Clinical Experience with Thoracoscopic and Minimally Invasive Surgery of Arrhythmias

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Summary

In this article, we describe an original technique of video-assisted thoracoscopic implantation of myocardial or epicardial electrodes for permanent pacing and epicardial radiofrequency ablation (RFA) of tachyarrhythmia by minimally invasive surgery. From November 1997 to December 1999, 25 patients (mean age 12.8 ± 9.8 years, 14 male, 11 female) underwent video-assisted thoracoscopic myocardial lead implantation (three patients) or minimally invasive brady- and tachyarrhythmia surgery (22 patients). A three-port system with one 5 mm- and two 12 mm-accesses was used in three infants with congenital 3rd degree heart block for implantation of screw-in myocardial leads in combination with a permanent VVIR pacemaker implanted in the abdominal or subpectoral positions. The Vista Cardio Thoracic Surgery 8000 system for video-assisted minimally invasive surgery was used to implant unipolar or bipolar steroid-eluting epicardial leads via thoracotomy at the the right 4th or 5th left intercostal space of 11 patients (mean body weight 11.2 ± 4.2 kg) with congenital 3rd degree AV block. Video-assisted minimally invasive surgery was used to ablate supraventricular tachycardia (ectopic atrial tachycardia, Wolff-Parkinson-White syndrome, atrial flutter) in 14 patients (mean age 27 ± 7.5 years, 8 male, 6 female). Conventional 7 – 8 F ablation electrodes with a 4 – 5 mm tip and a modified system of external cooling with a physiological solution were used to create the transmural ablation zone in the atrial myocardium through the delivery of 20 – 35 W high-frequency power (80 – 120 s duration for each application). The epicardial approach was used due to the inefficiency of endocardial RFA and the necessity of surgical correction of concomitant congenital malformations. The acute pacing threshold was 0.8 ± 0.3 V for the atrium, and 0.7 ± 0.2 V for the ventricle; the A-wave amplitude was 8.2 ± 3.5 mV, and the R-wave amplitude was 12.5 ± 2.5 mV. Chronic pacing thresholds for the steroid-eluting series did not change significantly after the 12-month follow-up (P = 0.1). Right anterior mini-thoracotomy at the 4th intercostal space is recommended for dual chamber pacemaker implantation in small infants with congenital 3rd degree AV block. Right-sided lateral thoracotomy performed by means of a 5 – 7 cm incision under normothermic cardio-pulmonary bypass with femoral artery cannulation was used for supraventricular tachycardia ablation and atrial septal defect closure. The intubation time, surgery duration, and the intensive care unit time were on average 5, 3.5 and 12 hours, respectively. There were no complications, arrhythmia recurrence, or steroid-eluting lead problems observed during the follow-up up to 30 months. Implantation of permanent epicardial steroid-eluting leads for dual chamber pacing via a small right-sided anterior-lateral thoracotomy approach is feasible and safe in small infants with congenital 3rd degree AV block. Video-assisted minimally invasive surgery can be successfully used to eliminate tachyarrhythmias after ineffective endocardial RFA. This obviates the need for fluoroscopy and provides good cosmetic results.

Key Words

Minimally invasive arrhythmia surgery, radio-frequency catheter ablation, cardiac pacemaker

Introduction

Radio-frequency catheter ablation (RFA) is currently the method of choice for curing different forms of supraventricular and ventricular tachycardias; it is effective in 95 % – 98 % of cases [1]. However, RFA has to be

repeated in 5 % to 30 % of cases due to recurrence of tachyarrhythmia [2], and open-heart surgery must to be performed in some cases. Simultaneous correction of the tachyarrhythmia and of the congenital, acquired, or ischemic heart disease is the method of choice as far as the long lasting fluoroscopy times that are characteristic of the catheter RFA approach are avoided This alternative simultaneous approach is becoming feasible with the introduction of minimally invasive surgery of congenital and acquired heart diseases [3,4].

