

EARLY EXPERIENCE WITH CARDIAC ELECTROPHYSIOLOGY STUDY AND RADIOFREQUENCY ABLATION IN PESHAWAR

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Contribution

All the authors contributed significantly to the research that resulted in the submitted manuscript.

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ABSTRACT

Objective: The aim of this study was to evaluate the success and efficacy of electrophysiological study (EPS) and radio frequency ablation (RFA) in Peshawar.

Methodology: It was a hospital based prospective study, conducted at cardiology department of HMC and EP Lab of LRH, Peshawar from September 2006 to December 2012. All adult patients with documented tachycardia and any one of following symptoms, palpitation, pre-syncope/near syncope, syncope, drop attack and dyspnea related to arrhythmias were included. EPS and radiofrequency success and complications were recorded. Statistical analysis was performed using SPSS version.15.0.

Results: During this period, 570 patients underwent EPS. The mean age was 37.34 ± 11 years (20-82 years), 90% of the patients were in reproductive age group (20-50 years), male were 51%. All the patients were symptomatic and most common symptom was paroxysmal palpitation, reported in 470 (82%) cases. Twenty nine (4.8%) patients have life threatening arrhythmias. EPS revealed accurate mechanism of arrhythmia and localized the focus and pathways in 550 (96.5%) and RFA carried out in all those patients. Inter-atrial puncture was done in 120 (21%) patients, for ablation of left sided pathways. The overall success of RFA was in 95%. No death and no major complication documented related to the procedure. Self limiting RBBB in 1 patient and minor bleeding in 20 (4.3%) were immediate complications. Exposure to radiation in all patients, DVT in 5 (0.8%) and recurrence of symptoms in 6 (1%) were the late complications.

Conclusion: The EPS and RFA is a useful procedure with less morbidity and no mortality.

Key Words: Cardiac Electrophysiology, Radiofrequency Ablation, Arrhythmia

INTRODUCTION

The current era of clinical cardiac electrophysiology (EP) began in the late 1960s with the introduction of Electro-Physiology laboratory (EP lab). EP is the science of understanding, diagnosing and treating the electrical activities of the heart. Cardiac electrical abnormalities are common; some are life threatening, others merely a nuisance. They are caused by abnormalities in impulse formation or conduction that lead to regular or irregular, slow or fast heart rate. It is not difficult to treat patients with slow heart rate. The situation is different, however, for patients with rapid rhythms. Such rhythms can originate anywhere in the heart and result from a variety of mechanisms.¹⁻⁴

Historically, pharmacologic interventions were used in attempts to terminate and prevent rapid rhythms. During the past two decades, however, it has become clear that anti-arrhythmic drugs may have serious side effects and may sometimes even facilitate the occurrence of life threatening arrhythmias and sudden death. The alternative was surgical ablation of accessory pathways and modification of the atrio-ventricular node (AVN) in recurrent Supra Ventricular Tachycardia (SVT).⁵ But the limitation was major open heart surgery and its associated morbidity and mortality. The recognition of these side effects has led to increasing interest in developing intra cardiac catheter techniques for localizing the site of origin or pathway of an arrhythmia and then isolating or destroying the tissue that is responsible for it. Today, this task can be accomplished by EPS.^{6,7} It can determine the focus and then cure the rhythm disturbance by applying, through the catheter, radiofrequency ablation (RFA), laser, ultrasound, or microwave energy or freezing temperatures to the tissue causing the arrhythmia.^{7,8}

When EPS and RFA should be performed? The decision is easy when the arrhythmia is life-threatening as, for example, in the case of a ventricular tachycardia (VT) or Atrial Fibrillation (AF) in a patient with the Wolff-Parkinson-White (WPW) syndrome. During AF in patient with WPW syndrome, the ventricular rate can reach more than 300 beats per minute, leading to ventricular fibrillation (VF) and sudden cardiac death (SCD). This risk is 1 in 100 patients year.^{1,4,6,9} Catheter ablation is also indicated when a rapid rhythm is present most of the day, severely impairing cardiac function and resulting in a so called tachycardia induce cardiomyopathy (TIC). When the tachycardia is not life-threatening but interferes with physical and social well-being, the risk of complications from catheter ablation has to be weighed against the possibility of a definite cure.^{1,3,4}

