Remote Robotic Navigation and Electroanatomical Mapping for Ablation of Atrial Fibrillation

Considerations for Navigation and Impact on Procedural Outcome

Boris Schmidt, MD; Roland R. Tilz, MD; Kars Neven, MD; K.R. Julian Chun, MD; Alexander Fünnkranz, MD; Feifan Ouyang, MD

Background—Radiofrequency current ablation of atrial fibrillation (AF) requires high technical skills to achieve optimal catheter stability and is associated with an individually high x-ray exposure to both the patient and the operator. To facilitate catheter navigation and to reduce the operator’s x-ray burden, remote navigation (RN) systems have been developed. Considerations for navigation of a novel remote robotic navigation system in pulmonary vein isolation (PVI) procedures are reported.

Methods and Results—In 65 patients with drug-refractory AF (43 paroxysmal, 22 persistent), complete circumferential PVI was performed using RN in conjunction with different electroanatomic mapping systems. Acute complete PVI using exclusively RN was achieved in 95%. The procedure time was 195±40 minutes. The operator’s x-ray exposure time was reduced by 6±4 minutes (35%) using RN. In 7 of 14 patients with persistent AF, conversion to sinus rhythm was achieved by radiofrequency current ablation. During a median follow-up period of 239 days (range, 184 to 314 days), 47 of 65 patients (73%) remained free of any documented atrial tachyarrhythmia recurrences after a single procedure. The relative proportion of patients remaining free of AF was 76% and 68% for paroxysmal and persistent AF, respectively.

Conclusions—PVI using the novel RN system can be performed safely and effectively. One third of the operator’s fluoroscopy exposure time might be saved using RN. However, the questions of whether the overall fluoroscopy exposure is reduced by RN and whether RN improves PVI procedures needs to be assessed during a comparative trial between man and machine. (Circ Arrhythmia Electrophysiol. 2009;2:120-128.)

Key Words: ablation ■ fibrillation ■ mapping ■ pulmonary vein isolation ■ remote robotic navigation

Pulmonary vein isolation (PVI) has become the cornerstone procedure for patients with drug-refractory symptomatic atrial fibrillation (AF). The most commonly used ablation technique is circumferential PVI around the ipsilateral PV ostia using irrigated radiofrequency current (RFC). To establish contiguous transmural ablation lesions excellent catheter stability is an indispensable prerequisite.

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Long procedure times with individually long exposure times to scattered x-ray are “side effects” that might affect the operator’s health during a long career as an interventional electrophysiologist. To improve catheter stability and to reduce x-ray exposure, remote navigation (RN) systems have been developed and used in preclinical and clinical settings. The aim of this study was to describe the application of a novel remote robotic navigation system during PVI procedures in conjunction with different electroanatomical mapping systems with special emphasis on its ability to reduce the operator’s x-ray exposure.

Patients and Methods

The study population consisted of 65 patients (12 female; mean age, 61±9 years) with drug refractory paroxysmal (n=43) or persistent (n=22) AF (Table 1). Patients were highly symptomatic, despite the use of antiarrhythmic drugs and had suffered from AF for a median of 6 years (range, 1 to 46 years). Arterial hypertension was present in more than half of the patients in both groups. In addition, 6 patients (11%) suffered from stable coronary artery disease, and in 2 patients a pacemaker had been implanted for sick sinus syndrome. Before the ablation, all patients underwent transesophageal echocardiography to rule out left atrial (LA) thrombus. Mean LA size was 43±5 mm. No additional preprocedural imaging was performed.

The Sensei Robotic Navigation System

The Sensei (Hansen Medical) RN system was described in detail previously. In brief, it is an electromechanical system that facilitates catheter navigation through 2 steerable sheaths (Artisan, Hansen Medical), incorporating an ablation catheter. The outer (14F)
and inner sheath (10.5F) are both manipulated via a pull-wire mechanism by a sheath carrying roboter arm that is fixed at the patient’s table. The roboter arm obeys the commands of the central workstation positioned in the control room. Catheter navigation using a 3D joystick (Instinctive Motion Controller, Hansen Medical) allows a broad range of motion in virtually any direction. To provide a tactile feedback, the system continuously monitors the contact force (g) that is exerted by the catheter tip using a specially designed algorithm (IntelliSense, Hansen Medical). If the contact force exceeds a preset limit, an optical alarm is displayed and catheter advancement is rendered virtually impossible.

