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Pulmonary Vein Isolation by Robotic-Enhanced Thoracoscopy for Symptomatic Paroxysmal Atrial Fibrillation

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ABSTRACT

Background: Pulmonary vein isolation (PVI) has been shown to be effective treatment of patients with symptomatic paroxysmal atrial fibrillation (PAF). The percutaneous approach is currently the technique of choice. Unfortunately, this procedure has limitations and complications that lead to fluctuating success rates. We explored an alternative technique of robotic-enhanced, closed-chest PVI with an endoscopic microwave-based catheter.

Methods: Seven symptomatic PAF patients were included in the study. The pulmonary veins were isolated through right (only) robotic-enhanced thoracoscopy on the beating heart.

Results: Six patients underwent successful endoscopic PVI. In 1 patient the operation was converted into small right thoracotomy. Operative assessment of the ablation line showed a successful electric block in every patient. Three months after the procedure, the first 5 patients were in permanent sinus rhythm. The 2 other patients had AF but had less frequent and less symptomatic episodes compared with the preoperative situation.

Conclusions: On the basis of this preliminary experience, we believe that in the near future endoscopic right-chest robotic-enhanced PVI on the beating heart may become a valid option in the treatment of symptomatic PAF patients. This procedure allows for more-reproducible ablation lines and may avoid many of the pitfalls and drawbacks of the percutaneous approach. Therefore this technique deserves larger prospective evaluation in the treatment of AF.

INTRODUCTION

Atrial fibrillation (AF) is the most frequent cardiac arrhythmia and is associated with significant morbidity and mortality. Despite progress in understanding of the physiopathology of this condition, curative treatment of AF without concomitant cardiac disease is not well established. Although the results of initial experience with catheter ablation procedures were disappointing, the findings led to the important observation that initiation of AF may be due to focal triggers localized in the pulmonary veins (PVs) [Pappone 2000, Roux 2004]. With advances in experience and technology, it became clear that electrical isolation of all 4 PVs from the left atrium provides the highest cure rates [Papppone 2000, Pappone 2001, Oral 2003] after catheter-based interventions. However, the percutaneous procedure is still highly operator dependent and is associated with several complications and drawbacks, such as PV stenosis [Saad 2003].

The best curative treatment of AF is the Cox maze procedure [Chiappini 2004]. This operation provides excellent long-term results [Prasad 2003] but at the price of high surgical invasiveness and technical complexity. Therefore it has never gained sufficient acceptance to become the standard of therapy for AF without concomitant cardiac disease and is generally performed in combination with mitral valve surgery.

Only few centers have used surgical treatment of AF as sole therapy, mainly because a conventional surgical approach is not comparable with catheter ablation in terms of invasiveness. To compete with results of percutaneous treatment as sole therapy for AF, any specific surgical technique should provide success rates similar to those of the Cox procedure, should be minimally invasive, and should not expose the patient to the side effects of incisions, aortic manipulation, or cardiopulmonary bypass. The recent advent of 2 new technologies has enabled us to achieve this goal. First, with the experience of catheter-based ablation technology as a background, innovative catheters with different energy sources were developed to enable epicardial ablation, which is mandatory in operations on the beating heart [Haissaguerre 1998]. Second, robotics has launched the era of totally endoscopic cardiac surgical procedures. The focus has been on totally endoscopic coronary artery revascularization [De Cannière 2003], mitral valve surgery [Kypson 2003], and epicardial lead implantation for cardiac resynchronization therapy in heart failure patients [Jansens 2003]. This technology

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enables precise closed-chest surgical maneuvers and allows perfect visualization of the heart.

With robotic experience in the aforementioned cardiac fields, we considered that PV isolation (PVI) is feasible and that the procedure could benefit from a robotic approach combining the advantages of thoracotomy or sternotomy (excellent results and ease of surgery) with those of video-assisted thoracoscopic surgery (minimal incisions and postoperative pain).

In the current pilot study, we evaluated the feasibility of PVI through robotic-enhanced thoracoscopy in the treatment of symptomatic paroxysmal AF (PAF).

MATERIALS AND METHODS

Patients

Between June 2003 and February 2004, 7 patients with symptomatic PAF underwent PVI with the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA) under a prospectively defined protocol approved by the Ethics Committee of Erasme Academic Hospital, Brussels University Medical Center. All patients gave written informed consent prior to their participation in this study. The purposes of the study were to investigate the safety and efficiency of the procedure and to study overall postoperative patient outcome. Patients with major AF symptoms resistant to medical treatment or cardioversion were included in the evaluation.

Preoperative evaluation included clinical assessment, 48-hour Holter monitoring, transesophageal echocardiography, and cardiac magnetic resonance imaging. Anticoagulation (acenocoumarol) was initiated at least 1 month before the operation.

Follow-up consisted of 24-hour Holter monitoring, which was repeated in combination with echocardiography 3 and 6 months after the operation. After 6 months, if the results were good, the patients were allowed to stop anticoagulation.