Apart from the general risks associated with cardiac catheterization, such as bleeding and infection, there are specific risks related to the site where catheter ablation has to be performed, especially when that site is close to the AV node, a coronary artery, or the valvular apparatus. For

example, catheter ablation for a tachycardia in the AV node carries the risk of creating AV block and necessitating the implantation of a pacemaker. EP & RFA is a highly successful and sophisticated technique. There are several EP centers that have had excellent long-term success and a low complication rate.^{3,7,10-12}

In this study we reviewed our experience with EPS and RFA for catheter ablation of patient with recurrent SVT and ILVT.

METHODOLOGY

It was a hospital based prospective study, conducted at Cardiology Department of Hayatabad Medical Complex (HMC) and EP Lab in Lady Reading Hospital (LRH) Peshawar. The study period was between September 2006 and December 2012. All adult patients with documented tachycardia and any one of following symptoms, palpitation, pre-syncope/near syncope, syncope, drop attack and dyspnea related to arrhythmias were included.

“Palpitation” was defined as heart beat sensations in the chest or throat that feel like pounding or racing or an unpleasant awareness of heart beat or feeling of skipped beats or a pause. “Pre-syncope/near syncope” was defined as dizziness or light headedness or feeling faint or Graying out. “Syncope” was defined as sudden loss of consciousness with loss of postural tone, not related to anesthesia, with spontaneous recovery as reported by patient or observer. Patient may experience syncope when supine. “Drop attack” was defined as abrupt loss of postural tone (collapse) without reported loss of consciousness. Dyspnea was defined and classified according to New York Heart association (NYHA) functional class. Electrocardiogram (ECG) was evaluated for presence of, tachycardia, delta waves, axis, arrhythmias specially any documented SVT and other abnormalities, while echocardiography (Echo) was for ejection fraction (EF) and structural heart diseases.¹

Before the procedure, informed and written consent was obtained. The EPS was performed in the fasting state, with intravenous midazolam 3 mg for sedation administered in the EP Lab in selected apprehensive patients. Standard EPS was done with 4 wires and RFA with the 5th wire, three catheters passed through right femoral vein and two left femoral vein punctures. A right femoral arterial sheath and catheter were also used in those patients with left sided pathway and needed retrograde approach through aorta and LV cavity. A quadri-polar catheter for right atrium (RA) and right ventricle (RV), deca-polar for coronary sinus (CS) and an octa-polar catheter for the His bundle recording were used. The catheters were positioned under fluoroscopy, and the exact site determined by the intra cardiac electrogram (EGM) signals. The signals were filtered between 30 and 500 Hz. BARD electrophysiology stimulator or Bloom EP

stimulator were used for pacing the heart and give extra stimuli. St. Jude Medical EnSite Velocity amplifier was used for intra-cardiac signal amplification. The St. Jude Medical EP workmate 4.2 was used as electro-physiological platform. St. Jude medical EP-4 was used for 3D mapping. General Electronics (GE) innova was used for fluoroscopy. A basic EPS with right ventricular extra stimuli (RVES) and incremental studies, and right atrial extra stimuli (RAES) and incremental studies were then performed. The mechanism of the tachycardia was determined, and the abnormal pathways were localized with standard EP techniques and maneuver. We used Stockert EP shuttle by Biosense Webster for RF generation and RF energy applied by the United States Catheter and Instruments (USCI) steerable catheter with a 7 French, 4mm tip, deflectable electrode catheter.