Before the insertion of the Artisan sheath, both sheathes were flushed with heparinized saline and the ablation catheter was inserted into the inner sheath. Throughout the procedure, both the inner and the outer sheath were continuously flushed with heparinized normal saline to prevent clot formation and air embolism.

### Electrophysiological Study and Ablation Procedure

All EP studies were performed during deep analgo-sedation with fentanyl, midazolam, and continuous infusion of propofol. Vital parameters were continuously monitored. Two standard catheters were positioned: a 6F catheter (Biosense-Webster, Inc) at the His bundle region via a femoral vein and a 6F catheter in the coronary sinus (CS) via the left subclavian vein. A single 8F SL1 sheath (St Jude Medical, Daig Division) was advanced to the LA by the Brockenbrough technique. After placement of a guide wire in the left superior (LS) PV, the puncture site was dilated by repeatedly advancing and retracting the sheath and dilator across the interatrial septum. Finally, the sheath was retracted to the right atrium (RA).

The Artisan sheath was advanced manually to the right atrium (RA) from the left femoral vein via a 14F sheath, until the outer sheath reached the level of the CS ostium. It was then attached to the robotic arm, and the inner sheath of the Artisan catheter was navigated remotely across the interatrial septum to the LSPV following the previously placed guide wire. After successful transseptal penetration of the inner sheath, the outer sheath was advanced close to the interatrial septum but remained in the RA to improve stability. Subsequently, the regular 8F transseptal sheath was advanced to the LA via the same hole and the guide wire removed.

After transseptal catheterization, intravenous heparin was administered targeting an activated clotting time of 200 to 300 seconds. Additionally, continuous infusion with heparinized saline through the outer sheath were continuously flushed with heparinized normal saline to prevent clots formation and air embolism.

### 3D Electroanatomic Mapping Using CARTO

The method of 3D electroanatomic mapping in the LA has been described previously in detail. In brief, mapping was performed with a 3.5-mm-tip catheter (ThermoCool Navi-Star, Biosense-Webster Inc) during sinus rhythm or AF. After LA reconstruction, the ipsilateral PV ostia were tagged on the electroanatomic map according to fluoroscopic and electrophysiological criteria. A decapolar spiral mapping catheter (Lasso, Biosense Webster) was positioned at the respective PV ostium where the ablation was performed.

### 3D Electroanatomic Mapping Using NavX

Mapping was performed using a spiral mapping catheter. Initially, the spiral catheter was advanced to a distal position in the respective PV, and data collection was started while continuously advancing and retracting the catheter inside the PV. This maneuver was repeated for all PVs and in a similar fashion for the left atrial appendage (LAA). The remainder of the LA was mapped by roving the spiral catheter inside the LA. In addition, distinct areas (eg, PV ostia) were remapped remotely with the mapping catheter. The PV ostia were tagged using 3D points at 4 locations (anterior, inferior, posterior, superior) to accurately delineate the PV-LA junction and to prevent RFC delivery inside the PV.

### Irrigated RFC Ablation

Irrigated RFC was delivered at target temperature of 43°C, a maximal power limit of 40 W, and an infusion rate of 17 to 25 mL/min. RFC ablation sites were tagged on the reconstructed 3D LA. RFC was applied for a minimum of 30 seconds or until the maximal local electrogram amplitude decreased by 70% or double potentials were noted. Irrigated RFC ablation was performed along the posterior wall more than 1 cm and along the anterior wall more than 5 mm from the angiographically defined PV ostia. The end point for ablation was defined as the absence of PV spikes registered on the spiral mapping catheter within the ipsilateral PVs.