The exclusion criteria were as follows: any patient for whom follow-up at 6 or 12 months was unlikely; patients who presented with a clot in the left atrial appendage (LAA); patients with left atria larger than 6.0 cm; any patient who had undergone a cardiac surgical procedure or previous sternotomy; any patient with asymptomatic PAF; and any patient with permanent AF.

Symptom Assessment

Clinical improvement, or success, was measured as follows. Improvement in symptoms was evaluated according to a standardized method of assessment of symptom severity, duration, and frequency. This tool was developed to assess the efficacy of treatment by measuring postsurgical severity of AF, frequency of AF occurrence, duration of symptoms, and the patient's own account of significant improvements in quality of life.

Method for Assessing Symptoms and Quality of Life

A prospective assessment of symptom frequency, severity, and duration and quality of life was performed with a combination of methods described by O'Callaghan et al [2001] and Tada et al [2003]. At 3 and 6 months of follow-up, symptom frequency and severity were assessed with the following questions: (1) On a scale of 1 to 5, how would you describe your symptom frequency since the surgery: 1, much more frequent; 2, more frequent; 3, unchanged; 4, less frequent; 5, much less frequent? (2) On a scale of 1 to 5, how would you describe your symptom severity since the surgery: 1, much more severe; 2, more severe; 3, unchanged; 4, less severe; 5, much less severe? (3) On a scale of 1 to 5, how would you describe the duration of the symptoms related to AF since the surgery: 1, much longer; 2, longer; 3, unchanged; 4, shorter; 5, much shorter? (4) On a scale of 1 to 5, how would you describe your quality of life since the surgery: 1, much worse; 2, worse; 3, unchanged; 4, better; 5, much better? The scores of the 4 responses were used to calculate a final score as follows:

Final Score = (0.2 * frequency score) + (0.3 * severity score) + (0.1 * duration) + (0.4 * quality of life score)

The treatment was considered successful if the final score was 3.5 or greater.

Procedure Guidelines

PVI was the only lesion made without excluding the LAA. Operative time and complications associated with the procedure were recorded.

Operative Technique

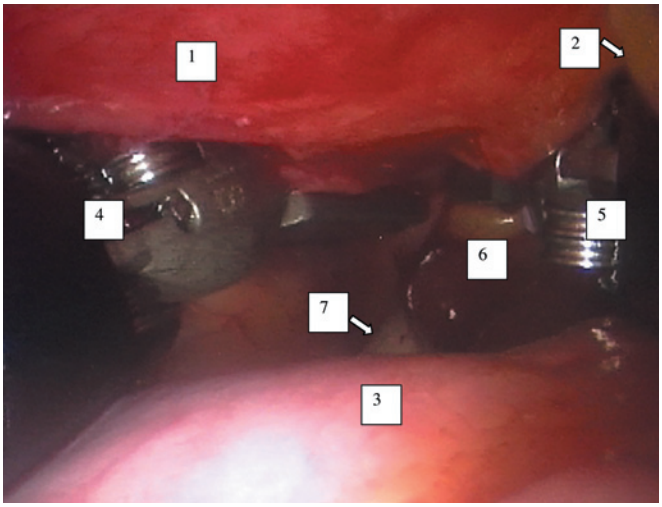
Three ports were created on the right chest at the second, third, and fifth intercostal spaces posterior to the right anterior axillary line. The da Vinci robot telemanipulator (Intuitive Surgical) was used for both endoscopic visualization and manipulation. After sharp opening of the pericardium, the superior vena cava and inferior vena cava were dissected circumferentially. This procedure allowed free access to the transverse and oblique sinuses. A 150-cm guide wire (Terumo, Tokyo, Japan) was used to position the microwave probe (Flex 10; AFx, Inc., Fremont, CA, USA) around the PVs.

Device positioning posterior to the LAA was confirmed by introduction of the robotic camera into the transverse sinus (Figure). This maneuver enabled us to accurately address this major technical issue in all cases. Once the ablation probe was positioned around the PVs, the "box lesion" was made to isolate the veins from the remaining atrial tissue. After a continuous encircling ablation line was made around the PVs, a bipolar stimulation probe was introduced into the chest for assessment of electrical completion of the ablation lines.

RESULTS

There were 5 male and 2 female patients in the study. The mean age was 55 years (SD, 13.49 years). The average preoperative duration of AF was 103.25 months (SD, 171.67 months). The mean overall procedure duration was 3.87 ± 1.84 hours, including sterile draping of the robot, its calibration, and the endoscopic surgical procedure (Table 1). The mean duration for the last 4 patients was 2.17 ± 0.76 hours (Table 2).

The first patient experienced severe pulmonary edema in the early postoperative period and therefore had to stay in the



Assessment of the probe position around the left atrial appendage (LAA). 1 indicates ascending aorta; 2, right atrial appendage; 3, superior vena cava; 4, left robotic arm; 5, right robotic arm; 6, LAA; 7, microwave probe positioned posterior to the LAA.

hospital for 10 days. In 1 patient the operation was converted to small right thoracotomy because of trauma to the right pulmonary artery that mandated direct repair. The entire procedure, including assessment of the position of the probe, was performed through this access.

