Video Article

Robotic Ablation of Atrial Fibrillation

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Abstract

Background: Pulmonary vein isolation (PVI) is an established treatment for atrial fibrillation (AF). During PVI an electrical conduction block between pulmonary vein (PV) and left atrium (LA) is created. This conduction block prevents AF, which is triggered by irregular electric activity originating from the PV. However, transmural atrial lesions are required which can be challenging. Re-conduction and AF recurrence occur in 20 - 40% of the cases. Robotic catheter systems aim to improve catheter steerability. Here, a procedure with a new remote catheter system (RCS), is presented. Objective of this article is to show feasibility of robotic AF ablation with a novel system. Materials and Methods: After interatrial trans-septal puncture is performed using a long sheath and needle under fluoroscopic guidance. The needle is removed and a guide wire is placed in the left superior PV. Then an ablation catheter is positioned in the LA, using the sheath and wire as guide to the LA. LA angiography is performed over the sheath. A circular mapping catheter is positioned via the long sheath into the LA and a three-dimensional (3-D) anatomical reconstruction of the LA is performed. The handle of the ablation catheter is positioned in the robotic arm of the Amigo system and the ablation procedure begins. During the ablation procedure, the operator manipulates the ablation catheter via the robotic arm with the use of a remote control. The ablation is performed by creating point-by-point lesions around the left and right PV ostia. Contact force is measured at the catheter tip to provide feedback of catheter-tissue contact. Conduction block is confirmed by recording the PV potentials on the circular mapping catheter and by pacing maneuvers. The operator stays out of the radiationfield during ablation. Conclusion: The novel catheter system allows ablation with high stability on low operator fluoroscopy exposure.

Video Link

The video component of this article can be found at http://www.jove.com/video/52560/

Introduction

AF is the most common cardiac arrhythmia with a prevalence of 1 - 2% in the general population. Symptoms include palpitations, dizziness, dyspnea and reduced exercise capacity. Furthermore, stroke risk is substantially increased in AF patients. Over the past decade, PVI has become an established curative treatment option for patients suffering from AF[1,2].

The basic principle of PVI is the application of circular lesions around the PV ostium with radiofrequency (RF) energy to create an electrical conduction block between PV and the left atrium. This conduction block prevents atrial fibrillation, which is triggered by irregular electric activity originating from the PV. However, transmural lesions are required to achieve conduction block and application of transmural lesions can be challenging. Re-conduction and recurrence of atrial fibrillation after catheter ablation occur in 20 - 40% of the cases[1,2].

As it has been shown recently, sufficient catheter-tissue contact and catheter stability are prerequisites of effective ablation lesions[3,4]. Numerous techniques and ablation approaches have been developed to improve catheter-stability, streerability and catheter-tissue contact. Among others, robotic systems are of special interest. The advantages and principles of robotic ablation have been discussed before[5-7]. These systems may not only improve catheter stability by minimizing artefacts of manual catheter manipulation, but also have the advantage of reduced fluoroscopy exposure for the operator since the system is operated via remote control from outside the radiation field. A novel robotic system with remote catheter steerability has recently been introduced. Feasibility and efficacy of this system for PVI and other electrophysiological procedures, such as AV-nodal-reentry-tachcardia, accessory pathways or atrial flutter and atrial or ventricular tachycardias has been evaluated[7-9]. A significant reduction of operator fluoroscopy exposure compared to manual ablation was shown, while all other procedural parameters and success rate at 12-month follow up were not significantly different [7].

A procedure of left atrial mapping and PVI with the use of this new remote catheter system is presented here.

