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ELECTROPHYSIOLOGIC STUDIES

Risks and Complications of Clinical Cardiac Electrophysiologic Studies: A Prospective Analysis of 1,000 Consecutive Patients

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The complications of clinical cardiac electrophysiologic studies were prospectively evaluated in 1,000 consecutive patients studied in one laboratory with an unaltered protocol to better assess the risks of this procedure. There were 728 men and the mean age of the entire group was 58 years (range 16 to 84). Coronary artery disease was the most common type of heart disease (56%) and 200 patients had no identifiable organic heart disease. The indication for study was a ventricular tachyarrhythmia or cardiac arrest in 582 patients. Each patient underwent an initial (baseline) study and 444 patients underwent serial drug studies (2.7/patient).

There was one death during these studies. Other major complications included arterial injury (0.4%), thrombophlebitis (0.6%), systemic arterial embolism (0.1%), pulmonary embolism (0.3%) and cardiac perforation (0.2%). Significant arrhythmic complications included catheter-induced permanent complete atrioventricular (AV) block in 1 patient, nonclinical atrial fibrillation that required therapy in 10 patients and severe proarrhythmic events in 12 (3%) of 397 patients undergoing drug studies for ventricular tachyarrhythmias. Cardioversion was required for termination of ventricular tachyarrhythmias in 179 baseline studies (53% of patients with inducible arrhythmia), and in an additional 35 patients, cardioversion was required at least once during follow-up studies. Although clinical cardiac electrophysiologic studies are associated with complications, the risks are small and acceptable.

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During the past decade, clinical electrophysiologic studies have become an accepted part of the diagnostic evaluation of patients with serious arrhythmias (1–5). Particularly in patients with malignant arrhythmias, selection of therapy by electrophysiologic techniques has resulted in a reduction in the incidence of recurrent arrhythmia and sudden death (6–10). Despite the increasingly wide application of this procedure, there is little information about the mortality, morbidity and risks associated with it. Therefore, we prospectively collected these data in patients undergoing electrophysiologic studies performed with a standardized procedure in a single laboratory.

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Methods

Study patients. The data were prospectively collected between October 27, 1981 and February 7, 1986 and represent a consecutive series of the initial 1,000 patients studied in this laboratory. Our procedures were unchanged during this period. The patients' clinical history and demographic data, methodologic details of the procedures, results and complications of the studies and other pertinent data were prospectively collected in a computerized data base. All records of patients who developed complications and a random selection of the hospital charts of 25% of the patients were reviewed to assure accuracy.

This series includes 1,000 consecutive patients who underwent an initial clinical electrophysiologic study. In 444 of the patients, one or more follow-up drug studies were performed. There were 728 men and 272 women; their ages ranged from 16 to 84 years (mean 58). The types of underlying heart disease and indications for electrophysiologic study are shown in Tables 1 and 2.

Electrophysiologic procedures. All procedures were performed in a catheterization laboratory used solely for

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Table 1. Type of Underlying Heart Disease in 1,000 Patients

	No. of Patients
Coronary artery disease	563
No previous MI	55
Recent (≤6 weeks) MI	67
Remote (>6 weeks) MI	441
Cardiomyopathy*	160
Valvular heart disease†	56
Congenital heart disease	21
No structural heart disease‡	200

*Hypertrophic (n = 21) or dilated congestive (n = 139) cardiomyopathy not related to coronary artery disease. †Not related to coronary artery disease. ‡Includes mitral valve prolapse without hemodynamically significant mitral regurgitation. MI = myocardial infarction.

electrophysiologic studies. Typically, two physicians, a nurse and a technician were present during all procedures. Catheter insertion and positioning and programmed stimulation were performed by a staff electrophysiologist or an electrophysiology trainee (third year fellow) under direct staff supervision. A staff member was present in the laboratory for all stimulation procedures.