### Lateral PVI

The first RFC ablation was typically performed at the roof of the lateral PV (LPV) ostium. The catheter was positioned rather parallel than perpendicular to the roof to prevent LA perforation (Figure 1). Wall contact was monitored by continuous registration of contact force using the IntelliSense algorithm. Then, RFC ablation was continued at the posterior wall by stepwise flexion and advancing the inner sheath as well as applying more distal bend to the outer sheath to increase stability. The latter was of particular importance at the anterior aspect of the LPV ostium that consists of the myocardial ridge to the LA appendage. Ablation catheter position was validated via fluoroscopic visualization and evaluation of local electrograms demonstrating a large amplitude atrial far-field potential and a small amplitude PV spike. Ablation along the anterior part of the LPV ostium was carried out from superior to inferior mainly by gradually increasing the distal bend of the outer sheath. If necessary, catheter position was adjusted by flexion of the inner sheath.

### Septal PVI

RFC ablation was typically started at the roof of the RPVs. Similar to the LPVs, we attempted a rather parallel catheter position to avoid LA perforation (Figure 2A). Wall contact was then continued anteriorly by gradually deinserting the outer sheath and optimizing the catheter position by moving the inner sheath. This approach mimics the “pull-down technique” used during conventional PVI procedures.

The ease of accessibility to the inferior border of the RIPV ostium was dependent on its anatomic position with regard to the transseptal puncture site. It was either accessible by a simple pull-down maneuver or in some cases by applying an explicit curve to the inner sheath to eventually reach the inferior border (Figure 2B).

### Transseptal Puncture Site

The anatomic relation between the transseptal puncture site and the anterior inferior border of the inferior RPV ostium was analyzed by distance measurements during selective angiography of the inferior RPV in a standard angulation (RAO 30°) using custom software (Coroskop T0P, Siemens). First, we assessed the distance between

<table>
<thead>
<tr>
<th>Table 1. Patient Characteristics</th>
<th>Paroxysmal AF (n = 43)</th>
<th>Persistent AF (n = 22)</th>
<th>Total (n = 65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>60 ± 8</td>
<td>63 ± 11</td>
<td>61 ± 9</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>83</td>
<td>86</td>
<td>83</td>
</tr>
<tr>
<td>Median (range) time of AF, years</td>
<td>6 (1–46)</td>
<td>5 (1–15)</td>
<td>6 (1–46)</td>
</tr>
<tr>
<td>LA size, mm</td>
<td>42 ± 5</td>
<td>46 ± 4</td>
<td>43 ± 5</td>
</tr>
<tr>
<td>Concomitant heart disease, n (%)</td>
<td>4 (9)</td>
<td>2 (9)</td>
<td>6 (9)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>24 (56%)</td>
<td>12 (54%)</td>
<td>36 (55%)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (2%)</td>
<td>1 (5%)</td>
<td>2 (3%)</td>
</tr>
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</table>
the anterior inferior PV ostium and the catheter placed within the coronary sinus (dCS), the latter being an anatomic approximation of the mitral annulus (Figure 3). Second, the distance between the transseptal puncture site marked by the Artisan sheath and the anterior inferior PV ostium was assessed (dPS). The ratio dPS:dCS was calculated to classify the transseptal puncture site as being posterior (ratio, 0 to 0.25), postero-medial (ratio, 0.26 to 0.5), antero-medial (ratio, 0.51 to 0.75), or anterior (ratio, ≥0.75) in the fossa ovalis.

**Ablation of Complex Fractionated Electrograms**

In patients with persistent AF who could not be cardioverted after PVI ablation of complex atrial fractionated electrograms (CAFEs) was performed as described previously.\textsuperscript{11,12} The end point of CAFE ablation was either (1) conversion into atrial tachycardia that was subsequently mapped and ablated, (2) conversion into sinus rhythm (SR) or (3) persistence of AF despite 60 minutes of additional RFC ablation. If AF persisted, external electric cardioversion was performed. In all cases, persistence of complete PVI was reassessed during SR and at least 30 minutes after PVI.