After obtaining vascular access via the femoral vein, interatrial trans-septal puncture is performed using a long trans-septal sheath and a trans-septal needle under fluoroscopic guidance. After trans-septal puncture, the needle is removed and a guide wire is place via the trans-septal sheath in the left superior pulmonary vein. Then the sheath in drawn back into the inferior vena cava and an ablation catheter is positioned in the LA, using the wire as guide to the fossa ovalis and the LA (“one-puncture, double-access”-technique). Once the ablation catheter has entered

the LA, the sheath is moved forward to the LA as well, the guide wire is removed and the ablation catheter is positioned in the left ventricle. A left atrial angiography is performed over the sheath, while the ablation catheter is used for high rate ventricular pacing to enhance contrast opacification. After LA angiography is completed, a circular mapping catheter is positioned via the long sheath into the LA and a 3-D-anatomical reconstruction if the LA is performed with the use of a mapping system. The circular mapping catheter is positioned in the right superior PV to record PV potentials and confirm conduction block after PVI. The ablation catheter is drawn back from the left ventricle into the left atrium and the handle of the ablation catheter is positioned in the robotic arm of the amigo system. During the ablation procedure, the operator manipulates the ablation catheter via the robotic arm with the use of a remote control. The ablation is performed by creating point-by-point lesions around the left and right PV ostia. Conduction block is confirmed by recording the PV potentials on the circular mapping catheter and by pacing maneuvers.

CASE PRESENTATION

Perform this procedure in a patient with symptomatic drug-refractory paroxysmal AF with no severe co-morbidities and no prior cardiac surgery. Perform the pre-diagnostic tests that are described below.

DIAGNOSIS, ASSESSMENT, AND PLAN

Diagnosis of AF is confirmed by repeated holter ECG recordings, including correlation of AF and symptoms (palpitations, dyspnea, reduced exercise capacity). If AF is recorded and symptoms are reported despite treatment with at least 1 antiarrhythmic drug, PVI is indicated for the treatment of symptomatic drug-refractory AF according to actual guidelines. PVI is scheduled and written informed consent is obtained from the patient. Prior to PVI physical examination, laboratory testing, transesophageal and transthoracic echocardiography are performed to rule out left atrial thrombus and severe structural heart disease. PVI procedure is performed in a fasting state under deep sedation. Vitamin K antagonists are discontinued 5 days prior to the ablation, low molecular weight heparin is started when international normalized ratio is <2.

Protocol

The protocol presented here is the standard approach of robotic catheter ablation RCS at the department of cardiology, Charité – Universitätsmedizin Berlin, Campus Virchow. The protocol and analysis of procedures and patient outcomes was approved by the local ethics committee of the Charité - Universitätsmedizin Berlin.

1. The Remote Catheter System (RCS)

1. Attach the robotic arm to the operating table, as described before[7] (**Figure 1**).
   NOTE: The RCS consists of a remote catheter manipulator, which is a robotic arm that can be moved by remote control.
2. Place the ablation catheter in the docking station of the RCS. Manipulate the catheter with the use of a remote controller, while the operating physician stays out of the radiation field[7]. Advance, withdraw, rotate and deflect the catheter with the use of the RCS.