Another point of interest is the use of pacemaker implantation in infants with congenital AV block (present in 1 out of every 20,000 newborns [5,6]). Myocardial electrodes were mainly implanted for permanent pacing in those patients with accompanying heart disease and low birth-weight and size. In comparison to endocardial leads, myocardial leads have a shorter operating lifetime due to the ever-increasing pacing threshold [7,8]. Development of the steroid-eluting leads for epicardial pacing can lead to new methods of application via mini-approaches. In this paper we analyze our first clinical experience with minimally invasive surgery for several forms of tachy- and bradyarrhythmia.

Materials and Methods

From November 1997 to December 1999, 25 patients (mean age 12.8 ± 9.8 years, 14 male, 11 female) underwent surgery for bradyarrhythmia (14 patients – group I) and tachyarrhythmia (11 patients – group II) using a minimally-invasive approach. The pacemaker implantation was indicated in group I due to congenital AV block (11 patients) or persistent total AV block after correction of the ventricular septal defect (three patients). The pacemaker was implanted 10 – 14 days after the initial heart surgery when the persistent AV block was documented by Holter monitoring. Symptomatic bradycardia and syncope were indications for the pacemaker implantation in patients with congenital AV block (mean age 4.0 ± 1.4 years over a range from 8 months to 5 years, mean weight 11.2 ± 4.2 kg over a range from 5 to 20 kg). Retrospective analysis also included lead-related complications after transvenous and myocardial implantation; this included 263 infants with 3rd degree AV block (68 of them with the congenital form).

Table 1 summarizes the clinical data on the bradyarrhythmia patients who underwent the video-assisted thoracoscopic technique (Karl Storz, Tutllingen, Germany) with the aid of instruments designed for thoracoscopy, the mini-approach, and the 3D video-system (Series 8000 system, Vista Medical Technologies, USA). Different techniques were used for epimyocardial pacing, in accordance with the difficulty of this procedure. During the mini-invasive operations a three-port (5 – 12 mm) system was used; the ports were placed in the 4th intercostal space along the medioclavicular line and the anterior subaxillary line, and one port was placed in the 3rd intercostal space along the anterior subaxillary line. The head of the myocardial lead (5071 lead, Medtronic, USA) was introduced through the first port (along the medioclavicular line), which had a diameter of 12 mm. In the case of left-thoracotomy lead implantation, the incision (2 – 3 cm long) was made in the 4th intercostal space along the medioclavicular line in the projection of the apex into to the chest. For the dual chamber pacemaker implantation, the heart was approached through the 4th intercostal space using a 4-cm long incision along the sternal edge. A 2D- and 3D-projection video camera was inserted through an additional aperture to control all surgical manipulations. Bipolar (eight patients) or unipolar (three patients) steroid-eluting leads (CapSure Epi 4468 and 4965, Medtronic) were fixated epicardially to the right atrium and the right ventricle, respec-

Diagnosis	Number of patients	Approach	Type of surgery	Pacing mode	Complication
Congenital CHB	3	VATS	Myocardial leads impl.	VVIR	Exit block (2) (reoperation)
Congenital CHB	8	Right thoracotomy (3 - 4 cm)	Epicardial leads implantation	DDD/DDDR	No
CHB following open-heart surgery	3	Left thoracotomy (2 - 3 cm)	Epicardial leads implantation	VVI/ VVIR	No

Table 1. Clinical data for 14 patients undergoing surgery for bradyarrhythmia; CHB- complete heart block; VATS- Video assisted thoracoscopic surgery.

Diagnosis	Number of patients	Approach	Type of surgery	Complication
Ectopic supraventricular tachycardia	4	Right thoracotomy (4 cm)	Epicardial RFA in right atrium and pulmonary vein	No
Wolff-Parkinson-White Syndrome (B)	2	Ministernotomy (6cm)	Sealy procedure (CPB)	No
AV nodal reentrant tachycardia and atrial septal defect (ASD)	2	Right thoracotomy (6 - 8 cm)	Perinodal ablation (CPB)	No
Atrial flutter and ASD	3	Right thoracotomy (6 - 8cm)	Endocardial RFA in istmus ASD closure	No

Table 2. Clinical data for 11 patients undergoing sugery for tachyarrhythmia. CPB = cardio-pulmonary bypass; RFA = radiofrequency ablation.

tively. The battery was placed in the fascia of the rectus abdominis muscle. After testing to find the optimal position for pacing in the high right atrium, the right ventricle (via the right-sided approach in eight cases) and the left ventricle (via the left-sided approach in six cases), the myocardial leads were fixated (5071 screw-in leads, Medtronic) in three cases. Epicardial steroid-eluting (Medtronic Capsure EPI 4968) leads were implanted in the bipolar (16 leads) or the unipolar configuration (six leads). The following pacemakers were implanted: Actros SR (1), Pikos 01 (2) (both Biotronik), Prodigy DR (8), and Prodigy SR (3) (both Medtronic).

