Early identification and treatment of PV re-connections: role of observation time and impact on clinical results of atrial fibrillation ablation

Xin-hua Wang, Xu Liu*, Yu-min Sun, Jia-ning Gu, Hai-feng Shi, Li Zhou, and Wei Hu

Department of Cardiology, Shanghai Chest Hospital affiliated to Jiaotong University, Shanghai 200030, People’s Republic of China

Received 20 February 2007; accepted after revision 21 April 2007; online publish-ahead-of-print 23 May 2007

Aims Circumferential pulmonary vein isolation (CPVI) has been reported to account for 30% of atrial fibrillation (AF) recurrence after initial ablation, and pulmonary vein (PV) re-connection accounts for about 80% of AF recurrence. There is no information in the literature whether early identification and treatment of acute PV conduction recovery during initial ablation has an impact on subsequent clinical results. The objective is to investigate the prevalence of acute PV conduction recovery during the observation time after PV isolation for paroxysmal AF, and to evaluate the impact of re-isolation treatment on clinical results.

Methods and results Ninety cases with paroxysmal AF (51 males, mean age of 56.4 ± 12.3 years) were randomized to 3 groups to undergo CPVI. In Group A, there was no observation time post-ablation. In Group B, there was 30 min of observation time post-ablation. In Group C, there was 60 min of observation time post-ablation. All PV re-conduction was re-isolated at the end of the observation time. ECG and Holter monitors were used to evaluate the clinical effectiveness of ablation. All cases underwent the procedure successfully. The mean procedural time in Group A was significantly shorter than in Group B and Group C, but there was no significant difference on fluoroscopic time and PV isolation time among the three groups. In Group B, PV re-conduction occurred in 8 cases (25%) at 30 min post-isolation, in 10 cases (31.2%) at 60 min post-isolation for left PVs, and in 6 cases (18.8%) at 30 min post-isolation for right PVs. In Group C, PV re-conduction for left PVs occurred in 9 cases (30%) at 30 min post-isolation and in 11 cases (36.7%) at 60 min post-isolation; for right PVs this occurred in 7 cases (23.3%) at 30 min post-isolation and in 8 cases (26.7%) at 60 min post-isolation. During a mean follow-up of 6.7 ± 2.3 months, 17 cases (60.7%) in Group A, 27 cases (84.3%) in Group B, and 26 cases (86.7%) in Group C had no recurrence of atrial tachyarrhythmias, P = 0.04.

Conclusion The prevalence of acute PV conduction recovery was about 30% after PV isolation, which mostly occurred within 30 min after initial isolation. Re-isolation of recovered PV conduction contributed to the improvement in the success rate of ablation for paroxysmal AF.

Keywords Atrial fibrillation; Pulmonary vein; Ablation; Recurrence

Introduction

It has been well established that pulmonary vein (PV) triggering or driving is the dominant mechanism for paroxysmal atrial fibrillation (AF),1,2 and circumferential PV isolation (CPVI) is the main approach for AF elimination.3-8 However, the recurrence rate of the procedure has been reported up to 30% after initial ablation, and PV conduction recovery accounts for 80% of AF recurrence, according to remapping results during a second procedure. Re-isolation of recovered PV conduction improves the success rate to 90%,9,10 making this of great importance to reduce prevalence of PV re-connection after the initial procedure. To our knowledge, there is no information in the literature whether early identification and treatment of acute PV conduction recovery during the observation time after initial ablation has an impact on subsequent clinical results.

Methods

Patients’ characteristics

Between April 2006 and September 2006, 90 cases [51 males, mean age of 56.4 ± 12.3 (range 45–73) years] with paroxysmal AF were enrolled to undergo a CPVI procedure. They were randomly assigned to three groups. In Group A, no additional observation time was spent when PV isolation was achieved. In Group B, there was an additional 30 min of observation and in Group C, an additional 60 min of observation when PV isolation was obtained. Transesophageal echocardiography was performed during a mean follow-up of 6.7 ± 2.3 months, 17 cases (60.7%) in Group A, 27 cases (84.3%) in Group B, and 26 cases (86.7%) in Group C had no recurrence of atrial tachyarrhythmias, P = 0.04.