**Catheter Stability**

Catheter stability was analyzed semiquantitatively. The ipsilateral PV ostia were divided into 4 quadrants: superior, anterior, inferior, and posterior (Figure 4). At each position, the stability of the
Figure 2. A, Catheter ablation at the septal PVs. Screenshots from the Sensei workstation are displayed containing the fluoroscopic view (left) and the NavX map (right), both in RAO 30°. The ablation catheter is moved caudally by continuously deinserting the outer sheath (upper to lower panel; see insertion value in the middle of the screen). A spiral mapping catheter is positioned in the right superior PV (red), and a multipolar catheter is advanced to the distal coronary sinus. A blue virtual catheter displays the calculated bend of the mapping catheter. In the 3D map, the LAA (green), LSPV (blue), LIPV (yellow), RSPV (red), and RIPV (light green) are visible. B, Screenshots from the Sensei workstation are displayed containing the fluoroscopic view (right) and the NavX map (left), both in RAO 30°. The inferior aspect of the RIPV ostium was caudal to the transseptal puncture site in this patient. Therefore, the pull-down technique was not sufficient to reach the inferior border of the RIPV ostium, and the catheter had to be deflected maximally.
Ablation catheter was assessed and classified as good (no catheter dislodgement during RF delivery), moderate (1 interrupted RF application attributable to catheter dislodgement), or poor (>1 interrupted RF application attributable to catheter dislodgement), respectively.

Postablational Care

After sheath removal and pressure taping, all patients were anticoagulated with unfractionated heparin targeting a partial thromboplastin time of 50 to 70 seconds until an international normalized ratio of 2 to 3 was reached. Oral anticoagulation was resumed the day after the procedure. Before discharge, all patients underwent transthoracic echocardiography to rule out pericardial effusion as well as a 24-hour Holter ECG and a 12-lead ECG.

Oral anticoagulation was maintained for at least 3 months after ablation and thereafter according to the individual’s risk (CHADS2 score). Previously ineffective antiarrhythmic drugs were continued for 4 weeks.

Follow-Up

Follow-up was carried out according to the recently established HRS/EHRA/ECAS Expert Consensus Statement on Catheter and Surgical Ablation of Atrial Fibrillation. All patients underwent rhythm screening in form of 12-lead ECG and 24-hour Holter monitoring at 1, 3, and 6 months, respectively. In case of symptoms suggestive of arrhythmia recurrence (eg, palpitations, heart racing), patients transmitted a 30-second rhythm strip via an event recorder. In addition, telephonic interviews were carried out to assess the patient’s clinical symptoms and current medication. The success rate was calculated without using a blanking period.

Procedural Analysis

To analyze the contribution of the different steps to the total procedure and fluoroscopy times, we divided the procedure into three phases (A through C). Phase A included the time for preparation of the Artisan sheath, insertion of diagnostic catheters, transseptal puncture and ended when navigation of the Artisan sheath to the LA was completed. Phase B comprised the time for mapping (including PV ostial tagging) and angiographies and phase C incorporated the time from first RFC application to removal of all sheathes including a 30-minute waiting period after the last ablation.

In addition, fluoroscopy times were analyzed according to operator presence at the table or in the control room.

Statistical Analysis

All continuous variables are expressed as mean±SD or median and range, as appropriate. For between-group comparisons, the unpaired 2-tailed Student t test with $\alpha=0.05$ was applied, assuming that the data were approximately normally distributed. The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Results

Acute PVI

In 62 of 65 patients (95%), the end point of complete PVI of all PVs exclusively using RN was achieved. In 1 patient, access to the LA could not be achieved by RN because of a technical malfunction of the Artisan sheath (as post hoc technical analysis confirmed). In 2 patients, electric isolation of the LPVs was finalized manually at a posterior inferior gap and an anterior inferior gap in the circumferential ablation line, respectively. Both patients were among the first 12 patients treated. Afterward, all PVs were isolated using RN.

Catheter Stability

Catheter stability at the septal PV roof was good and moderate in 63 and 2 patients, respectively (Figure 4).
The total procedure time (skin to skin) was 195 minutes.