Eleven patients in group II (mean age 20.5 ± 7.2 years) were operated on due to tachyarrhythmias (Table 2). Four patients underwent operations without a cardiopulmonary bypass (CPB). These operations were performed via a right-sided anterior-lateral thoracotomy (4 cm) with the aid of cooled epicardial RFA. Two patients were being treated for right-sided ectopic tachycardia, one patient for ectopic left-atrial tachycardia, and one patient for Wolff-Parkinson-White (WPW) syndrome with right-sided epicardial localization of the accessory pathway. Seven patients were operated on under hypothermic CPB and antegrade Custodiol-bolus cardioplegia (single 2-liter infusion) with peripheral cannulation of the femoral artery. Five patients (71 %) underwent surgical repair of an interatrial septal defect and ablation of the AV nodal reentrant tachycardia (AVNT) (two patients), and three patients had type I atrial flutter. The cooled RFA method was used in those cases; the ablation catheter electrodes (Blazer 7F, EPT, USA or Mariner 7F, Medtronic) with a 4 – 5 mm distal tip were inserted through a modified Swartz 8F introducer. Physiological solution was injected at the rate of 10 – 30 ml/min through the introducer lumen directly into the electrode head. High-frequency power was applied under controlled temperature (70 °C) and impedance (250 Ω) (Osypka 200, Atakr, Medtronic). In WPW patients, RFA was performed in the zone of maximal pre-excitation defined by epicardial mapping. Four patients with AVNT underwent RFA applied in the zone of anatomically localized slow pathways (base of the Koch triangle), and at the heart «isthmus» in the case of atrial flutter type I. Surgical manipulations in the hard-to-approach zones were controlled in some cases with the Vista 3D-video system. Transvenous RFA was not effective in patients with ectopic tachycardia and WPW syndrome.

Follow-up

The patients were followed up regularly over a period of 2 to 30 months. The pacemaker patients were evaluated for pacing thresholds and IEGM data. The patients that received the mini-approach tachyarrhythmia correction were evaluated for the rate of tachyarrhythmia recurrence rate and the cosmetic result of the operation. Echocardiography and transesophageal programmed stimulation were performed to estimate the operation's effectiveness.

Statistical Analysis

All measured values were expressed as mean percentages ± standard deviation (SD). Student's t-test for paired data was used to assess the statistical significance of parameter differences. A confidence level with a P-value < 0.05 was considered significant. The absence of lead-related re-operation during follow-up was visualized using the Kaplan-Meier method. The statistical computation was performed with the statistics software (Statistika 5.0, StatSoft, USA).

Results

Bradyarrhythmia Surgery

The following features have been revealed in the bradyarrhythmia group (n = 14). We stopped using epimyocardial pacing leads of the screw-in type (Medtronic 5071) because the pacing threshold increased over a period of 6 to 24 months after the thoracoscopic lead implantation procedure. All three patients with congenital AV block underwent lead re-implantation with steroid-eluting leads 3, 6 and 24 months later. Finally, eight children with congenital AV block received steroid-eluting leads for dual chamber pacing. In 80 % of the cases, we implanted the steroid-eluting bipolar leads (CapSure Epi 4968, Medtronic) with appropriate pacing thresholds of 0.8 ± 0.3 V for the atrium and 0.7 ± 0.2 V for the ventricle. The IEGM amplitude was 8.2 ± 3.5 mV for the A-wave and 12.5 ± 2.5 mV for the R-wave. 16 bipolar and three unipolar leads were implanted in 11 children. DDD or DDDR dual chamber pacemakers were implanted in all patients with congenital AV block via a right-sided anterolateral thoracotomy. For ventricular pacing we used unipolar steroid-eluting leads due to iatrogenic total AV block resulting from the correction of the ventricular septal defect.