2. Pre-ablation Preparation

1. Position the patient on the operating table and induce deep sedation with Midazolam (0.03 mg/kg bolus) and Propofol (continuous infusion 4 mg/kg/hr).
2. Place a temperature probe in the esophagus to measure esophageal temperature and prevent esophageal injury.
3. Attach 12-lead ECG and surface electrodes of the 3D-Mapping system to the body of the patient.
4. Before starting the procedure ensure that the following material are ready.
   1. A transseptal needle (71 cm) and an 8.5 F SL0 sheath with guidewire. A 6 F and 7 F 25 cm sheath. A decapolar and a circular streerable diagnostic catheter. An open-irrigated ablation catheter and an ablation generator.
   2. Additionally, ensure that a contrast syringe and a pericardiocentesis tray are available for acute treatment of complications.
5. Position the robotic arm of the system in a sterile drape and ready to use. Attach the handheld remote controller to the robotic arm (**Figure 1**).
6. Obtain venous access via bilateral venous puncture with a 6 F, 7 F and 8.5 F sheath and place a decapolar diagnostic catheter in the coronary sinus (CS).
7. Perform transseptal puncture under fluoroscopic guidance using a 8.5 F long SLO sheath and a 71 cm transseptal needle.
8. After trans-septal puncture, remove the needle and introduce a guide wire via the trans-septal sheath in the left superior pulmonary vein. Then draw back the sheath in the inferior vena cava.
9. Place a 8.5 F long SRO sheath with a wire in the left atrium (LA), using the wire as guide to the fossa ovalis and the LA (“one-puncture, double-access”-technique). Advance an open-irrigated ablation catheter with a 3.5 mm tip with contact force measurement via the SR0 sheath to the LA.
10. Administer Heparin with a rate of 15 UI/kg/h following a bolus of 140 IU/kg to maintain an activated clotting time (ACT) between 300 and 350 sec throughout the procedure.
11. Once the ablation catheter has entered the LA, introduce the sheath into the LA as well. Remove the guide wire and dilator of the SLO sheath and place the ablation catheter in the left ventricle. Perform LA angiography over the sheath, while using the ablation catheter for high rate ventricular pacing to enhance contrast opacification (LA angiography is shown in **Figure 2A**).
12. Advance a circular mapping catheter via the long sheath into the LA (circular mapping catheter shown in **Figure 2B**).
13. Perform a 3-D anatomical reconstruction of the LA with the use of a mapping system and the circular mapping catheter. Create a 3-D-anatomical reconstruction of the LA by moving the circular catheter on the inner surface of the LA, all of the four PVs and the left atrial appendage, while using a computerized mapping system for registration of the movement in relation to a reference electrode (complete 3-D-map is shown in **Figure 2C and D**).
14. Place the circular mapping catheter in the right superior PV to record PV potentials and confirm conduction block after PVI. Draw back the ablation catheter from the left ventricle to the left atrium (target position of both catheters shown in **Figure 2B**).

15. Drape the RCS with a sterile cover. Position the handle of the ablation catheter in the robotic arm of the amigo system.

3. Ablation Procedure

1. Perform catheter ablation as wide antral circumferential ablation (WACA) using a maximal temperature of 43 °C and maximum power of 35 W (septal) or 25 W (posterior wall) respectively ad a flow rate of 17 ml/min. Manipulate the ablation catheter via the robotic arm with the use of a remote control from outside the radiation field.
2. Perform ablation by creating point-by-point lesions around the left and right PV ostia. Measure contact force during ablation. Use the local electrogram amplitude reduction recorded on the tip of the ablation catheter, elimination or dissociation of the PV electrograms on the circular catheter and entry/exit block as ablation endpoints.
3. Mark each ablation point on the 3-D reconstruction.
4. Confirm conduction block for every single PV by recording potentials on the circular mapping catheter inside the PV (entry block) and by pacing from inside the PV without capture of the atrium (exit block).

4. Post-ablation Procedure and Patient Recovery

1. Stop Propofol infusion and remove all catheters.
2. Measure activated clotting time (ACT) and administer 3,000 IE protamine if ACT >300 sec before removal of sheaths. Remove the sheaths and perform manual compression on the puncture site for 10 min and until the bleedings stops. Place a pressure dressing in the groin and advise the patient to lay still for 8 hr.
3. Transfer patient to a step down unit and monitor for 4 hr and until fully responsive.
4. Administer low molecular weight heparin as anticoagulant until discharge. Begin oral anticoagulation (Warfarin or a direct oral anticoagulant) on the day after the procedure.
5. Perform transthoracic echocardiography on the day after the procedure as described before[17]. Rule out pericardial effusion and determine valvular function and left ventricular ejection fraction[17].

Representative Results

Endpoint of the procedure is complete electrical isolation of all PVs. It was shown recently in a study with 119 patients, that procedural parameters and outcomes were not significantly different in procedures with the RCS (n = 40) compared to the standard manual approach (n = 79). Statistical analysis (Mann-Whitney-U-test) revealed no significant differences in procedure duration (159.1 ± 45.4 *vs.* 146 ± 30.1 min, p = 0.19) total energy delivery (78146.3 ± 26992.4 *vs.* 87963.9 ± 79202.1 Ws, p = 0.57) and total fluoroscopy time (21.2 ± 8.6 *vs.* 23.9 ± 5.4 min, p = 0.15). Yet, operator fluoroscopy exposure was significantly reduced in the RCS group (13.4 ± 6.1 *vs.* 23.9 ± 5.4 min, p < 0.001) [7].

