Higher contact-force values associated with better mid-term outcome of paroxysmal atrial fibrillation ablation using the SmartTouch™ catheter

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Aims
Real-time measurement of contact force (CF) during catheter ablation of atrial fibrillation (AF) has been recently suggested to potentially impact procedural outcome. However, the role of CF intensity on mid-term results using the SmartTouch™ catheter has not been investigated so far.

Methods and results
Pulmonary vein isolation (PVI) using the SmartTouch™ catheter was performed in 100 eligible patients (age 62 ± 8; 79% men) undergoing a first procedure of paroxysmal AF catheter ablation. Continuous CF monitoring during catheter ablation allowed calculation of mean CF per patient. Patients were dichotomized into high CF (≥ 22 g, upper quartile) and low CF (< 22 g, remaining) and enrolled in a standardized follow-up programme (after a 3-month blanking period), free from antiarrhythmic therapy, with regular evaluations including 24 h Holter recordings at 1, 3, 6, 9, 12, 18, and 24 months. Atrial fibrillation relapse was defined as any symptomatic or asymptomatic atrial arrhythmia lasting > 30 s. The average CF among all procedures was 19.6 ± 3.7 g. Though complete PVI was eventually achieved in all cases in both groups, success using an exclusively anatomical approach was higher in the high CF group (92.0 vs. 72.0%; P = 0.04). During a mean follow-up of 19 ± 5 months, a lower incidence of AF relapse was observed in higher CF patients (4.0 vs. 20.0%; log rank P = 0.04). Pericardial tamponade occurred in one patient in the higher CF group. No thromboembolism or procedure-associated deaths were observed.

Conclusion
Higher values of CF overall during antral PVI appear to be associated with a higher likelihood of sinus rhythm maintenance without significantly increasing the complication rate.

Keywords
Contact-assisted ablation • Catheter ablation • Outcomes • Arrhythmia

Introduction
Catheter ablation is currently accepted as a treatment option for symptomatic atrial fibrillation (AF). However, the relatively high proportion of recurrence over time remains an important concern. Paroxysmal AF has shown to mainly depend on triggers from the pulmonary veins (PVs). Accordingly, PV isolation (PVI) with bidirectional block across the PV–atrial junction is currently the accepted endpoint of this treatment. However, PV reconnection is common and is held responsible for most arrhythmia recurrences after ablation. Contact-force (CF) monitoring has recently been made available. This new technology appears to significantly impact on short-term results with shorter procedural and fluoroscopy times, lower incidence of acute reconnection, and less need of complementary segmentary radiofrequency applications. In addition, preliminary data at 12 months, with higher prevalence of freedom from AF when compared with patients treated with non-contact catheters, have been recently published.

In the TOCCATA trial, average values of CF (using the TactiCath™ catheter; Endosense©) were found to have an impact on the success of AF ablation. Best results were observed with CF
What’s new?

- We provide the first data on mid-term outcome, beyond 12 months, after catheter ablation of paroxysmal atrial fibrillation with the SmartTouch™ catheter.
- We demonstrate the association of higher contact-force values with better mid-term outcome using the SmartTouch™ catheter.

Methods

Patient population

This single-centre, non-randomized, prospective study comprised the first 100 eligible patients with paroxysmal AF refractory to at least one antiarrhythmic agent undergoing a first procedure of radiofrequency ablation between March 2011 and March 2013 using the Thermocool® SmartTouch™ catheter. The procedures were performed in a highly experienced centre (>500 AF ablation procedures/year) with fellows in training. All patients provided an informed consent prior to the procedure. The study complied with the Declaration of Helsinki and the research protocol was approved by the local ethics committee.

Among the first 110 patients undergoing paroxysmal AF ablation with this catheter at our centre, 100 were considered eligible. Exclusion criteria were the following: performance of additional lines beyond PV encirclement (n = 4), PV isolation solely on segmentary radiofrequency applications (n = 1), and the absence/unavailability/problems with acquisitions of CF values obtained along the radiofrequency lesions due to technical reasons (catheter problems, interferences, and storage problems) (n = 5).

General procedural details

A computed tomography scan (64-slice Siemens® dual-source CT scan) was performed 24 h prior to the procedure to exclude the presence of thrombi in the left atrial appendage and assessing PV and left atrial anatomy. Transthoracic echocardiography was also performed in all patients for assessing left atrial size, left ventricle ejection fraction, and the presence of valvular heart disease. Our centre’s approach to peri-procedural anticoagulation has been previously described.