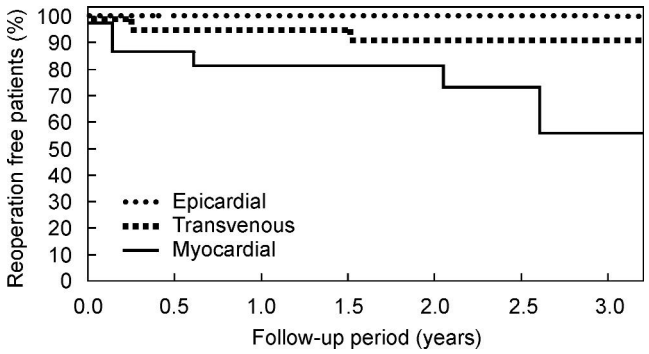

Figure 1. Lead-related reoperation-free interval of pediatric patients with transvenous or steroid-eluting epicardial leads (n = 132).

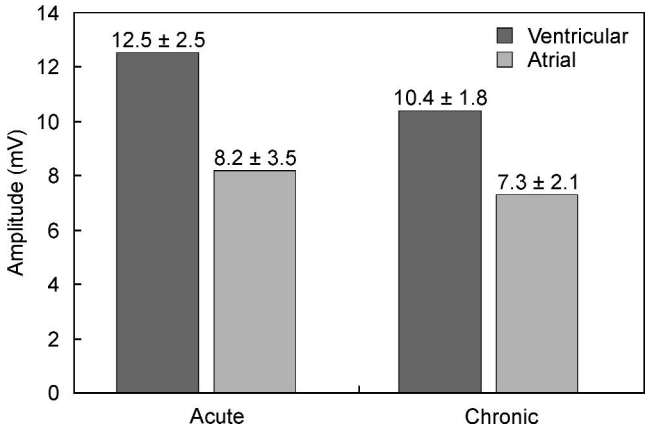

Figure 2. Acute and chronic bipolar signal amplitudes of steroid-eluting epicardial leads in 14 patients undergoing.

Over the same period, we implanted 98 endocardial and 15 myocardial leads in patients (aged 4 to 20 years) with 2nd and 3rd degree AV block and sick sinus syndrome. Figure 1 depicts the re-operation data of patients with leads of different types implanted over 3 years. A lead-related operation was defined as re-operation due to early battery depletion (< 3 years), chronic pacing threshold increase (as the result of lead fracture or dislocation), and exit block. The age-adjusted rate of lead-related re-operation was significantly lower for patients with myocardial lead placement ($P < 0.02$). Better results were achieved over the 3-year period with the steroid-eluting epicardial leads (rather than the transvenous leads), but these improvements were not statistically significant. It is worth noting that even in the long follow-up period of the steroid-eluting epicardial leads, there were no statistically significant changes in atrial and ventricular signals (Fig. 2). Over the 3-year long follow-up of the CapSure Epi lead, the pacing threshold increased on the average from 0.7 V to 1.2 V for the ventricle and from 0.8 V to 1.3 V for the atrium. We have not discovered statistically significant differences during the post-operative follow-up between the patients with leads implanted thoracoscopically and those with leads implanted via the mini-approach. There were no significant differences between the two groups in the duration of the operation, ventilation duration, clinical stay, or complication rate. From the economic point of view, it should be noted that the mini-approach requires the video-technique application and a sufficient access for dual chamber pacemaker implantation in patients of any age with congenital AV block. No complications were observed after implantation of the dual chamber pacemaker via the mini-approach.