Additionally, analysis of the first 21 patients of PVI with the RCS was performed. Patient characteristics and clinical data are depicted in **Table 1**. This analysis represents a single-centre experience. Data was analysed for a series of 20 patients with PVI (data from one patient was unavailable due to technical reasons). Statistical analysis of procedural parameters was performed using the Mann-Whitney-U-test. Results are presented as mean ± standard deviation (SD) for continuous variables and as numbers and percentages for discrete variables. Total procedure duration was 137.3 ± 24.2 min, total fluoroscopy time was 26.1 ± 6.1 min, operator fluoroscopy exposure was 14.8 ± 6.1 min. Isolation of pulmonary veins (PVs) was achieved in all patients with the use of the remote system. Comparison of procedure duration, total fluoroscopy time and operator fluoroscopy exposure duration between was performed to analyse procedural improvement with growing experience with the technique. Mean duration of cases 11 - 20 was significantly reduced compared to cases 1 - 10 (125.5 ± 18.1 *vs.* 149 ± 24.6 min, p = 0.029), while reduction of total fluoroscopy time (23.1 ± 6.4 *vs.* 28.7 ± 9.3 min, p = 0.21) and operator fluoroscopy exposure time (12.9 ± 5.35 *vs.* 17 ± 6.48 min, p = 0.2) did not reach significance (**Figures 3** and **4**). Measurement of contact force was not performed. No complications occurred.

These initial results suggest that left atrial mapping and PVI is feasible and effective. Isolation of the PVs was achieved in all cases. The learning curve was short with a significant reduction of procedure time in case[11-20]. Operator fluoroscopy exposure was considerably reduced.