All patients were studied in the postabsorptive state after written informed consent had been given. No premedication was used; however, intravenous diazepam was administered for mild sedation when necessary during the study. The electrocardiogram (ECG) was continuously monitored from the time the patient entered the laboratory until he or she was returned to the hospital room by laboratory personnel. Blood pressure was monitored throughout the procedures by sphygmomanometry.

Woven Dacron catheters (USCI) were inserted percutaneously by the Seldinger technique or by cutdown under local anesthesia (bupivacaine, 0.25%) and positioned under fluoroscopic observation. After catheters were inserted, heparin was administered in a 2,500 U bolus followed by an infusion of 500 U/h for the duration of the study. If arterial catheterization was performed, an additional 2,500 U bolus of heparin was given and the continuous infusion was increased to 1,000 U/h. Anticoagulation was not reversed unless arterial catheterization was performed, in which case protamine was given.

Table 2. Indications for Clinical Electrophysiologic Studies in 1,000 Patients

	No. of Patients
Sustained monomorphic ventricular tachycardia	239
Nonsustained ventricular tachycardia	206
Cardiac arrest	175
Paroxysmal supraventricular tachycardia	73
Tachycardia or palpitation of uncertain type	69
Syncope of unknown cause	181
AV conduction disturbance	66
Sinus node dysfunction	46
Wolff-Parkinson-White syndrome with tachyarrhythmia	21
Total	1,076*

*Eleven patients had three indications for study and 54 patients had two indications for study, making a total of 1,076.

After each laboratory session, catheters were removed and hemostasis was obtained. Patients remained at bed rest for 12 hours after each procedure (overnight if arterial catheterization was performed). Catheters were not left in position for drug studies but were inserted for each laboratory visit.

Catheters were reused a maximum of 10 times. Before reuse they underwent a rigorous procedure of cleaning, checks of mechanical and electrical integrity and gas sterilization.

Initial studies. These included evaluation of atrial, atrioventricular (AV) conduction system and ventricular electrophysiologic variables. Unless vascular access was limited, three catheters were used in an initial study. Initial studies were performed after antiarrhythmic drugs had been discontinued for five drug half-lives in 980 patients. In 20 patients, ventricular tachyarrhythmias were so frequent that no drug-free interval could be obtained and the initial study was performed while the patient was on an antiarrhythmic regimen.

Drug testing. After the initial study, drug tests (follow-up studies) were performed in most patients with inducible paroxysmal supraventricular tachycardia, sustained ventricular tachycardia or ventricular fibrillation. Drugs were administered intravenously or orally and programmed electrical stimulation was performed. A single drug and, at most, one combination regimen were evaluated in each laboratory session. Evaluation of each drug regimen was considered a follow-up study even if it was performed in the same laboratory session as the initial study or another drug study.

Recordings. ECG leads and intracardiac electrograms were obtained with a physiologic recorder (E for M VR16) and were recorded on analog magnetic tape (Honeywell 5600C). Real time analog records were obtained on a Mingograf ink jet recorder. Electrical stimulation was performed with a digital stimulator and optically isolated constant current sources (Bloom Associates, Ltd.). The stimulus was a rectangular pulse delivered at an amplitude of twice the late diastolic threshold. However, the amplitude was not allowed to exceed 10 mA in the atria and 2 mA in the ventricles.

Standard protocol of programmed electrical stimulation. The standard protocol included: 1) atrial and ventricular pacing at cycle lengths ranging from just under that of sinus rhythm to 300 ms; 2) single atrial extrastimuli delivered during high right atrial pacing at one or two cycle lengths

and during sinus rhythm; and 3) single and double ventricular extrastimuli delivered during right ventricular apical pacing at cycle lengths of 600 and 450 ms and during sinus rhythm. In patients with paroxysmal supraventricular tachyarrhythmia or Wolff-Parkinson-White syndrome, or both, double atrial extrastimuli and left atrial stimulation were performed. Patients studied for evaluation of ventricular tachycardia, cardiac arrest or syncope of uncertain origin underwent administration of triple ventricular extrastimuli and stimulation at the right ventricular outflow tract. Left ventricular stimulation was performed in patients who had sustained monomorphic ventricular tachycardia or a cardiac arrest and in whom right ventricular stimulation had failed to induce a ventricular tachyarrhythmia (9).