Conclusion The prevalence of acute PV conduction recovery was about 30% after PV isolation, which mostly occurred within 30 min after initial isolation. Re-isolation of recovered PV conduction contributed to the improvement in the success rate of ablation for paroxysmal AF.
The endpoint of the procedure was PV isolation (as the place with the shortest interval of atrium to PV conduction) ablation catheter along the initial circular lines. A 'gap' was defined for each point. The 'conduction gaps' were mapped by roving the ery for each point. The 'conduction gaps' were mapped by roving the

Electrophysiological study

All antiarrhythmic drugs except amiodarone were discontinued for at least five half-lives. One decapolar catheter ( Biosense Webster) was advanced into the coronary sinus via the left subclavian vein. Two L1-type Swartz sheaths (St Jude Medical) were advanced into the left atrium after two successful trans-septal procedures. Heparin 5000–6000 u was infused via the sheath and followed by 1000 u per hour to maintain activated clotting time in the range of 300-350 s. One 6F 3.5 Judkin’s right coronary catheter was used to perform selective PV angiography. One decapolar circular mapping catheter (Lasso, Biosense Webster) was positioned in every PV ostium to map PV potentials (PVPs). Surface ECG and bipolar endocardial electrograms were stored continuously for further analysis. Bipolar recordings were filtered from 30 to 500 Hz.

Circumferential pulmonary vein (PV) antrum isolation

The procedure was performed using a CARTO system ( Biosense Webster). A 3.5 mm saline-irrigated ablation catheter (Thermocool Navistar, Biosense Webster) was advanced into the left atrium to reconstruct its geometry. The ostium of every PV was identified and tagged on the geometry reconstructed by PV angiography. In cases with common PV ostia, each branch of the PV was not separately tagged. Circumferential PV antrum ablation was performed to encircle the ipsilateral left and right PVs. Left-sided and right-sided PVs were sequentially ablated. The methodology has been described in detail elsewhere. Briefly, saline-irrigated radiofrequency (RF) was delivered at the PV antrum, which was anteriorly 0.5 cm and posteriorly 1.0 cm away from the angiographically defined PV ostia. The power and temperature set was 40 W, 45

Table 1: The basic clinical characteristics of three groups

<table>
<thead>
<tr>
<th>Complications</th>
<th>Group A (n = 28)</th>
<th>Group B (n = 32)</th>
<th>Group C (n = 30)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male [n (%)]</td>
<td>16 (57.1)</td>
<td>18 (56.3)</td>
<td>17 (56.7)</td>
<td>1.0</td>
</tr>
<tr>
<td>Age (years)</td>
<td>55.7 ± 14.3</td>
<td>54.6 ± 12.3</td>
<td>56.1 ± 11.8</td>
<td>0.78</td>
</tr>
<tr>
<td>AF duration (years)</td>
<td>5.1 ± 2.4</td>
<td>3.2 ± 2.7</td>
<td>4.5 ± 2.1</td>
<td>0.81</td>
</tr>
<tr>
<td>Diameter of LA (mm)</td>
<td>37.9 ± 7.7</td>
<td>36.9 ± 7.5</td>
<td>38.1 ± 6.4</td>
<td>0.79</td>
</tr>
<tr>
<td>Complications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension [n (%)]</td>
<td>10 (35.7)</td>
<td>15 (46.9)</td>
<td>10 (33.3)</td>
<td>0.56</td>
</tr>
<tr>
<td>Coronary artery disease [n (%)]</td>
<td>1 (3.6)</td>
<td>2 (6.3)</td>
<td>1 (3.3)</td>
<td>–</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD or counts (%). LA, left atrium.

to exclude left atrial thrombi. Written informed consent was obtained in all cases.

Post-ablation management and follow-up

All cases received low molecular weight heparin injection subcutaneously twice a day for 3-5 days, followed by oral coagulation with warfarin for at least 1 month, keeping international normalized ratio ranging 2-3. Amiodarone or class IC antiarrhythmic drugs were administered for 1 month. Surface ECG was taken and repeated 1 day, 2 days, 7 days, 14 days, 1 month, 3 months, 6 months, and 9 months after the procedure. Holter monitoring was performed for 24 hours every 2 months to evaluate the arrhythmic events. Cases were always asked to record their ECGs when symptomatic. After 1 month of blanking period, any episode of symptomatic or asymptomatic atrial tachyarrhythmias (ATa) that lasted more than 30 s documented with ECG/Holter was considered a recurrence.

Statistical analysis

Continuous variables were expressed as mean ± SD and categorical variables as counts or proportions (%). One-way ANOVA for continuous variables of normal distribution or non-parameter test for inhomogeneity of variance and χ² test for categorical variables was undertaken for comparison among groups. P < 0.05 was considered statistically significant. Statistical analysis was performed with SPSS for Windows (version 12.0.1, SPSS Inc., Chicago, IL).

Results

All cases underwent the procedure successfully. In Group A, the mean procedural time was 165 ± 20 min and the mean fluoroscopic time was 21 ± 10 min. The mean isolation time for left PVs was 50 ± 15 min, and for right PVs it was 35 ± 9 min.