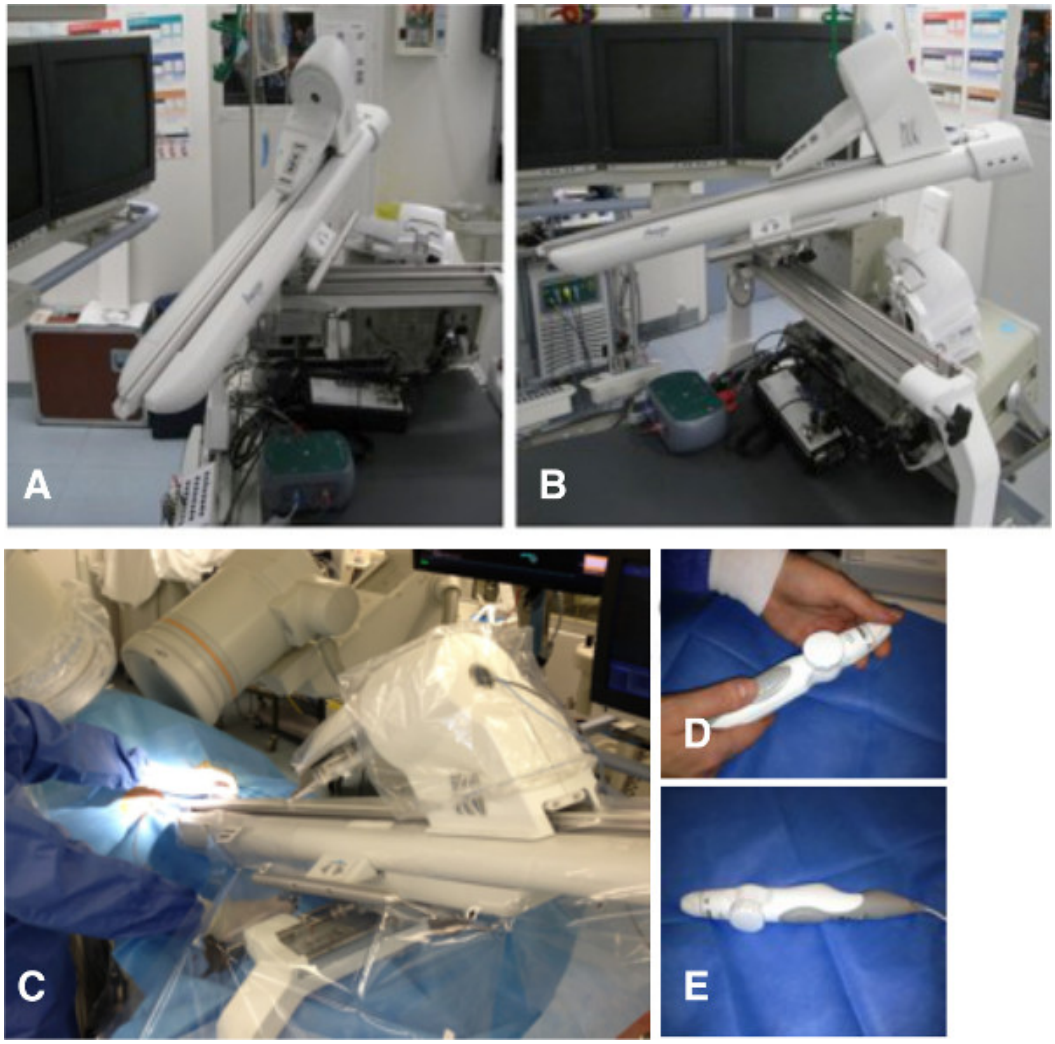

Figure 1. Remote catheter system. Robotic arm attached to the catheter table before (**A** and **B**) and after (**C**) insertion of the ablation catheter.Handheld remote controller (**D** and **E**). Please click here to view a larger version of this figure.

