise definition of the circuits (microenviroment)/substrate (low-voltage areas).

Towards an automatic electrogram acquisition

Our study emphasizes the superiority of MEM over the conventional technique, using an operator-dependent acquisition. New electroanatomical systems (Rhythmia, Boston Scientific) and recent software (Confidense, Biosense Webster Inc.) now allow automatic and faster electrogram acquisition with multielectrode catheters, eventually associated with manual correction. Those techniques will need further evaluation, but are not currently in widespread use. They should represent a considerable advantage over non-automated physician electrogram interpretation [21].

Study limitations

This study was not randomized; and included only a limited cohort of patients. In addition, the follow-up was based on symptomatic recurrences and periodic Holter-ECG monitoring. No implantable loop recorder device was used in the vast majority of the patients. The newly released software with contact information concerning the PentaRay catheter was not used in this study (Confidense, Biosense Webster Inc.).

Further, none of the circuits were mapped sequentially with MEM and with the conventional technique. As the majority of the procedures were persistent AF ablation (including an initial step of PV isolation and complex fractionated atrial electrogram ablation) with per-procedural conversion into AT, the operator felt that it would not be appropriate to map the same circuit with both strategies to avoid unnecessary additional time.

The PentaRay catheter may represent an additional cost for complex atrial arrhythmias ablation but, in our experience, it was also used for PV mapping, with good accuracy, without the need for the use of another circular mapping catheter for PV isolation.

Conclusion

MEM is faster and more accurate for multiple AT ablation when compared to the conventional technique.

Sources of funding

None.

Disclosure of interest

The authors declare that they have no competing interest.

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