All the intra cardiac catheters were connected to a junction box to allow for easy switching from one mode to another. A back plate was attached to the patient's left scapular region for completing pole for RFA. Radiofrequency ablation of accessory pathways was performed with a USCI catheter positioned at the mitral annulus by the trans-septal approach for left sided pathways, or by the femoral vein to the tricuspid annulus for right sided pathways. In some patient with left sided pathways, a retrograde approach through femoral artery, aortic root and left ventricle was also successfully tried. Patients with left-sided pathways or those who had multiple RF applications (usually greater than 10 RF applications) on the right side were administered intravenous bolus Heparin with ICT monitoring.

Success was defined as the complete elimination of accessory pathway conduction. If unsuccessful, RF energy was terminated within 10-15 seconds. A booster RF pulse of 30-60 seconds was usually administered at the successful site of ablation.

For patients with AV nodal reentrant tachycardia (AVNRT), an attempt was made to map for the slow pathway potential at the region of the OS of coronary sinus as described by Jackman or Haissaguirre.^{13,14} If no slow pathway potential was seen, RFA was performed using the anatomical approach described by Jazayeri and Wathcn et al.^{15,16} Radiofrequency modification of the AV node was performed, using a power of 50J for 15-20 seconds during sinus rhythm. Success of AV nodal modification was defined as the failure of induction of AV nodal reentrant tachycardia at the baseline pacing, or with extra stimuli or with isoprenaline infusion (1-4 microgram per minute). However, single AV nodal echo or single jump was acceptable endpoints. Multiple echo beats were not acceptable.

Immediately after ablation, patients were observed in the EP laboratory for 30 to 60 minutes. The patients were observed

in the ward for another 24 hours before they were discharged. Patients with left-sided pathways or those who had multiple RF applications (usually greater than 10 RF applications) on the right side were discharged on tablet Aspirin 150 milligram (mg) once daily for one month.

The major complication related to EPS were defined as death, cerebrovascular accidents (CVA), myocardial infarction (MI), bleeding requiring blood transfusion, cardiac tamponade, complete heart block (CHB) requiring permanent pace maker (PPM), large pneumothorax, pulmonary embolism (PE) and drug anaphylaxis. In cases of major complications, further procedures were carried out to stabilize the patients. Minor complications were defined as transient, self limiting and do not need any other procedure or therapy for stabilization. All patients were reviewed after four weeks for any complications.

Statistical analysis was performed using SPSS version 16. Numerical Variables were presented as mean \pm SD. Categorical variables were presented as frequencies and percentages.

RESULTS

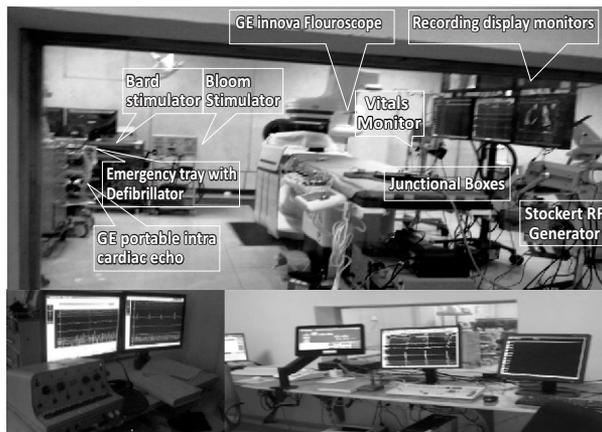
A total of 570 patients underwent EPS from September 2006 to December 2012. Mean age was 37.34 ± 11 years (20-82 years). Majority of the patients, 513 (90%) were in productive age group (20-50 years), male and female were 291 (51%) and 279 (49%) respectively. Six (1%) of the patients have previous EP/RFA done anywhere and presented with recurrence of symptoms. Thirty (5%) of the patients have previous Direct Current Cardioversion (DCC) and 15 (2.6%) have DCC on more than one occasion. Total DCC were 60 and all were done in emergency.

Four hundred and forty seven (78%) had visited hospital emergency for treatment of tachycardia at least once in last five years. Majority of them 400 (70%) visited hospital more than once and the average was 4 visits per patient. The cumulative total emergency hospital visit was 1950. One hundred and thirty (23%) patients visited hospital in emergency more than five times in last five years. The cumulative total of more than five visits to hospital in emergency was 1064 (54%).