Cardioversion. Whenever sustained arrhythmias were induced, attempts were made to terminate them with programmed stimulation. If stimulation techniques were unsuccessful, cardioversion was used. If the patient remained conscious during the arrhythmia, anesthesia with methohexital sodium (Brevital) was administered before cardioversion. Cardioversion and defibrillation were accomplished with a device that allowed monitoring of chest wall impedance to assure good electrical contact. Adhesive electrode pads (R2 pads) were used in the anteroposterior configuration. The initial shock was delivered with a stored energy of 60 to 150 J depending on the patient's body size. All subsequent shocks were delivered at 360 J. If more than three shocks were required during a study, the study was terminated for that day.

Definitions. A study-related death was defined as death that occurred during the study or within 24 hours of the study and was not attributable to any cause not related to the procedure, or that was related to a complication of the study.

Vascular complications were defined as those that occurred within 7 days of the study and required surgical or other specific therapy (for example, thrombolytic agents) or resulted in prolongation of hospitalization. This category included arterial (thrombosis, dissection, rupture and so forth) and venous (thrombophlebitis, thrombosis) complications, arteriovenous malformations and hematoma.

Embolic complications included arterial and venous embolism that occurred within 7 days of a procedure or recognition of vascular complication of a procedure. Arterial embolization included embolization to the central nervous system or peripheral or coronary arteries producing clinically recognizable symptoms or signs. Venous embolization included documented pulmonary embolism and venous thrombosis in a vein catheterized during the procedure.

Cardiac perforation was diagnosed by echocardiographic demonstration of blood in the pericardial space or by pericardiocentesis during the procedure or immediately after catheter withdrawal. It should be emphasized that the serious vascular, embolic and perforation complications include only symptomatic events. No studies were performed to identify asymptomatic events; thus, only clinically significant complications are reported.

Significant hypotension was defined as symptomatic reduction in arterial blood pressure that occurred during or within 24 hours of a procedure and did not respond to leg raising and an infusion of 250 cc of saline solution.

Standard clinical definitions of angina pectoris, acute myocardial infarction, congestive heart failure and pneumothorax were used (10). The occurrence of any of these during or within 24 hours of a procedure was considered a complication.

An arrhythmic complication of electrophysiologic study was a bradycardia or tachyarrhythmia that persisted 6 hours after the study or required therapy or both. This definition excluded the induction of arrhythmias that were clinically relevant to the patient's indication for study. Our definitions of induced ventricular tachyarrhythmias have previously been published (9).

Results

Catheterization procedures. In the 1,000 initial studies performed, 2,821 venous catheters were inserted, 2,685 (95%) in the femoral veins and 133 (5%) in the basilic veins. Three catheters were inserted in subclavian veins. A basilic vein cutdown was required in seven insertions. There were 32 arterial catheters inserted, all inserted percutaneously in femoral arteries. Two patients received five catheters, 124 patients had four, 640 patients had three, 193 patients had two and 41 patients had one.

Catheters were positioned to record or stimulate, or both, in the high right atrium in 998 patients and at the right ventricular apex in 986. A His bundle electrogram was recorded in 933 patients. The coronary sinus was catheterized in 111 patients and the left atrium was entered through a patent foramen ovale in 8. A catheter was positioned in the right ventricular outflow tract in 563 patients and in the left ventricle in 32.

The mean time from the insertion of the first introducer to removal of catheters was 167 minutes (range 60 to 420) for initial studies. The mean fluoroscopy time (actual minutes of on-time) was 11.6 minutes (range 1.5 to 99) (Fig. 1).