Procedural Parameters

<table>
<thead>
<tr>
<th></th>
<th>Manual Navigation</th>
<th>Robotic Navigation</th>
<th>Phase</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopy time, min</td>
<td>11±6</td>
<td>6±4</td>
<td></td>
<td>8±4</td>
<td>4±2</td>
<td>5±3</td>
<td>17±7</td>
</tr>
<tr>
<td>Procedure time, min</td>
<td>93±77</td>
<td>29±11</td>
<td></td>
<td>73±19</td>
<td>195±40</td>
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</table>

Fluoroscopy time is for both manual and robotic navigation.

Similarly, catheter stability was good or moderate at the inferior part of the RPV ostium. In contrast, catheter dislodgement was more often observed at the posterior wall (48, 14, and 3 patients with good, moderate, or poor stability, respectively). Along the anterior part of the RPV ostium good, moderate, or poor catheter stability was observed in 53, 11, and 1 patient, respectively.

At the lateral PVs, catheter stability, both superior and inferior, was good or moderate in almost all cases. Posteriorly, catheter dislodgement was more often observed (46, 15, and 4 patients with good, moderate, or poor stability). In almost half of the cases (22 patients with moderate and 8 with poor catheter stability), RF delivery at the anterior aspect of the LPV ostium (eg, the ridge to the LA appendage) had to be interrupted because of catheter dislodgement.

Catheter Navigation and Transseptal Puncture Site

The mean distance between the anterior RPV border and the CS catheter (dCS) was 123±8 mm, whereas the mean distance between the RPV ostium and the transseptal puncture site (dTS) was 55±17 mm (Figure 3). In 5 patients, the transseptal puncture site was in the posterior quarter (ratio dTS:dCS, 0 to 0.25); in 41, 18, and 1 patient, the transseptal puncture sites were in the 2 medial (ratio dTS:dCS, 0.26 to 0.5 and 0.51 to 0.75) or in the anterior quarter (ratio dTS:dCS, 0.76 to 1), respectively.

It was observed that the pull-down maneuver was impossible if the fossa ovalis had been punctured in the posterior quarter. In all other patients, the ablation along the anterior border of the RPV ostium was carried out by the pull-down maneuver.

Termination of AF in Patients With Persistent AF

This study incorporated 22 patients with persistent AF. Eight patients were successfully cardioverted after PVI. In 7 of 14 patients (50%) who could not be cardioverted electrically, AF was converted by ablation to a LA macro-reentrant tachycardia involving the mitral isthmus (LAMRT; n=4), typical RA flutter (n=2), or SR (n=1), respectively. The LAMRT and RA flutter were subsequently mapped and successfully ablated using RN.

Procedural Parameters

The total procedure time (skin to skin) was 195±40 minutes, including a 30-minute waiting time (Table 2). This consisted of 93±77 minutes for phase A, followed by 29±11 minutes and 73±19 minutes for phases B and C, respectively.

The total fluoroscopy time was 17±7 minutes, consisting of 8±4 minutes, 4±2 minutes, and 5±3 minutes for phases A, B, and C, respectively. The major fraction of the total fluoroscopy time was used when the operator was positioned at the table rather than in the control room (11±6 and 6±4 minutes, respectively).

The amount of RFC delivery time was 1480±490 seconds for the septal PVs and 1495±502 seconds for the lateral PVs.

Comparison of Mapping Systems

In 42 of 65 patients, PVI was performed using the CARTO system and in 23 of 65 patients, the NavX system was used. The total procedure and fluoroscopy times were not significantly different (Table 3). However, it became evident that using NavX the fluoroscopy time used manually tended to be longer (P=0.08) because LA mapping was performed with a spiral catheter and not using RN.

Learning Curve Using RN

Figure 5 shows the progressive shortening of procedural parameters using RN. A relatively steep learning curve was observed that led to stable procedural parameters after only 12 patients.

Complications

In 1 patient, transient ST segment elevation in all ECG leads occurred during RFC ablation at the lateral PVs. Immediate coronary angiography ruled out the presence of significant coronary artery disease. Thus, air embolism was deemed the most likely etiology for the observed ECG changes. Fortunately, the ECG changes resolved within 7 minutes and subsequent echocardiography did not demonstrate regional wall motion abnormalities. In addition, no neurological deficits were observed.