Postoperative Sinus Rhythm

After a follow-up period ranging 6 to 11 months, 4 of the first 5 patients were in normal permanent sinus rhythm. The fourth patient had an uneventful postoperative course until the third postoperative month. He had major improvement in quality of life and a significant decrease in AF symptoms. Unfortunately, in the fourth postoperative month the patient presented with sudden chest discomfort and fatigue (although less than before the procedure). Electrophysiological study showed left atrial atypical flutter, which is a classic complication after percutaneous AF ablation procedures. This complication is known to be caused by lack of a left isthmus ablation line from the inferior line of the box lesion to the mitral annulus. A percutaneous ablation line was made in this patient and solved the problem.

Table 1. Patient Demographics and Operative Data

Number of patients	7
Female/male ratio	2/5
Age (mean ± SD), y	55 ± 13.5
Duration of atrial fibrillation (mean ± SD), mo	103.25 ± 171.67
Procedure duration (mean ± SD), h	3.57 ± 1.84
Complications, n	
Conversion (thoracotomy)	1
Pulmonary edema	1
Phrenic nerve palsy (transient)	2

The last 2 patients continues to have AF, but the symptoms were much less severe than before the ablation procedure. Nevertheless the overall calculated scores were good in all our patients, meaning that the patients were subjectively satisfied with their short-term postoperative course.

DISCUSSION

The results of the present pilot study showed that robotics-enhanced thoracoscopic PVI is feasible and reproducible. It may avoid the drawbacks of conventional surgery and some of the limitations of the percutaneous approach. The latter is currently the technique of choice for treating symptomatic PAF. This procedure remains very operator dependent and technically demanding and accounts for significant complications, such as PV stenosis and atypical left atrial flutter. Moreover, this procedure usually takes a long time, leading to high levels of exposure to x-rays for the surgical team and the patient [O'Callaghan 2001].

The advantage of a surgical approach is that it enables direct visual and easy electrical assessment of the ablation line. On the other hand, it carries risk of injury to the circumflex coronary artery. This risk is theoretical if ablation is performed when the probe is misplaced in front of the LAA. Moreover, in this procedural setting there is no possibility of making an ablation line to the mitral annulus. Such an ablation line can lead to postoperative left atrial flutter, as in the percutaneous approach. Finally, the procedure requires general anesthesia and a longer hospital stay.

Few data have been reported on totally endoscopic surgical ablation for AF therapy. Reported techniques usually involve a bilateral sequential approach from the right and from the left sides of the chest. This technique generates specific problems and leads to a long-lasting and sometimes quite demanding procedure. The need for the bilateral approach is caused by the need for assessment of probe positioning with regard to the LAA and the circumflex artery and/or by the degree of willingness to exclude the LAA. We found that this bilateral approach was obviated when we checked the probe position directly from the right side, inserting the robotic camera through the transverse

Table 2. Procedure Duration and Symptoms and Quality of Life Assessment*

Patient	Procedure Duration, h	Postoperative Score at 3 Months	Postoperative Score at 6 Months
1	6	4	5
2	4	5	5
3	5	4.1	4.6
4†	3	5	4
5	2	5	5
6	1.25	4	NA
7	1.75	5	NA

*A procedure was considered successful with a score higher than 3.5. NA indicates not available.

†Patient 4 developed left atrial flutter in the fourth postoperative month.

sinus. By doing so, we were able to safely perform a reproducible operation in 90 minutes, after a fairly short learning period.

This right robotic approach, however, is only for simple PVI and does not allow multiple ablation lines. It also does not exclude the LAA. It seems clear that in patients with permanent AF, in whose care the goals are other than symptom relief, such as prevention of thromboembolic events, another surgical approach should be used. Similarly, to improve the success rate of ablation (compared with the percutaneous approach), procedural modifications should be investigated, such as finding a way to ablate the left isthmus.

If robotic-enhanced thoracoscopy allows expeditious dissection in robotics-experienced hands, this beating heart procedure could also be performed with alternative surgical techniques, depending on the operator's skills in minimally invasive techniques (conventional thoracoscopy or minithoracotomy).

Comparing surgical with percutaneous intervention addresses the major issue of surgical versus medical competition for the "marketplace." We believe this competition, although it affects strategy to a significant extent in the "real" world, is not a relevant issue. Surgery is no longer the worse-case scenario just because anesthesia is used. Extubation on the operating table after a short noninvasive procedure accounts for low complication rates and few adverse sequelae. In this case the risk/benefit ratio no longer justifies balancing the eventual better surgical results with the prohibitive invasiveness and potential complications of the operation. On the contrary, we believe that both approaches may be combined in the near future and enhance each other rather than compete.

In summary, robotic-enhanced thoracoscopy for PVI is feasible and safe in the treatment of PAF patients. Promising postoperative antiarrhythmic results should be confirmed in larger studies and be compared with those of the percutaneous approach. Many strategic issues must be solved, such as the optimal adjunct pharmacological therapy. To refine the ablation lines (to improve long-term results) and to broaden the indications, strategies such as surgical or combined percutaneous/surgical techniques should be developed, and new devices should be considered for safe exclusion of the LAA.

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