Drug studies. A total of 1,210 follow-up drug studies were performed in 444 patients (2.7/patient). In 353 patients, the first drug study was performed on the day of the initial study and did not require insertion of additional catheters. In 75 other drug studies, performed on the day of another drug evaluation, insertion of additional catheters was not required. In the 782 remaining follow-up drug studies, 1,001 catheter insertions were required (1.3/patient).

The mean laboratory time for follow-up drug studies that required catheter insertion was 108 minutes (range 60 to

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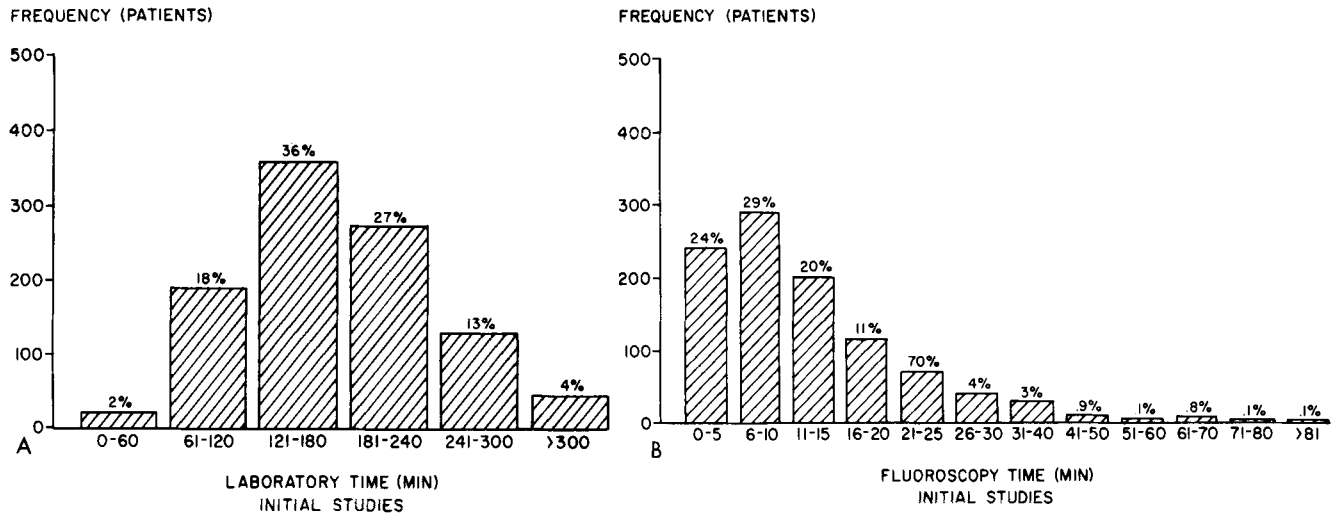

Figure 1. Total laboratory (**A**) and fluoroscopy time (**B**) for 1,000 initial electrophysiologic studies. These histograms show the number and percent of patients in the respective durations of total laboratory time (in minutes) and fluoroscopy time (in minutes).

285); the mean fluoroscopy time for these follow-up studies was 7.0 minutes (range 1 to 62) (Fig. 2).

Arrhythmias. The arrhythmias induced during the initial studies are presented in Table 3. The majority (89%) of the drug studies (1,081 of 1,210) were performed in patients with inducible ventricular tachycardia or fibrillation.

Figure 2. Total laboratory (**A**) and fluoroscopy time (**B**) for follow-up (drug study) electrophysiologic studies. These histograms show the number and percent of patients in respective durations of total laboratory time (in minutes) and fluoroscopy time (in minutes).

Complications (Table 4)

Mortality. One death occurred during these studies. The patient was a 53 year old man who 5 weeks before study, had had an acute anterior myocardial infarction that was complicated by bundle branch block, heart failure, pericarditis and sepsis. Recurrent sustained ventricular tachycardia began 4 weeks after the infarction and it was unresponsive to procainamide, lidocaine, quinidine and bretylium alone and in combinations. The patient was apparently clinically stable at the time of study and bretylium had been discontinued 48 hours before study. Sustained monomorphic ventricular tachycardia was initiated with double right ventricular apical extrastimuli. The tachycardia cycle length was 280 ms and the systolic blood pressure during tachycardia was 54 mm Hg. The arrhythmia was terminated with burst ventricular pacing after 32 seconds. Sinus rhythm resumed; however, electromechanical dissociation occurred and prolonged resuscitative efforts were unsuccessful.