In Group B, the mean procedural time was 200 ± 23 min and the mean fluoroscopic time was 23 ± 10 min. The mean isolation time for left PVs was 55 ± 8 min. Left PV conduction recurred in 8 cases (25%) at 30 min after prior PV isolation, and in another 2 cases when the procedure was over (~60 min after left PV isolation); altogether left PV re-connection occurred in 10 cases (31.2%). Conduction of superior and inferior PVs occurred simultaneously in 9 of
10 cases, but single inferior PV conduction recurred in 1 out of 10 cases. The mean interval between atrium (A) and PVP was $187 \pm 33$ ms. Mapping along the initial ablation line revealed 12 gaps, including 7 gaps in the antero-superior wall of left PVs, 3 gaps on the roof, and 2 gaps in the postero-superior wall. The mean isolation time for right PVs was $29 \pm 12$ min. During 30 min of observation, PV conduction recovered in six cases (18.8%). PV conduction was recovered simultaneously in superior and inferior PVs in all cases. The mean A–PVP conduction interval was $140 \pm 12$ ms. During the re-isolation procedure, mapping along the initial ablation line revealed 8 gaps, including 3 gaps in the postero-inferior wall, 2 gaps in the postero-superior wall, and 2 gaps in the antero-superior wall. All gaps were closed successfully by additional RF delivery at the end of the procedure.

In Group C, the mean procedural time was $237 \pm 34$ min (there was significant difference among the three groups, $P = 0.03$) and the mean fluoroscopic time was $19 \pm 12$ min. The mean isolation time for left PVs was $60 \pm 11$ min. Left PVPs recurred in nine cases (30%) within 30 min after initial isolation, and in another two cases within 60 min after initial isolation. No more PV re-connection occurred at the end of the procedure (about 90 min later after left PV isolation). Altogether in 11 cases (36.7%), left PV conduction recurred. In seven cases superior

Figure 1  Conduction gap identification, closure, and PV isolation. Part (A) shows the modified right lateral view of voltage mapping of LA after CPVI procedure. White dots stand for the ostia of right PVs. The red area represented right PV antrum with a low voltage <0.15 mV. Six electrograms stands for endocardial mapping of different location. Tracings were surface ECG V1, coronary sinus (CS), and ablation catheter (ABL). Red dot represented the conduction gap, where atrial and PV potentials were running together. Part (B) shows that right PVs were isolated by applying RF energy at the conduction gap. Tracings were surface ECG lead I, aVF, V1, ABLd, ABLp, PV1,2 to PV 9,10, CS3,4, and CS1,2. FFP, far-field potential.
and inferior PVP recovered simultaneously; in three cases only superior PVP recovered and in one case only inferior PVP recovered. The mean A–PVP interval was 145 ± 22 ms.

Remapping along the initial ablation line revealed 14 gaps: 2 located in the antero-superior wall, 4 in the mid-anterior wall, another 4 on the roof, and still another 4 in the postero-superior wall. The mean ablation time for right PVs was 34 ± 14 min. Right PVPs recurred in seven cases (23.3%) within 30 min after right PV isolation and in another one case within 60 min after right PV isolation. Altogether in eight cases (26.7%), right PV conduction recurred. All PV conduction recovered in both superior and inferior PVs. The mean A–PVP interval was 166 ± 19 ms.

There were 10 gaps along the initial ablation line: including three in the postero-superior wall, two on the roof, and five in the postero-inferior wall. All gaps were closed by additional RF delivery at the end of the procedure. The procedural parameters of the three groups are listed in Table 2. The PV conduction recovery during observation period is shown in Figure 2.

Complications: no stroke or cardiac tamponade occurred. Pseudo-aneurysm developed in one case each in Groups A and B and was cured by conservative treatment.

Follow-up
We set the first month after ablation as the blanking period in this study, so the follow-up data were collected from the second month after ablation and later. The total number of cases and cases with ATa recurrence were recorded every month of follow-up. The ATa recurrence proportion was compared for each group every month, and at 5 and 6 months of follow-up there was a statistically significant difference for the three groups, P = 0.02 and 0.03, respectively. The follow-up results are shown in Table 3 and Figure 3.

In Group A, ATa recurred in five cases within 3 months post-ablation and remitted in none during follow-up. ATa recurred in six cases after 3 months and remitted in none. Altogether 11 cases had ATa recurrence, including 7 with AF, 3 with AF and atrial tachycardia/left atrial flutter, and only 1 case with atrial tachycardia/left atrial flutter. In Group B, ATa recurred in two cases within 3 months post-ablation and subsided in none. ATa recurred in three cases after 3 months without remission. Altogether 5 cases had ATa recurrence, including 4 with AF, and 1 with AF and atrial tachycardia/left atrial flutter. In Group C, four cases had ATa recurrence, which occurred in two cases within 3 months post-ablation and in another two cases 3 months later. All had AF recurrence and without remission.

At the end of 6.7 ± 2.3 (range 4–9 months) of follow-up, 17 cases (60.7%) in Group A, 27 cases (84.3%) in Group B, and 26 cases (86.7%) in Group C were free of AT, P = 0.04.