Two hundred forty (12%) events responded to vagal maneuver, 60 (0.3%) events needed DCC and remaining 1650 (85%) events terminated with pharmaco-therapy. Injection Verapamil 5-10 mg was frequently used to terminate 852 (52%) SVT followed by Injection Adenosine 6-12 mg was used in 200 (12%) events. Injection Amiodarone was used mainly for broad complex tachycardia, needed in 143 (8.6%) events. The remaining 455 (27.5%) events were terminated by other agents like Injection Metoprolol or injection Digoxin or combination of Verapamil with other agents. All the patients (100%) were

using maintenance pharmacotherapy but only 235 (50%) were taking medication regularly for more than one year. The remaining 50% were taking irregularly and usually after the onset and few days after the termination of tachycardia. Majority 535 (94%), were taking oral beta blocker or calcium channel blocker or Digoxin. The remaining 35 (6%) were using other class 1C or class III anti arrhythmic drugs. Of these arrhythmias, 29 (4.8%) having immediate life threatening arrhythmias like ILVT (16 cases) and AF in WPW syndrome (13 cases). Fourteen (2.4%) cases have incessant atrial tachycardia (AT) and thus a potential threat

Figure 1: Electrophysiological Laboratory (Fully Equipped)



for heart failure. Trans-septal puncture was done in 120 (21%) cases while retrograde studies through aortic root and left ventricular (LV) cavity were performed in 5 (0.9%) cases. The remaining 445 (78.1%) were standard right sided EPS. Our fully equipped EP lab has been shown in Figure 1. Majority of the patients were symptomatic for a long time, 342 (60%) of patients having symptoms for more than 5 years. Table 1 shows the duration of symptoms in all the patients. The heart was structurally normal in 536 (94%) patients. Five patients have mitral stenosis, 2 having hypertrophic cardiomyopathy and 1 Ebsteine anomaly.

Tachycardia was documented on surface ECG or holter monitor in all the patients before admission for EPS. Surface

Table 1: Duration of Paroxysmal Palpitation

DURATION OF SYMPTOMS	FREQUENCY (%)
>10 years	83 (14.5%)
5-10 years	200 (35%)
1-5 year	240 (42%)
1-12 Months	44 (8%)
Less than 1 month	03 (0.5%)

Table 2: ECG Findings During Tachycardia and Sinus Rhythm

Ecg Based Diagnosis			n (%)
NCT ¹	Regular	Long RP	134(23.5%)
	Regular	Short RP	295(51.6%)
	Regular	RP not clearly defined	98(17.2%)
	Irregular	RP not clearly defined	14(2.5%)
BCT ²	Regular	RBBB Pattern	16(2.8%)
	Irregular	Pre excited	13(2.3%)
Sinus Rhythm	Delta waves	WPW syndrome	121(21%)
Sinus Rhythm	Normal PR		449(79%)

¹ NCT=Narrow Complex Tachycardia,
² BCT=Board Complex Tachy

ECG based distribution of tachycardia shown in Table 2. Most of the patients were poly symptomatic during the episode of tachycardia, but palpitation was noted in 470 (82%) of patients either alone or as part of other symptoms. The symptoms during the episode and EPS based diagnosis of tachycardia has been shown in Figure 2 and 3, respectively. RFA was carried out in 550 patients. Immediate successful ablation was recorded in 185 of 200 (92.5%) accessory pathways, 14 of 16 (87.5%) ILVTs and 290 of 305 (95%) AVNRT. The overall average success rate was 92%. The mean duration of the EPS and RFA, including 30-60 minutes of post ablation observation in EP lab, was 150 ± 60 minutes. The fluoroscopy time was 30 ± 20 minutes: There were very few major and minor complications related to EPS. One patient had a right bundle branch block after ablation of a concealed antero-septal accessory pathway and minor bleeding at site of femoral vein puncture in 20 (4.3%) cases were immediate complications. Exposure to radiation, deep vein thrombosis in 5 (0.8%) and recurrence of symptoms in 6 (1%) were the late complications.