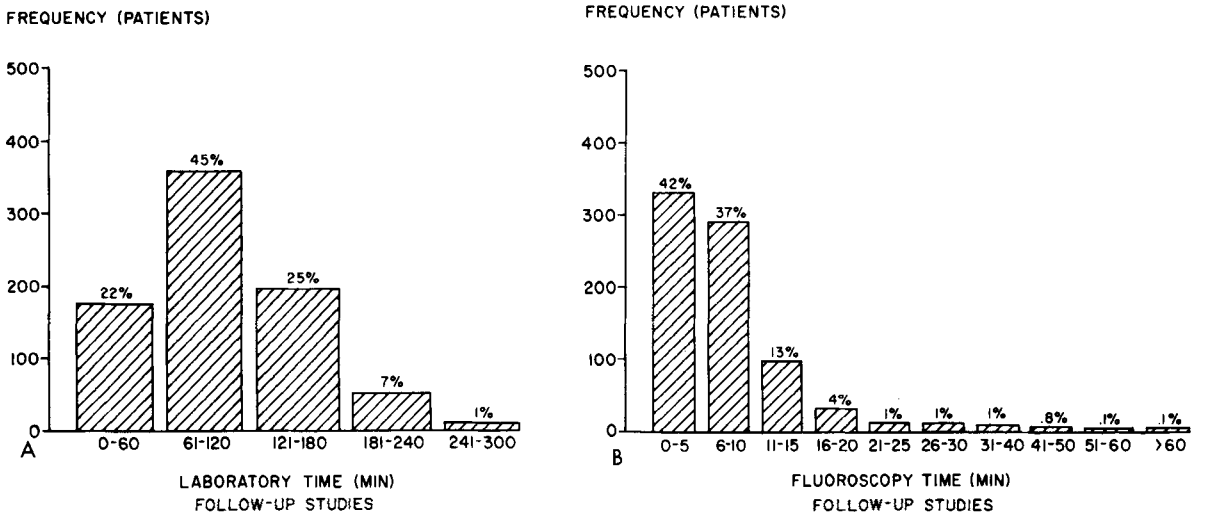

Table 3. Arrhythmias Induced During Initial Electrophysiologic Studies in 1,000 Patients

	No. of Patients
Atrial fibrillation	46
Atrial flutter	59
Supraventricular tachycardia	100
Sustained ventricular tachycardia	289
Nonsustained ventricular tachycardia	132
Ventricular fibrillation	52
Total	678*

*At least one arrhythmia was initiated by programmed electrical stimulation in 582 patients.

There were no deaths after the conclusion of any initial study or during or after any drug study.

Vascular complications. Arterial complications occurred in four patients. None were observed in patients undergoing arterial catheterization. In two patients, inadvertent puncture of the superficial femoral artery produced a pseudoaneurysm that required surgical repair. In one patient, the anterior and posterior walls of this artery were lacerated and hemostasis could not be obtained after removal of catheters; these lacerations were surgically repaired. In the fourth patient, an in situ thrombus in the superficial femoral artery developed the day after an initial study. At surgical exploration, the artery was not injured and a fresh thrombus was found. It was postulated that pressure used to obtain hemostasis may have caused internal injury that resulted in the thrombus. All four patients recovered after surgery and there was no evidence of chronic arterial insufficiency in any patient.

Thrombophlebitis occurred in six patients. In two patients it occurred after the initial procedure. The other four patients had three to five procedures involving catheter insertions and the phlebitis occurred after the third, fourth (two patients) and fifth laboratory sessions. All six patients responded to conventional therapy with heparin and warfarin and no chronic sequelae occurred.