The procedure was performed under general anaesthesia. Using a transfemoral venous approach, a quadripolar catheter was placed in the coronary sinus. A single transseptal puncture was performed under fluoroscopic guidance. Transoesophageal echocardiographic guidance was used only in cases of difficult anatomy. Upon completion of the transseptal puncture, patients received intravenous heparin to maintain an activated clotting time of 300–350 s.

A circumferential decapolar mapping Lasso® catheter (Biosense Webster®) was introduced into the left atrium using an 8.5 F long sheath. The Lasso® catheter was used to collect left atrial geometry using the 3D electroanatomic mapping system CARTO®. After completion of left atrial geometry, the Lasso® catheter was removed and an ablation catheter Thermocool® SmartTouch™ was introduced through the same transseptal sheath. Initial circumferential PV isolation was performed by systematic radiofrequency application around the PV ostia, consisting of an encirclement of ipsilateral pairs of PVs’ antra (no more than 2 cm from the ostium on the posterior wall on both sides, and anterior aspect of right PVs, and guided by the ridge between the left PVs and the appendage). The circumferential isolation was first performed ‘anatomically’ (i.e. without the Lasso® catheter, using an exclusive anatomical approach). In our approach, we systematically perform a continuous line without interruption of the application if the catheter position remains stable. The same sequence was used for every procedure, starting the ablation in the posterior wall of the left PVs’ antra, followed by the homolateral anterior wall and then switching to the right PVs’ antra anterior wall, and finally ablating the posterior wall of the right PVs.

The Lasso® catheter was then used after completion of anatomical isolation to confirm full PVI. This was done by testing both entrance and exit block (bidirectional block), with a waiting period of 20 min after last radiofrequency application. When complete PVI was not achieved (failure of either exit or entrance block), the ablation catheter was reintroduced into the left atrium with the Lasso® remaining in place using a double wire technique through the transseptal sheath. Thereafter, PVI was completed with Lasso® guidance to eliminate all points of residual PV connection.

Power was not adjusted according to CF, but to the location of radiofrequency ablation: it was limited to 30 W at anterior, superior, and inferior sites (flow rate, 17–20 mL/min) and 25 W in the posterior wall (flow rate, 17 mL/min), with temperature limited to 48°C for each lesion. The duration of ablation per point ranged between 20 and 30 s depending on force values (e.g. 20 s in high CF zones, >20 g, and 30 s or more if lower CF values were observed) and location (e.g. shorter applications in the posterior wall and longer applications in the ridge between the left PVs and the left atrial appendage).

Real-time assessment of contact force

The operators had access to the values of CF obtained while manipulating the Thermocool® SmartTouch™ catheter to assess catheter–tissue contact. The position of the vector was controlled visually and helped the operators in obtaining high CF values and precisely controlling the positioning of the catheter (e.g. in the ridge allowing them to know if the catheter was on the appendage or pulmonary side, according to the direction of the vector).

The aim was to achieve a CF of at least 10 g force (mean), ideally 20 g, with a vector perpendicular to the tissue. The upper limit defined was 50 g force.
Contact-force data for all ablation sites used to achieve PVI were recorded and analysed offline after the procedure (16 170 points). During the procedure, the CARTO 3® console continuously estimated the value of CF every 50 ms. The average of these values in the previous 1000 ms (20 measurements) was displayed and updated in real time. During radiofrequency ablation, when a point was collected, the respective CF value (mean of the measurements in the previous 1000 ms) was recorded. These values were used for estimating the average and standard deviation of CF and percentage of points with < 10 g of CF for each patient.

Follow-up and outcomes
After the index procedure, patients were followed for a minimum of 12 months. Patients were evaluated pre-discharge at 1, 3, 6, 9, 12, 18, and 24 months post-procedure. Information collected included a 12-lead electrocardiogram (ECG) and a 24 h Holter monitoring at each visit. No anti-arrhythmic medication was prescribed following ablation. The first 3 months post-procedure was considered a blanking period. If there was documented recurrence of symptomatic AF during this time interval and the patient required antiarrhythmic drug therapy, a previously ineffective but tolerated Class 1 or Class 3 drug was the preferred option. After this period, antiarrhythmic therapy was stopped in all patients. The primary mid-term endpoint was defined by the rate of AF recurrence, defined as any symptomatic or asymptomatic atrial arrhythmia lasting > 30 s after the blanking period.

In patients presenting with clinical relapse and undergoing a second ablation procedure, PV disconnection and, eventually, the number of reconnected veins were assessed at the beginning of the ‘redo’ procedure.