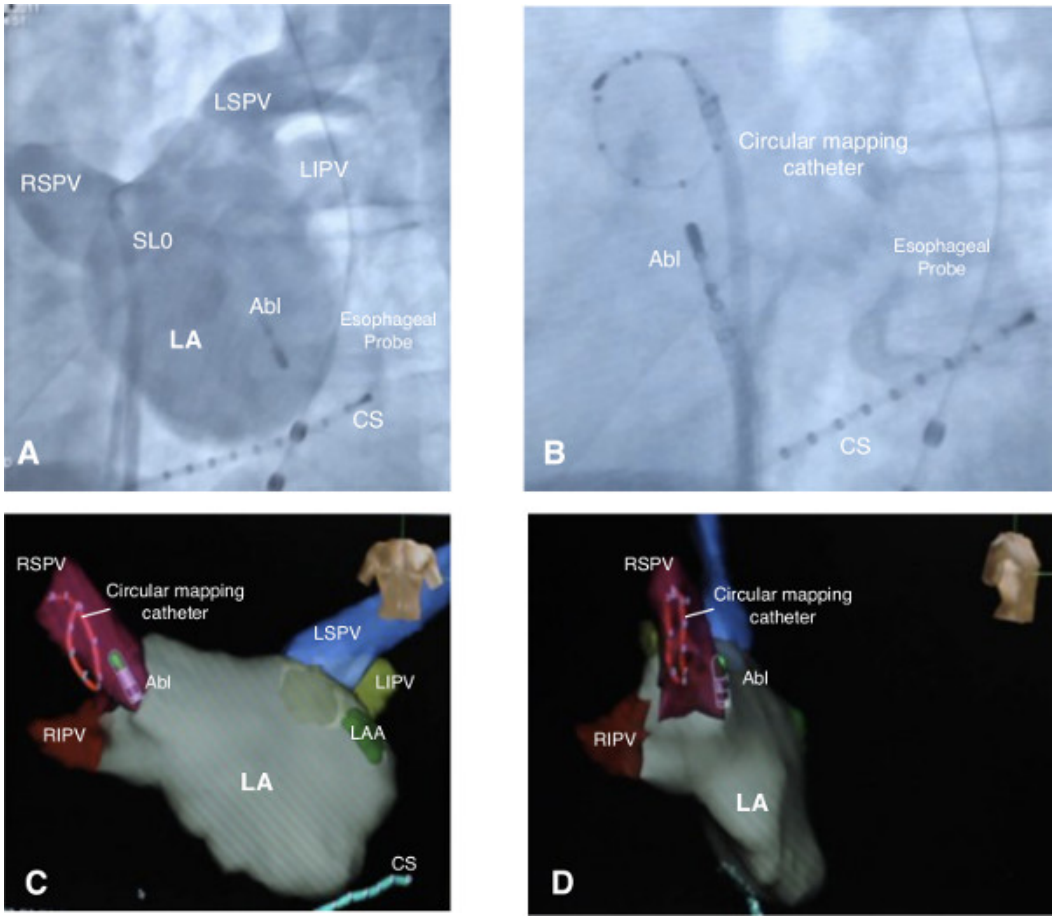

Figure 2. Images of the left atrium. Left atrial angiography in left anterior oblique view with the use of a SLO sheath for angiography and an ablation catheter for high rate ventricular pacing (**A**). Circular mapping catheter positioned in the right superior pulmonary vein (**B**). 3-D-reconstruction of the left atrium. The circular mapping catheter is shown in the right superior pulmonary vein. Left atrium is shown in anterior-posterior (**C**) and right lateral (**D**) view. Abl = ablation catheter, CS = coronary sinus catheter, LAA = left atrial appendage, LA = left atrium, LIPV = left inferior pulmonary vein, LSPV = left superior pulmonary vein, RIPV = right inferior pulmonary vein, RSPV = right superior pulmonary vein. Please click here to view a larger version of this figure.