Figure 2: Main Symptoms During the Episode

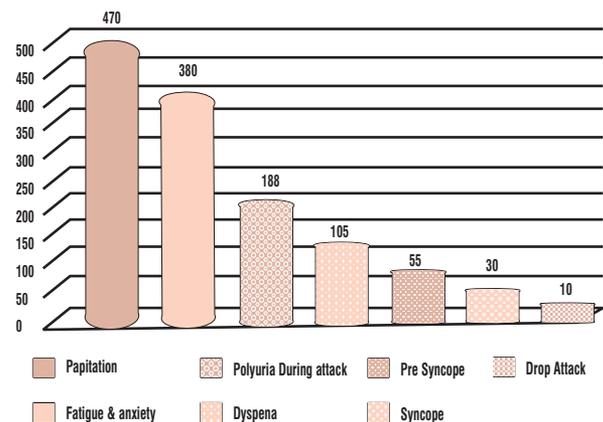
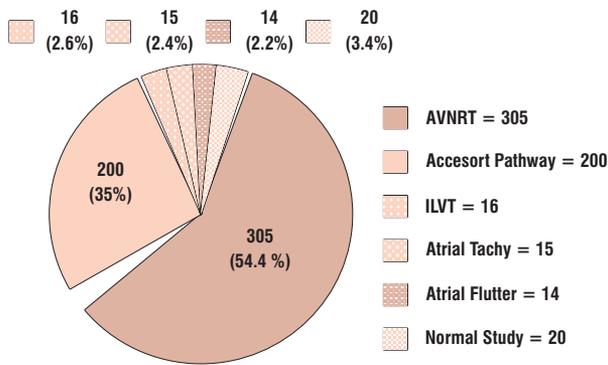


Figure 3: EPS based diagnosis of Arrhythmias

DISCUSSION

Cardiac electrophysiology is an emerging modality in invasive cardiology.^{1,3} It can provide curative care to many cardiac arrhythmias as compared to only palliative care by pharmacotherapy.^{4,16} The EPS needs not only sophisticated and dedicated laboratory but also a well-trained electrophysiologist. The learning curve in EP improves gradually with experience. There are very few centers worldwide for EP training. In Pakistan, the only recognized center is EP department in Armed Forces Institute of Cardiology (AFIC) Rawalpindi. The facility is partially available in Karachi and Lahore. Despite all these, availability of EPS and RFA in Peshawar is not less than a miracle.

Due to non-availability of this modality, most of the patients suffer for a long time.^{3,4} In our study, 283 (50%) of the patients were symptomatic for more than five years. Recurrent SVT is a common cardiac problem and it is very distressing in many occasions. The patient needs frequent visit to hospital emergency, needs injections to control the rapid rhythm and at times need DCC.^{1,4} In our study, the cumulative total of hospital emergency visit was 1950 with an average of 4 per patient in last 5 years. One hundred and thirty patients visited hospital emergency more than five times in last 5 years with cumulative total visits were 1064. Adenosine is an expensive drug and not freely available in this region; therefore, despite being drug of choice,^{3,4} it has been used in 200 (12%) events as compare to cheap and freely available injection Verapamil, which has been used in 852 (52%) events. SVT usually occurs in structurally normal heart.⁴ In this study, 536 (94%) of the patients were having structurally normal heart. Delta wave is an important landmark in diagnosis of accessory pathway and WPW syndrome. We recorded delta waves in 121 (21%) patients. AVNRT is the most common SVT documented in literature.^{1-3,7,11} In our study, about half of the cases were AVNRT, based on dual AV node physiology and other maneuvers on EPS.