Tachyarrhythmia Surgery

Right-sided anterolateral thoracotomy was performed in four patients to destroy either right-sided (n = 3) or left-sided (n = 1) ectopic foci after an inefficient trans-

venous high-frequency ablation procedure. Intra-operative epicardial mapping of arrhythmogenic zones had been performed in all of the cases. Right-sided atrial ectopic foci were located near the AV groove. The earliest left-sided ectopic activity was located between the superior and the inferior pulmonary veins. Five patients underwent corrective surgery to repair the interatrial septal defect and the RFA procedure (at 60 – 70 °C) at the region with slow pathways in the AVNT patients or at the heart isthmus zone in patients with atrial flutter type I. The right-sided thoracotomy with the 6 – 8 cm cutis incision was sufficient to perform surgical manipulations on the right atrium. We consider it possible to perform a successful simultaneous operation when atrial septal defect is combined with a tachycardia that requires RFA. None of our patients had any post-operative complications or tachycardia recurrences over the 3-year period. The video-control system with 14x-magnification enabled us to perform mapping of hard-to-access heart zones using full-range surgical manipulations. No special equipment was required to perform operations via the mini-approach.

Discussion

Epicardial stimulation is usually indicated in patients with low weight or those with contra-indications for transvenous lead implantation, i.e., patients who underwent the earlier Fontane-type procedure, or who have a right to left shunt, a mechanical prosthesis of the tricuspid valve, a vein thrombosis, etc. [9,10]. According to our experience and the data published elsewhere [11], myocardial leads have a much shorter service time due to their fractures, the exit block. The rate of lead complications for transvenous implantation (2 %) and the myocardial implantation (26 %) was significantly different in our group of children with bradyarrhythmia (n = 132). Twenty-four epicardial steroid-eluting leads with good acute and chronic pacing thresholds were implanted at the same time. The rate of lead-related re-implantations did not differ significantly for transvenous and epicardial approaches in patients with congenital AV block in the 3-year follow-up period. We would like to emphasize that in 100 % of cases of epicardial implantation via right-sided thoracotomy, physiological dual chamber pacing was used. Meanwhile, this pacing mode could be accomplished in only 40 % of children of the same age (mean 4.0 ± 1.4 years) with the transvenous lead configuration. No doubt, epicardial leads can be implanted via an extra-pleural subxyphoidal approach as well. But, we consider the difficulty in viewing the operating field, and the complexity of atrial lead implantation at the subxyphoidal approach to be reasons for choosing the right-sided thoracoscopic approach. The applicability of bifocal systems in 100 % of cases, the lack of complications, and the good cosmetic results allow us to recommend this approach for pacemaker implantation in children with low weight and primary AV block. Based on reports on steroid-eluting epicardial leads, particularly in combination with autocapture-controlled devices and our own experience, we advocate more extensive application of the right-sided thoracoscopic approach in the treatment of bradycardiain clinical practice. The only limitation in this recommendation might be the follow-up duration, since it was only 3 years long.

Two-hundred twelve open-heart operations for simultaneous surgical correction of arrhythmia with congenital, acquired and ischemic heart diseases were performed in our center during the promotion of the mini-invasive arrhythmia surgery method from November 1997 to December 1999. Overall, 575 successful RFA procedures were performed in patients with different forms of tachycardia, and only 25 of them (3 %) were minimally invasive or required video-assisted surgery of arrhythmias. At the time of transvenous catheter RFA for tachycardia, the method failed in 2 % to 30 % of patients with epicardial accessory pathways, or who had ectopic foci in the atria and ventricles [1,2,12]. In those cases, the mini-approach operation with or without CPB is the method of choice, since fluoroscopy is not necessary to perform repetitive RFA catheter procedures. The right-sided mini-approach in comparison to mediastinal sternotomy not only has a better cosmetic result, but also shortens the stay in the intensive care unit and at the clinic, and reduces the pain syndrome. We consider simultaneous correction of the heart pathology justified in patients with concomitant tachyarrhythmias (WPW syndrome, ectopic tachycardia, ventricular tachycardia). First, the necessity for the long-lasting fluoroscopy is eliminated. And as long as the failure is corrected under CPB, with the epicardial mapping system available, the tachycardia correction does not increase the operation's risk, thereby substantially reducing the operation's costs.

Conclusion

Cooled RFA technique is a simple and efficient method for eliminating tachyarrhythmia substrates during heart surgery. The cooled RFA, in addition to the cryoablation method, can be used for the idiopathic atrial fibrillation treatment by the MAZE operation, as our experimental results indicate. Along with that, improvement of the thoracoscopic method or application of mini-approaches will help to define the most efficient alternative to catheter methods in atrial fibrillation therapy in the near future.

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