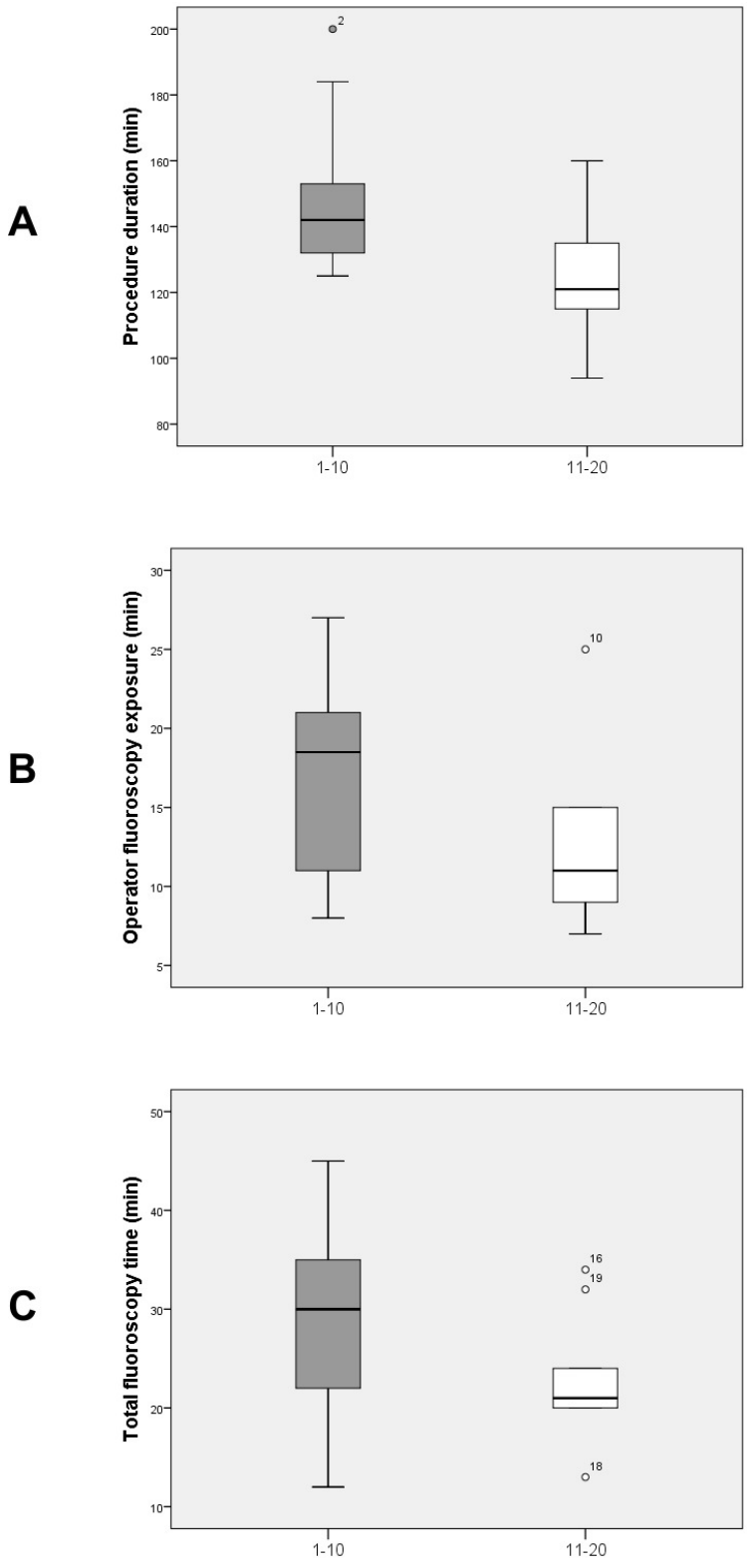

Figure 3. Procedural data for procedure 1 - 10 *vs.* 11 - 20. Procedure duration (**A**), total fluoroscopy time (**B**), and operator fluoroscopy exposure time (**C**) for procedure 1 - 10 and 11 - 20. * statistically significant.

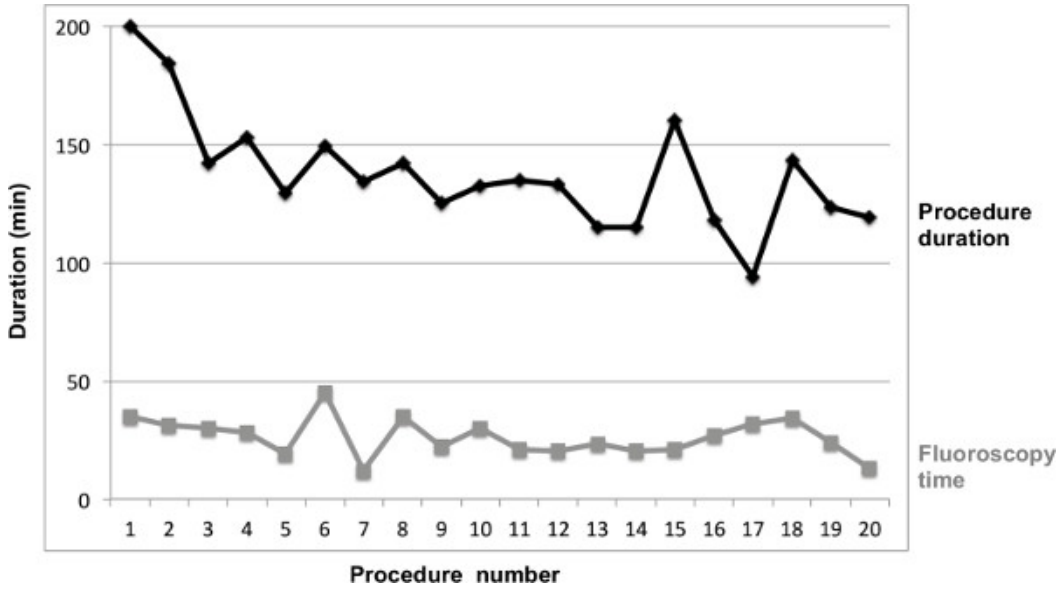

Figure 4. Procedure duration and total fluoroscopy time for procedure 1 - 20.

Baseline Characteristics	
Number of patients	21
Age (years) (SD)	64.1 (8.5)
Male (%)	17 (81)
BMI (SD)	28.1 (4.1)
Paroxysmal AF (%)	14 (66.7)
Hypertension (%)	16 (76.2)
CAD (%)	5 (23.8)
LVEF (%) (SD)	56.9 (4.6)
LA diameter (mm) (SD)	42.4 (4.9)

Table 1. Patients' characteristics and clinical data. Characteristics and clinical data of the first 20 patients undergoing AF ablation with the remote catheter system at our center. AF = atrial fibrillation, CAD = coronary artery disease, LA = left atrium, LVEF = left ventricular ejection fraction

Discussion

It has been reported by the group of Haissaguerre that antral PVI is a curative treatment for paroxysmal AF[1,2,10]. More recent data compared PVI with medical treatment in paroxysmal AF and found a lower rate of AF recurrence after PVI compared to antiarrhythmia treatment after 2 years of follow up[11]. However, as the authors of the RAAFT-2 trial conclude, recurrence rates after both types of treatment are high[11]. Therefore, improvement of the technique is necessary.