Statistical analysis
Chi-square was used for the comparison of nominal variables. The Student’s t-test, or its non-parametric equivalent, Mann–Whitney when appropriate, was used for comparison of continuous variables; the Levene’s test was used to check the homogeneity of variance. The results with P < 0.05 were regarded as significant.

The association of CF with procedural success (freedom from AF after the blanking period) and complications (thromboembolism, pericardial effusion, and procedure-related death) was estimated. As no cut-off values have yet been validated for the SmartTouch™ catheter in AF ablation, CF was categorized as high (mean value above or equal to upper quartile: ≥ 22 g) or low (below upper quartile: < 22 g) according to the mean CF value of all applications.

Comparisons between the two CF groups were performed. Predictors of procedural success were evaluated. In addition, the correlation between the average CF value and the number of reconnected veins at the beginning of the second procedure was estimated using the Pearson coefficient (one-tailed, P, based on the assumption that the lower the average CF, the higher the number of reconnected PVs).

Kaplan–Meier curves were traced for comparing sinus rhythm maintenance among the two pre-specified CF groups. A sensitivity analysis was performed using different cut-off values: 10–20 g of CF vs. > 20 g and ≤ vs. > 33% of points with CF < 10 g. 11 The log-rank test was used for assessing the existence of differences.

PASW Statistics (SPSS Inc.) version 18.0 was used for descriptive and inferential statistical analysis.

Results

Patient characteristics and procedural results
Most patients (79.0%) were men and the average age was 62.6 ± 8.7 years. CHADS2 and CHA2DS2-VASc were 0.8 ± 0.9 and 1.5 ± 1.3, respectively. Baseline characteristics of the study population are present on Table 1.

Procedures had a mean duration of 99.1 ± 29.1 min. Pulmonary vein isolation was obtained for all PVs and an exclusively anatomical approach was used in 77.0% of patients. No thrombo-embolic events occurred, and one pericardial tamponade was observed. Overall, the average CF value for the entire group of 100 patients was 19.6 ± 3.7 g (maximum = 30.62 ± 21.64 g; minimum = 11.26 ± 4.59 g). The average CF value was lower in the left PVs than

| Table 1  | Baseline sample data: overall, and according to average CF |
|----------------- |----------------- |----------------- |----------------- |----------------- |
| Overall (n = 100) | CF ≥ 22 g (n = 25) | CF < 22 g (n = 75) | P |
| Age | 62.6 ± 8.7 | 62.8 ± 7.0 | 62.5 ± 9.3 | 0.884 |
| Female gender | 21.0% (21) | 32.0% (8) | 17.3% (13) | 0.119 |
| BMI | 26.6 ± 4.2 | 25.6 ± 3.7 | 26.9 ± 4.3 | 0.168 |
| Congestive HF, % (n) | 4.0% (4) | 0% | 5.3% (4) | 0.239 |
| Hypertension, % (n) | 44.0% (44) | 40.0% (10) | 45.3% (34) | 0.642 |
| Diabetes mellitus, % (n) | 4.0% (4) | 8.0% (2) | 2.7% (2) | 0.239 |
| TIA/stroke, % (n) | 9.0% (9) | 16.0% (4) | 6.7% (5) | 0.159 |
| Vascular disease, % (n) | 8.0% (8) | 4.0% (1) | 9.3% (7) | 0.395 |
| CHADS2 | 0.8 ± 0.9 | 0.8 ± 0.9 | 0.7 ± 0.9 | 0.642 |
| CHA2DS2-VASc | 1.5 ± 1.3 | 1.6 ± 1.4 | 1.4 ± 1.2 | 0.491 |
| Haemoglobin (g/dL) | 14.8 ± 1.2 | 14.8 ± 1.3 | 14.7 ± 1.2 | 0.782 |
| C-reactive protein (mg/L) | 3.2 ± 3.5 | 2.6 ± 3.3 | 3.4 ± 3.6 | 0.356 |
| eGFR Cockroft–Gault (mL/min) | 66.6 ± 18.3 | 66.8 ± 14.5 | 66.6 ± 19.5 | 0.960 |
| Indexed LA volume (mL/m²) | 40.9 ± 12.9 | 41.4 ± 12.6 | 40.8 ± 13.1 | 0.837 |
| LV ejection fraction (%) | 65 ± 7 | 67 ± 6 | 65 ± 7 | 0.193 |

CF, contact force; BMI, body mass index; HF, heart failure; TIA, transient ischaemic attack; eGFR, estimated glomerular filtration rate; LA, left atrium, LV, left ventricular.
in the right PVs \((17.8 \pm 3.7 \text{ vs. } 21.4 \pm 5.4; P < 0.001)\). The variation of CF during radiofrequency applications, expressed as standard deviation, was \(12.0 \pm 3.1\) g. Overall, variation was lower in the left PVs compared with the right ones \((10.8 \pm 3.5 \text{ vs. } 12.4 \pm 3.6; P = 0.001)\). Further procedural information can be found on Figure 1 and Table 2.