One patient developed cardiac tamponade after RA perforation caused by the outer sheath. This occurred during

Table 3. Comparison of Electroanatomical Mapping Systems

<table>
<thead>
<tr>
<th></th>
<th>CARTO (n=42)</th>
<th>NavX (n=23)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopy time, min</td>
<td>11±4</td>
<td>13±8</td>
<td>0.08</td>
</tr>
<tr>
<td>Procedural time, minutes</td>
<td>93±48</td>
<td>84±25</td>
<td>0.28</td>
</tr>
<tr>
<td>Phase A</td>
<td>29±10</td>
<td>30±12</td>
<td>0.35</td>
</tr>
<tr>
<td>Phase B</td>
<td>72±18</td>
<td>83±22</td>
<td>0.11</td>
</tr>
<tr>
<td>Phase C</td>
<td>194±40</td>
<td>197±43</td>
<td>0.42</td>
</tr>
</tbody>
</table>
remote transseptal access and became clinically evident by a drop in blood pressure after completion of the remote LA map. Interestingly, after immediate pericardiocentesis, only saline used for continuous flushing of the outer sheath was aspirated from the pericardial space. The patient experienced complete recovery with conservative management.

In 1 patient with severe odynophagia after ablation, an esophageal ulcer was discovered by endoscopy and resolved within 2 weeks of treatment with proton pump inhibitors.

**Follow-Up**

During a median follow-up period of 239 days (range, 184 to 314 days), 47 of 65 patients (73%) remained free of any documented atrial tachyarrhythmia recurrences after a single procedure. The relative proportion of patients remaining free of AF was 76% and 68% for paroxysmal and persistent AF, respectively. At 6-month follow-up, 10 of 65 patients (15%) were still on previously ineffective antiarrhythmic drugs.

Eleven patients underwent a second procedure because of documented recurrences of atrial tachyarrhythmias. Electric reconnection of the PVs was found during 9 repeat procedures, and reisolation was achieved at single conduction gaps along the previously circumferential ablation line. In 2 patients, all PVs were isolated at the repeat procedure.

In 4 patients, the RPVs showed reconduction, and the gaps were located superior (n=2) and posterior (n=2). In the remaining 7 patients, the RPVs were isolated. In 6 patients, the LPVs were reconnected and the gaps were located superior (n=4) or anterior-inferior (n=2).

Both patients with isolated PVs during the repeat procedures presented with perimital atrial flutter that was successfully treated by an ablation line between the inferior LPV and the lateral mitral annulus. No PV stenosis was detected during the repeat procedures.

There was no difference in chronic success rates with regard to the mapping system used.

**Discussion**

The present study describes the application of a novel robotic navigation system for catheter ablation of paroxysmal and persistent AF using different 3D mapping systems. It was demonstrated that (1) in this initial study, PVI using RN could be performed as safe and as efficient as using manual techniques; (2) RN can be used in conjunction with any of the 2 major 3D mapping systems; (3) the fluoroscopy exposure to the operator is reduced by approximately one third; and (4) the chronic success rate is similar to previously reported data using manual ablation techniques. However, the sample size of this study is rather small, the study design is nonrandomized, and the results reflect the outcomes of a single high-volume AF ablation (>1000 patients per year) center. If the results can be reproduced by a less experienced EP laboratory remains an unanswered question. A randomized prospective trial to compare RN to conventional manual PVI is necessary to truly compare success rates and potential reduction in the operator’s fluoroscopy exposure.

Current ablation concepts for AF aim at PVI. When RFC is used, a wide circumferential ablation line has been proven superior to a segmental approach. However, achieving contiguous linear ablation lesions is technically challenging and requires high navigation skills as well as excellent catheter stability.

**Navigation Properties**

In this series, it became evident that the major advantage of RN with respect to stability as compared to manual navigation was along the LA roof (Figure 4). However, at the anterior inferior portion along the lateral circumferential ablation line, catheter stability is suboptimal in almost 50% of the cases despite RN. This might be explained by the fact that this is the most distant location from the transseptal puncture site, thus decreasing stability. This can be partially compensated by a rather LA position of the outer sheath and distal bend application. Navigation to the anterior inferior aspect of the septal PVs proved challenging in those 5 patients in whom the transseptal puncture site was very posterior (Figure 3). As previously described, the distance between the fossa ovalis and anterior inferior border of the RPVs is short. To allow RN to this region, a rather anterior transseptal puncture site (medial quarter of the fossa ovalis) is advisable.