It has been discussed before, that manual catheter control may result in inaccurate catheter movements[5,7]. It therefore is of clinical interest, if ablation with the use of a robotic arm is feasible and effective. On the other hand, increased stability could lead to severe complications such as cardiac wall perforation and injury of adjacent structures. In a previously published study, is was shown that left atrial mapping and PVI with the RCS is feasible and effective. No major complication was observed[7], confirming previously published results on the safety of robotic ablation[12,13]. Operator fluoroscopy exposure is significantly lower without decrease of procedural success rates[7].

The first critical step is the trans-septal puncture. There is a significant risk of atrial wall perforation and cardiac tamponade as well as injury to the aorta. Puncture should be performed in the fossa ovalis under fluoroscopic guidance and with a CS catheter as landmark to minimize the risk. The next critical step is the 3-D-reconstruction. Accuracy of the 3-D-image depends on patient anatomy, catheter stability and patient immobilisation. Therefore, sufficient patient sedation is crucial to avoid movement artefacts and create a reliable image. The third critical step is the application of the ablation lesions. Optima catheter stability and wall contact should be achieved.

One of the major advantages of the RCS (compared to other robotic systems) is that it is possible to switch to manual ablation during the procedure and back to robotic ablation. This can be very helpful in case of anatomical abnormalities or difficult structures (*e.g.,* a common ostium of left PVs). The operator may perform ablation manually in difficult areas and use the RCS for the remaining ablation sites. Therefore, switching from robotic to manual ablation could be a solution for difficult situations during the procedure.

As mentioned before, measurement of contact force could add valuable information for the operator[7]. In the case presented here, contact force and catheter tissue contact with the use of the mapping system are assessed. Contact force mapping could further increase efficacy and safety of the procedure[14].

It is important to note, that despite the use of RCS certain steps of the procedure still have to be carried out manually, such as trans-septal puncture and positioning of the circular mapping catheter inside the pulmonary veins. Yet, those steps generally can be carried out quickly and do not necessitate long fluoroscopy time.

Furthermore, tactile feedback is lacking during robotic catheter ablation. The physician has to rely on fluoroscopy, 3-D reconstruction and contact force measurement. Studies on the use of contact force measurement during AF ablation have shown that tactile feedback is of very limited value for the estimation of contact force[15]. Therefore, contact force measurement is considered superior to tactile feedback in terms of efficacy. However, the value of tactile feedback for safety endpoints (*e.g.,* the prevention of atrial wall perforation) is less clear, since incidence of perforation is much lower than incidence of AF recurrence due to PV reconnection. Theoretically, measurement of contact force should also prevent excessively high force and wall perforation. One previous study found a relatively high incidence of esophageal lesions after robotic AF ablation[16]. Even though a different robotic system was used and no contact force was measured the results of the study by Tilz *et al.* may at least in part apply to the RCS used in our protocol. Large randomized prospective trials are missing, but numerous studies on initial experience with the RCS support the view that robotic ablation with the RCS is safe[7-9].

We here present a protocol for robotic ablation of AF. In contrast to previous studies we use a catheter with contact force measurement to increase safety and efficacy of the procedure. Operator fluoroscopy exposure can significantly be reduced. Catheter stability is most likely increased and outcomes are comparable to manual ablation. Additionally, switching between manual of robotic ablation is easy, which is a unique aspect of the RCS. In conclusion, ablation with the use of the RCS may in the future optimize PVI procedures, reduce operator radiation exposure and increase accuracy of the technique. Therefore, robotic ablation with the RCS is a promising approach in the treatment of AF.

Disclosures

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