**Early and mid-term procedural success**

Neither atrio-oesophageal fistulas nor deaths were observed in the first 3 months after the index ablation procedure.

Eight patients (8.0%) relapsed during the blanking period. During a mean follow-up of \(19 \pm 5\) months, only 16 patients (16.0%) presented an AF relapse. Seventy-five per cent of relapses \((n = 12)\) occurred in the first 12 months. Relapse occurred five times more frequently in patients with lower CF (see the next section).

Among patients with AF relapse, 11 underwent a second AF ablation procedure and in 2 of them (18%) all 4 PVs were electrically disconnected at the beginning of the procedure (Table 3).

**Association of contact force with acute and mid-term procedural results**

Patients with higher average CF values \((\geq 22\) g\)) delivered a significantly higher voltage and amount of current to the tissue and presented a trend for lower impedance values (Table 2). Furthermore, in patients with CF \(\geq 22\) g, PVI was obtained more frequently without the need of complementary segmentary radiofrequency ablation \((8.0 \text{ vs. } 28.0\% ; P = 0.04)\).

Average CF \(\geq 22\) g was associated with a higher mid-term freedom from AF on Kaplan–Meier curves \((\log rank P = 0.04)\) (Figure 2).

No other predictors of post-procedural AF relapse besides CF were found (see Supplementary material online, Table S4).

Sensitivity analysis using different cut-off values for CF yielded slight numerical, but non-significant, higher relapse rate in patients with CF < 20 g and > 33% of CF values of < 10 g (Figure 3).

Among patients who underwent a second ablation procedure, a trend for a negative correlation between average CF in the previous ablation and number of reconnected PVs at the beginning of the re-ablation procedure was found \((r = -0.465; P = 0.075)\).

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**Table 2: Procedural data: overall, and according to average CF**

|                        | Overall \((n = 100)\) | CF \(\geq 22\) g \((n = 25)\) | CF < 22 g \((n = 75)\) | \(P\)  |
|------------------------|------------------------|-------------------------------|------------------------|-------|
| Procedure duration (min) | 99.1 ± 29.1            | 89.9 ± 24.2                   | 102.2 ± 30.1           | 0.081 |
| Fluoroscopy duration (min) | 20.9 ± 8.7             | 18.7 ± 7.0                    | 21.6 ± 9.1             | 0.174 |
| Radiation dosage (Gy cm²) | 54.2 ± 73.3            | 36.9 ± 11.9                   | 69.7 ± 83.5            | 0.206 |
| Current (A)            | 454 ± 36               | 474 ± 30                      | 446 ± 36               | 0.005 |
| Impedance (Ω)          | 145 ± 12               | 141 ± 10                      | 146 ± 12               | 0.076 |
| Power (W)              | 23 ± 2                 | 24 ± 2                        | 22 ± 2                 | 0.015 |
| Temperature (°C)       | 36.6 ± 1.5             | 37.0 ± 2.0                    | 36.5 ± 1.2             | 0.180 |
| Duration of RF (min)   | 31.0 ± 12.4            | 29.5 ± 7.8                    | 31.7 ± 14.2            | 0.487 |
| Voltage (V)            | 54 ± 5                 | 54 ± 5                        | 54 ± 4                 | 0.858 |
| Average CF (g)         | 19.6 ± 3.7             | 24.4 ± 2.1                    | 18.0 ± 2.5             | <0.001 |
| Points with CF < 10 g (%) | 22.3 ± 10.1           | 13.7 ± 5.3                    | 25.1 ± 9.7             | <0.001 |
| Need of complementary RF segmentary ablation, % \((n)\) | 23.0% \((23)\) | 8.0% \((2)\) | 28.0% \((21)\) | 0.040 |
| Standard deviation of CF (g) | 12.0 ± 3.1         | 15.2 ± 2.8                    | 11.0 ± 2.3             | <0.001 |
| Average CF on left PVs | 17.8 ± 3.7             | 21.2 ± 3.7                    | 16.7 ± 3.0             | <0.001 |
| Average CF on right PVs | 21.4 ± 5.4             | 27.5 ± 4.0                    | 19.3 ± 4.1             | <0.001 |
| AF relapse during blanking, % \((n)\) | 8.0% \((8)\) | 4.0% \((1)\) | 9.3% \((7)\) | 0.379 |
| AF relapse after blanking, % \((n)\) | 16.0% \((16)\) | 4.0% \((1)\) | 20.0% \((15)\) | 0.059 |
| Pericardial effusion/tamponade, % \((n)\) | 1.0% \((1)\) | 4.0% \((1)\) | 0% | 0.082 |
| Peri-procedural thromboembolism, % \((n)\) | 0% \((0)\) | 0% | 0% | NA |