To perform a predominantly remote procedure, the transseptal navigation with the inner sheath was performed remotely during this study. Because the technology does not provide fully automated catheter control yet and one of the major complications was associated with this maneuver, it might be safer to perform this step manually. However, in the future, nonsteerable ablation catheters will be engaged in the Artisan sheath rendering manual navigation virtually impossible.

Due to the large outer diameter of the sheath, RN to the distal coronary sinus is discouraged. This might limit its use in ablation procedures for long-lasting persistent AF or perimtrial LA macroreentrant tachycardias, which frequently require epicardial ablation via the coronary sinus. However, temporary occlusion of the CS using a balloon catheter showed promising results and may allow for transmural lesion creation by endocardial RFC ablation along the LA isthmus. A further systematic evaluation is needed with special regard to the LA isthmus line.
offset by additional cost. However, this potential benefit may be reduced x-ray use. However, this potential benefit may be offset by additional cost.

**Lesion Quality**

Animal experiments demonstrated that increased stability and well-controlled contact force contribute to a better lesion quality. During this study, a systematic evaluation of stability and contact force was not performed. Although the RFC energy settings were not changed as compared with manual procedures, immediate and delayed reconnection of previously isolated PVs was observed. In addition, during repeat procedures electric reconnection of the PVs was the major finding. Therefore, it is still mandatory to ascertain optimal catheter position to achieve permanent transmural lesions. The optimal power settings and contact forces remain to be determined in future studies. Notably, no cardiac tamponade following a steam pop occurred.

**Complications**

The overall complication rate in our series of RN for PVI was low. The air embolism is a complication that may be related to any PVI procedure, whereas development of cardiac tamponade and esophageal ulceration deserve further exploration with regard to the safety of RN.

Because the contact force along the posterior wall is high, one may hypothesize that the LA wall is pushed toward the esophagus during RFC ablation, thereby increasing the risk for thermal damage within the esophagus. Temperature monitoring was not performed but may be helpful to avoid esophageal complications in the future as suggested by other groups. Whether the incidence of esophageal complications is higher than in conventionally treated patients remains to be determined.

The RA perforation by the outer sheath underlines the importance of continuous registration of and attention to the contact force as the operator is deprived of tactile feedback. At present, the Intellisense algorithm provides an approximate value of contact force. However, it remains unknown whether this algorithm is fully reliable, especially with regard to automatic catheter control. To date, it seems prudent not to rely solely on a software algorithm but to add electrophysiological and fluoroscopic information to guide a safe remote procedure.

No LA perforation was observed during mapping and ablation in this series. The only reported LA perforation associated with RFC ablation occurred at very high power settings (50W; 30 mL/min irrigation flow). We limit our setting to a maximum of 40W at the anterior wall and only 30W at the posterior wall and LA roof, which has proven sufficient to create transmural lesions.

**Conclusion**

PVI using the novel RN system can be performed effectively. One third of the operator’s fluoroscopy exposure time might be saved using RN. However, the questions of whether the overall fluoroscopy exposure is reduced by RN and if RN improves PVI procedures needs to be assessed during a comparative trial between man and machine.

**Disclosures**

None.

**References**


**CLINICAL PERSPECTIVE**

The present article describes the initial experience with a remote robotic navigation system to perform pulmonary vein isolation in patients with atrial fibrillation. The main advantages of remote navigation are the opportunity to (1) reduce the operator’s x-ray exposure and (2) compensate for reduced technical skills among less experienced operators. In the future, a completely automated remotely performed procedure could set new and more homogenous treatment standards for this complex procedure. However, to date, the integration of anatomic, electrophysiologic, and software information by an experienced physician is an indispensable prerequisite to accomplish a safe and successful procedure. The true value of remote navigation in pulmonary vein isolation procedures remains to be determined in a prospective randomized trial, “Man Versus Machine.”
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