Discussion
Former studies focusing on PV conduction recovery were mostly limited to cases with AF recurrence and were usually undertaken several months after the initial

| Table 2 | The procedural parameters among three groups |
|-----------------|-----------------|-----------------|------------------|-------------------------|-------------------|
|               | Mean procedural duration (min) | Mean fluoroscopic duration (min) | Time for LPV isolation (min) | Time for RPV isolation (min) | 30-min LPV/RPV reconduction [n (%)] | 60-min LPV/RPV reconduction [n (%)] |
| Group A       | 165 ± 20
| Group B       | 200 ± 23
| Group C       | 37 ± 34

*P = 0.03, mean procedural duration compared among three groups.
This study evaluated the acute PV conduction recovery during the procedure among three groups of cases based on different observation times after PV isolation; it also evaluated the effect of different observation times on clinical results. PV conduction recovery was the dominant cause of AF recurrence after the initial ablation procedure and accounted for 80% of AF recurrence. A saline-irrigated ablation catheter delivered RF energy more efficiently than routine ablation catheters due to active cooling of the catheter tip, and facilitated the producing of transmural lesions. Furthermore, the CARTO system made it possible to maneuver the catheter precisely and helped to produce continuous lesions. Therefore, these techniques and apparatus were effective in achieving PV isolation by circumferential PV ablation, whereas we found moderately high prevalence of PV conduction recovery in routine practice. This could probably be attributed to the following factors: (1) circumferential PV ablation produced lesions around the PV antrum, which was 0.5–1 cm away from the PV ostia, a kind of structure in which PV sleeves connect with the left atrial myocardium circumferentially, rather than segmentally. Conduction recovery of any ablation lesion could lead to recurrence of PVP. (2) The complex anatomy of the PV antrum, i.e. the narrow ridge between the left superior PV and appendage, made it difficult to stabilize catheter tip positioning. The anatomical concave near the roof in some cases produced poor tip proximity to the atrial wall; in other cases the antero-inferior ridge of the right PVs also caused poor catheter tip stability. The effective energy delivery duration was shortened, and therefore unable to produce transmural lesions. (3) Severe pain caused by posterior wall ablation prevented enough energy delivery when anaesthesia was unsatisfactory, and deliberate shortening of energy delivery on the posterior wall for fear of atrial-esophageal fistular also facilitated incomplete ablation. (4) The mean thickness of the left atrial wall varied individually, so the power and duration of RF energy varied; fixed, rather than varying, energy and temperature was applied in some insufficiently ablated areas. (5) The slight dislocation of the reference patch could produce navigation failure, less precise navigation, or discontinuous lesion lines. (6) Catheter-manipulation skills varied individually.

PV conduction recovery after the initial PV isolation procedure could be classified into acute recovery and chronic recovery, according to the time it occurred. We postulated that their respective mechanism differed from each other. Acute PV conduction recovery might be attributable to discontinuous or non-transmural lesions, and chronic PV conduction recovery might be caused by the restoration of a few atrial myocardium cells which survived initial ablation. Theoretically, re-ablation of recovered PV conduction could produce transmural lesions, reduce living atrial tissues along lesion lines, and thus contribute to lowering of the prevalence of chronic PV conduction recovery and improving long-term success rate. The follow-up results of our study showed that the success rate in Groups B and C was significantly higher than that in Group A. The results of our study also showed that the prevalence of acute PV conduction recovery varied according to different observation time spent on evaluating it. Theoretically,
the longer the observation time was, the higher the prevalence of PV re-connection would be. Unfortunately, it was impossible to spend unlimited observation time on evaluating PV re-connection, so it was advisable to set the window of observation. Our study showed that the 30-min prevalence of acute PV conduction recovery was 25–30% for left PVs, while the 60-min prevalence was 32–36%. About 80% of recovery occurred within 30 min after initial PV isolation. For right PVs, the 30-min prevalence of acute PV conduction recovery was about 20%, while the 60-min prevalence was 30%. About 90% of recovery occurred within 30 min after initial PV isolation. According to these findings, it seemed reasonable to set the window of observation for 30 min after initial ablation.

Another result of our study showed that there was no significant difference for PV isolation time in the three groups, although more repetitive ablations were needed in Groups B and C than in Group A. According to the above results, we could see that during the re-isolation procedure, the A–PVP conduction was dramatically delayed and that by remapping, there was a mean of 1.2 gaps to close per case. One could, therefore, locate the gap(s) easily by identifying the shortest A–PVP interval when roving the catheter along the initial lesion line. Usually, a few additional RF deliveries was enough to re-isolate the target PV again.

In conclusion, the prevalence of acute PV conduction recovery was about 30%, which mostly occurred within 30 min after the initial PV isolation procedure. Re-isolation of recovered PV conduction contributed to the improvement of the success rate of ablation for paroxysmal AF.

Conflict of interest: none declared.

References