CF, contact force; RF, radiofrequency; AF, atrial fibrillation.
The evolution of mean procedural CF values during the enrol-ment period is illustrated in Figure S4 (see Supplementary material online).

**Discussion**

We have observed a very low rate of AF relapse after a CF-assisted circumferential PVI procedure. Most arrhythmia recurrences occurred in the first 12 months. Most importantly, the level of CF appears to influence the mid-term outcome, especially the rate of recurrence, which was five times lower in patients in the higher average CF group.

In our sample, we have observed that higher CF was associated with better acute procedural results and also with better mid-term outcome, despite the fact that PVI was achieved in all patients. This means that succeeding in PVI is important, but achieving durable lesions, which may be obtained through a more appropriate and effective catheter–tissue contact, is of utmost importance. Higher average CF values associated with a higher potency and energy delivery (optimization of energy coupling to tissue with less energy dissipation) for lesion formation at the catheter–tissue interface, possibly leading to deeper and more transmural lesions, as suggested by the trend to lower impedance values that were observed in these patients, in line with previous reports. 15,16,17 Consequently, PVI occurred more frequently without the need of complementary segmentary radiofrequency ablation. In addition, this is in line with the current body of evidence suggesting that CF information is more likely to correlate with electrogram (EGM) changes18,19 and findings on late gadolinium enhancement magnetic resonance imaging.20

In our previous early experience with the SmartTouch™ cath-eter,10 we have achieved lower CF values mostly in the ridge between the left PVs and the left atrial appendage and in the inferior section of the right inferior PV. In these zones, whenever a >22 g CF could not be achieved, we have tried to achieve as much contact as we could (most of the times, an average of 12–14 is possible10) and pro-longed the duration of the application until the attenuation of EGM.

**Table 3** Information regarding CF in patients with AF relapse after blanking and findings at the beginning of the redo procedure

| Subject | Average contact (± mean SD) | % CF < 10 g | Month of relapse | Reconnected PV |
|---------|-----------------------------|-------------|-----------------|----------------|
| PA      | 12.5 ± 5.8                  | 41%         | 4               | RIPV, RSPV    |
| FC      | 14.4 ± 9.1                  | 39%         | 6               | LSPV, LIPV, RIPV, RSPV |
| AT      | 14.5 ± 8.8                  | 38%         | 16              | –              |
| GC      | 15.5 ± 8.6                  | 33%         | 6               | RIPV, RSPV    |
| JG      | 16.2 ± 8.8                  | 21%         | 14              | LSPV, LIPV, RIPV |
| JR      | 17.6 ± 11.1                 | 29%         | 8               | –              |
| PB      | 17.8 ± 11.3                 | 24%         | 19              | –              |
| DC      | 18.0 ± 11.9                 | 29%         | 11              | –              |
| MC      | 18.5 ± 13.1                 | 26%         | 4               | None           |
| PO      | 19.2 ± 11.8                 | 22%         | 7               | RIPV, RSPV    |
| MB      | 19.5 ± 10.8                 | 18%         | 7               | RIPV, RSPV    |
| JA      | 20.7 ± 12.8                 | 24%         | 6               | RSPV           |
| CR      | 20.8 ± 10.1                 | 14%         | 5               | LSPV, RSPV    |
| GG      | 21.2 ± 11.3                 | 13%         | 1               | LIPV, RIPV, RSPV |
| SB      | 21.9 ± 13.0                 | 9%          | 9               | None           |
| JM      | 25.4 ± 14.7                 | 10%         | 18              | –              |

SD, standard deviation; CF, contact force; PV, pulmonary vein; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein; LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein; –, no redo procedure yet.