The safety and efficacy of this modality has been studied in many centers.¹⁹⁻²³ The meta analysis of all those studies

shows that RF catheter ablation is a highly effective approach to the treatment of cardiac arrhythmias. Success rates of greater than 90% with complication rates of less than 3% should be anticipated for catheter ablation of AVNRT, accessory pathways, atrial flutter, idiopathic ventricular tachycardia, and the atrioventricular junctional tachycardia. For these arrhythmias, the safety and efficacy profile of catheter ablation would suggest that it should be considered first-line therapy and an alternative to pharmacologic therapy. In contrast, the safety and efficacy of RF catheter ablation is considerably lower than 90%, and the incidence of complications is generally greater than 3% during catheter ablation of Atrial Fibrillation (AF) and non-idiopathic VT. This safety and efficacy profile would suggest that the appropriate role of catheter ablation for these arrhythmias is as second-line therapy after attempts at pharmacologic therapy have failed. In our study, 550 (96%) patients not only get final and conclusive diagnosis but also get effective treatment for it. Curative procedures were done in the same setting based on the diagnosis made on EPS. No mortality or major complications were attributed to the procedure in our study. The minor complications were few. There are many reasons behind the low morbidity and no mortality. Majority of the patients were young with average age of 37 years, having structurally normal heart (94%) and no serious co morbidity. These otherwise healthy patients tolerated the procedure very well. In a study carried out in Aga Khan University (AKU) and National Institute of Cardiovascular Disease (NICVD) in Karachi, one death was reported but in our study, no mortality recorded.¹⁰ Our 95% success in radio frequency ablation without any major complication is comparable to good EP center in the world.^{4,7,10,11,18-23}

Thus, in patients with supraventricular tachycardia, RFA, which provided curative therapy with minimal morbidity, can now be offered as an alternative to lifelong drug therapy, which is only palliative and not curative. In fact, RFA was the first choice in many patients who did not want to be burdened by trials of drug therapy or long-term drug therapy with its cost and possible side effects: The issue of cost has been highlighted in many studies,^{17,18} who demonstrated a reduction in medical costs associated with radiofrequency catheter ablation compared with surgical ablation of accessory pathway or long-term drug therapy. However, its role in ventricular tachycardia, especially ischemic ventricular tachycardia, is still being investigated.²

CONCLUSION

In conclusion, interventional electrophysiology represents a tremendous leap forward in the management of cardiac arrhythmias. With catheter ablation, it offers a safe curative therapy for patients with recurrent SVTs and ILVTs.