**Figure 2** Freedom from atrial fibrillation after the index procedure in patients with high and low average CF. CF, contact force.
A very low adverse event rate was observed in this cohort. Thromboembolic events and atrio-oesophageal fistulae, the most feared complications of PVI, were not observed. Although our study presented limited power to address this issue (several hundred patients would be needed due to the low incidence of these serious complications: 1–0.1%, respectively), we did not observe an excess of adverse events in the higher CF quartile. The authors suggest a very close surveillance of CF values during the procedure. Ideally, target values between 20 and 30 g should be maintained. Values of 50 and 60 g may be easily achieved at certain points (superior part of the right PVs or atrial diverticula) and should lead to prompt interruption of radiofrequency energy delivery and catheter repositioning at a lower CF location. Also, in our opinion and in agreement with recently published data, values of 10 g should be avoided (unless a more intense higher CF is impossible to achieve) since these may result in incompletely transmural lesions and eventually reconduction.

Another point to merit reflection would be the impact of the direction of the vector on procedural outcomes. Normally, CF levels of >10 or 20 g can only be obtained when a perpendicular position of the tip of the catheter is obtained. A perpendicular vector was observed in >90% of the ablation points. There may be a rationale for expecting a higher relapse rate in patients presenting with more ablation points resulting from a non-perpendicular force vector direction. However, due to the low number of applications with non-ideal vector and the low rate of relapse, our study did not have the power to prove such hypothesis.

Despite failing to achieve statistical significance, we found a trend for a negative correlation between average CF values and number of reconnected PVs at the beginning of a ‘redo’ procedure: patients with higher number of reconnected PVs had lower levels of average CF during the index procedure. The association between lower CF values and reconnection (the presence of gaps) had already been elegantly suggested in the EFFICAS I multi-centre study.11

Our previous results10 have shown the improvement in outcome resulting from using CF sensing during catheter ablation of paroxysmal AF when compared with the use of conventional non-contact catheters. However, the impact of specific values of CF in the mid-term success of paroxysmal AF ablation had not yet been shown with the SmartTouch™ catheter. We have previously shown that lower values of CF can be observed in the anterior portion of left PVs, next to the left atrial appendage ridge, and in the inferior aspect of the right PVs.10 Therefore, there seems to be a rationale for carefully positioning the catheter and obtaining an optimal level of contact in these specific technically challenging regions, as they may deeply influence the final average CF value and consequently the overall procedural success.

Proof of possible improved procedural outcome resulting from higher CF values has already been suggested by the TOCCATA trial.11 However, some differences must be signalled between this landmark trial and our present study: first, a different CF sensing catheter, TactiCath™, was used; secondly, the cohort of multi-centric TOCCATA trial consisted of a limited number of patients (n = 34).

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**Figure 3** Sensitivity analysis for procedural outcomes using different cut-off values of CF: (A) average CF < or ≥ 20 g; (B) percentage of CF < 10 g in ≤ vs. > 33% of ablations. CF, contact force.
who were followed for a maximal period of 12 months; finally, unlike our sample, mean CF value in TOCCATA was 14.2 g and in five patients (all with AF relapse) was below 10 g. Average CF below 10 g was not present in any of our study subjects. The ongoing multi-centric ‘TactiCath Contact Force Ablation Catheter Study for Atrial Fibrillation’ (TOCCASTAR) trial including 200 patients treated with a CF monitoring catheter may provide constructive insights regarding the optimal value to attain.

Limitations

There are several limitations to this study that merit reflection: first, these results were obtained in a high-volume single-centre performing AF ablation for longer than 10 years. Therefore, they need to be validated in a multi-centric trial before application in lower volume centres. Secondly, numerical but non-statistical differences were found regarding some aspects of the association of CF with outcome, namely on the sensitivity analyses, due to lack of power, although our population being larger than other samples published so far in this field. Thirdly, current recommendations suggest more prolonged monitoring of patients after the ablation procedure. We believe that if patients had been followed with long-duration Holter ECG or even implantable loop recorders, 10% more asymptomatic AF episodes might have been recorded. Fourth, a long inclusion period was necessary to eventually obtain 100 eligible patients. This resulted from both the higher cost of contact-force sensing catheters, which led to the use of non-contact force catheter in a substantial amount of patients, as well as the use of other techniques in our centre such as cryoballoon technology, nMARQ™ or the TactiCath™ catheter. Fifthly, there is a possibility that some unmeasured variables (like ablation time and delivered power per lesion) may have had a confounding effect in the association between CF and outcome. Also, ablation points were marked during the procedure by an operator and in places of less stability, where CF values may have experienced some variation, the recorded CF value may not exactly translate the average CF observed during that radiofrequency application. However, it is unlikely that these confounders acted differently in both groups. Finally, data regarding force time integral (FTI), force over time, and stability (retrievable from VISITAG™) were not available to us at the beginning of the study. We agree that these parameters may potentially present an additional impact on the procedural results. Force time integral and force over time might more closely relate the whole timecourse of the ablation lesion formation/acquisition of the point. Stability may be important for assuring the maintenance of homogeneous CF values and catheter position, assuring the continuity of lines/lack of gaps and FTI a particularly interesting parameter to consider.

Conclusions

Our results suggest that the presence of higher average levels of CF (≥ 22 g) may be associated with better acute procedural outcomes and with a five-fold less incidence of AF relapse in patients undergoing catheter ablation of paroxysmal AF. This benefit seems to extend beyond the first 12 months after the procedure.

These preliminary results also suggest no significant increase in complications when achieving average contact values of this magnitude (below 25 – 30 g), but caution should be exerted and extreme values avoided before further evidence becomes available.

Supplementary material

Supplementary material is available at Europace online.

Acknowledgements

The authors thank Delphine Grand-Larrieu for technical support in handing the CARTO console and extraction of data.

Conflict of interest: S.B. is a consultant for Medtronic and Boston Scientific. J.P.A. is a consultant for SJM and Biosense Webster. No conflicts of interest for other co-authors.

References

1. Daubert JC, Saxon L, Adamson PB, Auricchio A, Berger RD, Beshai JF et al. 2012 EHRA-HRS expert consensus statement on cardiac resynchronization therapy in heart failure: implant and follow-up recommendations and management. Europace 2012;14:1236–86.
2. Jatene AT, Wann LS, Alpert JS, Calkins H, Cleveland JC Jr. Cigarroa JE et al. 2014 AHA/ACC/HRS Guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. J Am Coll Cardiol 2014; pii: 50735-1097/140740-9. doi: 10.1016/j.jacc.2014.03.022. [EPUB ahead of print].
3. Weerasooriya R, Khary P, Litalien J, Macle L, Hocini M, Sacher F et al. Catheter ablation for atrial fibrillation: are results maintained at 5 years of follow-up? J Am Coll Cardiol 2011;57:160–6.
4. Oral H, Knight BP, Tada H, Ozaydin M, Chugh A, Hassan S et al. Pulmonary vein isolation for paroxysmal and persistent atrial fibrillation. Circulation 2002;105:1077–81.
5. Flaislaguerre M, Jais P, Shah DC, Takahashi A, Hocini M, Quiniou G et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Engl J Med 1998;339:659–66.
6. Calkins H, Kuck KH, Capponi R, Brugada J, Camm AJ, Chen SA et al. 2012 HRS/ EHRA/ECAS expert consensus statement on catheter and surgical ablation of atrial fibrillation: recommendations for patient selection, procedural techniques, patient management and follow-up, definitions, endpoints, and research trial design. Europace 2012;14:528–406.
7. Ouyang F, Ernst S, Chun J, Bänsch D, Li Y, Schaufmann A et al. Electrophysiological findings during ablation of persistent atrial fibrillation with electroanatomic mapping and double Lasso catheter technique. Circulation 2005;112:3038–48.
8. Stabile G, Solimene F, Caibà L, Angelloso M, Castro A, Pratalè G et al. Catheter-tissue contact force for pulmonary vein isolation: a pilot multicentre study on effect on procedure and fluoroscopy time. Europace 2014;16:1335–40.
9. Haldar S, Jarman JW, Paniker S, Jones DG, Saluñche T, Gupta D et al. Contact force sensing technology identifies sites of inadequate contact and reduces acute pulmonary vein reconnection: a prospective case control study. Int J Cardiol 2013;168:1160–6.
10. Marjan F, Ezzati S, Narayanan K, Goy-Moyat B, Bouzeman A, Providencia R et al. Real-time contact force sensing for pulmonary vein isolation in the setting of paroxysmal atrial fibrillation: procedural and 1-year results. J Cardiovasc Electrophysiol 2014;25:130–7.
11. Reddy VY, Shah D, Kautzner J, Schmidt B, Saoudi N, Herrera C et al. The relationship between contact force and clinical outcome during radiofrequency catheter ablation of atrial fibrillation in the TOCCATA study. Heart Rhythm 2012;9:1789–95.
12. Providencia R, Marjon E, Albanese JP, Combes S, Combes N, Jourda F et al. Rivaroxaban and dabigatran in patients undergoing catheter ablation of atrial fibrillation. Europace 2014;16:1137–44.
13. Yokoyama K, Nakagawa H, Shah DC, Lambert H, Leo G, Aebi N et al. Novel contact force sensor incorporated in irrigated radiofrequency ablation catheter predicts lesion size and incidence of steam pop and thrombus. Circ Arrhythm Electrophysiol 2008;1:354–62.
14. Thiagalingam A, D’Avila A, Foley L, Guerrero JL, Lambert H, Leo G et al. Importance of catheter contact force during irrigated radiofrequency ablation: evaluation in a
porcine ex vivo model using a force-sensing catheter. J Cardiovasc Electrophysiol 2010; 21:806–11.