REFERENCES

- Buxton AE, Calkins H, Callans CJ, DiMarco JP, Fisher JP, Greene HL, et al. ACC/AHA/HRS 2006 key data elements and definitions for electrophysiology studies and procedures: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Data Standards. *J Am Coll Cardiol* 2006;48:2360-96.
- Marcus GM, Keung E, Scheinman MM. The year in review of clinical cardiac electrophysiology. *J Am Coll Cardiol* 2013;61:772-82.
- Blomstrom LC, Scheinman MM, Aliot EM, Alpert JS, Calkins H, Camm AJ, et al. ACC/AHA/ESC guidelines for the management of patients with supraventricular arrhythmias-- executive summary. *J Am Coll Cardiol* 2003;42:1493-531.
- Delacrétaz E. Supraventricular tachycardia. *N Engl J Med* 2006;354:1039-51.
- Wong JWW, Tong MC, Koo CC, Tco WS, Tan ATH, Ong KK. Surgery for Cardiac Arrhythmias. *Ann Acad Med Singapore* 1992;21:230-7.
- Pappone C, Santinelli V, Rosanio S, Vicedomini G, Nardi S, Pappone A, et al. Usefulness of invasive electrophysiologic testing to stratify the risk of arrhythmic events in asymptomatic patients with Wolff-Parkinson-White pattern: results from a large prospective long-term follow-up study. *J Am Coll Cardiol* 2003;41:239-44.
- Teo WS, Kam R, Tan A. Interventional electrophysiology and its role in the treatment of cardiac arrhythmia. *Ann Acad Med Singapore* 1998;27:248-54.
- Friedman PL. Catheter cryoablation of cardiac arrhythmias. *Curr Opin Cardiol* 2005;20:48-54.
- Wang Y, Scheinman MM, Chien WW, Cohen TJ, Lesh MD, Griffin JC. Patients with supraventricular tachycardia presenting with aborted sudden death: incidence, mechanism and long term followup. *J Am Coll Cardiol* 1991;18:1711-9.
- Shafquat A, Imdad A, Khalid S, Jamal SZ. Cardiac electrophysiology studies and ablations for treatment of supraventricular arrhythmias: an initial experience from Karachi. *J Pak Med Assoc* 2011; 61:173-5.
- Udyavar AR, Benjamin S, Ravikumar M, Latchumanadhas K, Kumar RS, Mulasari AS, et al. Long-term results of radiofrequency ablation of slow pathway in patients with atrioventricular nodal reentrant tachycardia: single-center experience. *Indian Heart J* 2006;58:131-7.
- Iturralde TP, Colín LL, Guevara VM, Rodríguez CL, Kershenovich SS. Experience in 1,500 patients undergoing radiofrequency ablation in the treatment of tachycardia. *Arch Inst Cardiol Mex* 2000;70:349-66.
- Jackman WM, Beckman KJ, McClelland JH, Wang X, Friday KJ, Roman CA, et al. Treatment of supraventricular tachycardia due to atrioventricular nodal reentry by radiofrequency catheter ablation of slow pathway conduction. *N Engl J Med* 1992;327:313-8.
- Haissaguerre M, Gaita F, Fischer B, Commenges D, Montserrat P, d'Ivernois C, et al. Elimination of atrioventricular nodal reentrant tachycardia using discrete slow potentials to guide application of radiofrequency energy. *Circulation* 1992;85:2162-75.
- Jazayeri MR, Hcmpe S, Sra JS, Dhala AA, Blanck Z, Deshpande SS, et al. Selective transcatheter ablation of the fast and slow pathways using radiofrequency energy in patients with atrioventricular nodal reentrant tachycardia. *Circulation* 1992;85:1318-28.
- Wathcn M, Natalc A, Wolfe K, Yee R, Newrnan D, Klein G. An anatomically guided approach to atrioventricular node slow pathway ablation. *Am J Cardiol* 1998;70:886-9.
- De Buitleur M, Sousa J, Bolling SF, el-Atassi R, Calkins H, Langberg JJ, et al. Reduction in medical care cost associated with radiofrequency catheter ablation of accessory pathways. *Am J Cardiol* 1991;68:1656-61.
- Bathina MN, Mickelsen S, Brooks C, Jaramillo J, Hepton T, Kusumoto FM. Radiofrequency catheter ablation versus medical therapy for initial treatment of supraventricular tachycardia and its impact on quality of life and healthcare costs. *Am J Cardiol* 1998; 82:589-93.
- Scheinman MM, Huang S. The 1998 NASPE prospective catheter ablation registry. *Pacing Clin Electrophysiol* 2000;23:1020-8.
- Hindricks G. The Multicentre European Radiofrequency Survey (MERFS): complications of radiofrequency catheter ablation of arrhythmias. The Multicentre European Radiofrequency Survey (MERFS) investigators of the Working Group on Arrhythmias of the European Society of Cardiology. *Eur Heart J* 1993;14:1644-53.
- Calkins H, Yong P, Miller JM, Olshansky B, Carlson M, Saul JP, et al. Catheter ablation of accessory pathways, atrioventricular nodal reentrant tachycardia, and the atrioventricular junction: final results of a prospective,

- multicenter clinical trial. The Atakr Multicenter Investigators Group. *Circulation* 1999;99:262-70.
22. Calkins H, Niklason L, Sousa J. Radiation exposure during radiofrequency catheter ablation of accessory atrioventricular connections. *Circulation* 1991;84:2376-82.
23. Hirshfeld JW, Balter S, Brinker JA, Kern MJ, Klein LW, Lindsay BD, et al. ACCF/AHA/HRS/SCAI clinical competence statement on physician knowledge to optimize patient safety and image quality in fluoroscopically guided invasive cardiovascular procedures. *J Am Coll Cardiol* 2004;11:2259-2282.