15. Wakil R, Clauss S, Schmidt V, Ulbrich M, Hanefeld A, Schüssler F et al. Impact of real-time contact force and impedance measurement in pulmonary vein isolation procedures for treatment of atrial fibrillation. Clin Res Cardiol 2014;103: 97–106.

16. Reichlin T, Knecht S, Lane C, Kühne M, Noe E, Chopra N et al. Initial impedance decrease as an indicator of good catheter contact: insights from radiofrequency ablation with force sensing catheters. Heart Rhythm 2014;11:194–201.

17. Titz RR, Makimoto H, Lin T, Rilling A, Metzner A, Mathew S et al. In vivo left-ventricular contact force analysis: comparison of antegrade transseptal with retrograde transaortic mapping strategies and correlation of impedance and electrical amplitude with contact force. Europace 2014. [Epub ahead of print].

18. Kumar S, Chan M, Lee J, Wong MC, Yudi M, Morton JB et al. Catheter-tissue contact force determines atrial electrogram characteristics before and lesion efficacy after anterolateral pulmonary vein isolation in humans. J Cardiovasc Electrophysiol 2014;25: 122–9.

19. Squara F, Latsu DG, Massaad Y, Mahjoub M, Bun SS, Saoudi N. Contact force and force-time integral in atrial radiofrequency ablation predict transmurality of lesions. Europace 2014;16:660–7.

20. Sohns C, Karim R, Harrison J, Aruuna A, Linton N, Sennett R et al. Quantitative magnetic resonance imaging analysis of the relationship between contact force and left atrial scar formation after catheter ablation of atrial fibrillation. J Cardiovasc Electrophysiol 2014;25:138–45.

21. Neuzil P, Reddy VY, Kautzner J, Petru J, Wichterle D, Shah D et al. Electrical reconnection after pulmonary vein isolation is contingent on contact force during initial treatment: results from the EFFICAS I study. Circ Arrhythm Electrophysiol 2013;6: 327–33.

22. TOCCASTAR—TactiCath Contact Force Ablation Catheter Study for Atrial Fibrillation. http://clinicaltrials.gov/show/NCT01278953 (6 February 2014, date last assessed).

23. Eitel C, Husser D, Hindricks G, Fruehauf M, Hilbert S, Arya A et al. Performance of an implantable automatic atrial fibrillation detection device: impact of software adjustments and relevance of manual episode analysis. Europace 2011;13:480–5.

**EP CASE EXPRESS**

Resumption of dormant accessory pathway conduction with adenosine administration: a simple intervention to ensure successful accessory pathway ablation

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A 19-year-old with supraventricular tachycardia was referred for an electrophysiology study. Delta waves were absent and the HV interval 36 ms. Orthodromic atrioventricular reentrant tachycardia utilizing a left-septal accessory pathway (AP) was diagnosed and radiofrequency energy delivered at the site of earliest retrograde atrial activity during ventricular pacing. Loss of ventriculoatrial (VA) conduction occurred during ablation. Approximately 30 min post-ablation, administration of intravenous adenosine during ventricular pacing resulted in transient resumption of VA conduction (Panels A and B). As VA conduction was absent at various pacing rates and adenosine inhibits atrioventricular (AV) nodal conduction, our findings were consistent with transient retrograde AP conduction. Since VA conduction block persisted thereafter and for a total of 1 h post-ablation, the procedure was terminated. Unfortunately, there was recurrence of the index arrhythmia.

This case highlights the utility of adenosine in unmasking dormant retrograde AP conduction post-ablation. Adenosine’s effect in this case was not mediated by its effect on the AV node given the presence of VA conduction block prior to its administration. Rather, adenosine likely facilitated hyper-polarization of injured but still viable tissue at the AP atrial insertion site. Intra-procedural administration of adenosine may be valuable in identifying injured cardiac tissue, which may recover thereby resulting in future arrhythmia recurrence.

The full-length version of this report can be viewed at: http://www.escardio.org/communities/EHRA/publications/ep-case-reports/Documents/Resumption-of-dormant-accessory-pathway.pdf.

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