Significant hematomas developed in two patients. One patient required surgical drainage but neither required transfusion. In both, healing occurred without sequelae.

Embolic complications. An arterial embolus was detected in one patient. This patient had had a cardiac arrest, presumably due to disopyramide, 2 months before initial electrophysiologic study. Cardiac evaluation revealed only mitral anular calcification. No arrhythmia was initiated by programmed stimulation and the left ventricle was not entered. On the day after the study, symptoms of arterial insufficiency in her leg developed suddenly. A well organized thrombus was removed from the femoral artery and there were no sequelae.

Pulmonary embolism occurred in three patients; all had thrombophlebitis. The embolism was temporally related to the phlebitis rather than the catheterization procedure. No patient had severe symptoms and all responded to routine anticoagulant therapy. There were no long-term sequelae.

Cardiac perforation. Symptomatic and thus clinically recognizable cardiac perforation occurred during one initial study and one follow-up drug study. In the initial study, catheters were in the right atrium, His bundle recording position and right ventricular apex. During ventricular stimulation and without apparent patient movement, the patient complained of chest pressure and her blood pressure became unobtainable within 5 minutes. Classic signs and fluoroscopic evidence of cardiac tamponade appeared. Pericardiocentesis confirmed the diagnosis and blood was removed at a rate of 50 cc/min for approximately 15 to 20 minutes. Blood pressure was maintained with fluids and plasma expanders. Within 10 minutes of reversal of anticoagulation with protamine all pericardial drainage stopped. There were no sequelae.

In a follow-up study in another patient, catheters were positioned in the right atrium and right ventricular apex. The patient developed chest pain and hypotension. The blood pressure normalized with saline solution and albumin and an echocardiogram revealed pericardial effusion; however, no further therapy was required and the patient underwent a subseqeunt study without incident a week later.

Neither patient who had symptomatic and clinically detectable perforation had right ventricular damage detectable by noninvasive or invasive tests.

Hypotension. During or after study, 20 patients developed symptomatic hypotension (50 to 86 mm Hg systolic) that was not related to an arrhythmia and required treatment. In 11 patients, this was caused by intravenous antiarrhythmic drug administration (procainamide in nine patients, mexiletine and quinidine in one patient each). In nine patients, the hypotension was due to a vagal reaction during catheter insertion or withdrawal. All episodes responded to

Table 4. Significant Complications of Electrophysiologic Studies in 1,000 Patients

Complication	Incidence/1,000 Patients Exposed	Incidence/ Procedure
Death	1 (0.1%)	1/2,210 (0.05%)
Vascular	12 (1.2%)	12/1,782* (0.7%)
Arterial injury	4 (0.4%)	4/1,782 (0.2%)
Thrombophlebitis	6 (0.6%)	6/1,782 (0.3%)
Severe hematoma	2 (0.2%)	2/1,782 (0.1%)
Embolic	4 (0.4%)	4/2,210 (0.2%)
Systemic arterial embolus	1 (0.1%)	1/2,210 (0.5%)
Pulmonary embolus	3 (0.3%)	3/2,210 (0.15%)
Cardiac perforation	2 (0.2%)	2/1,782 (0.1%)
Hypotension	20 (2%)	20/2,210 (1%)

*The number of studies in which catheter insertion occurred.

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administration of saline solution, albumin or atropine, or combinations, and there were no sequelae.

Miscellaneous complications. Three patients developed frequent angina unrelated to arrhythmias or pacing during the studies and their studies were terminated. These episodes responded to routine therapy. No patient developed acute myocardial infarction as a result of electrophysiologic study.

One patient developed an urticarial reaction to intravenous procainamide infusion and two patients had an hysterical conversion reaction. There were no sequelae and no infections, sepsis, or pyrogenic reactions.

Arrhythmic complications. Arrhythmias initiated by programmed electrical stimulation or catheter manipulation were considered complications if they were not clinically relevant to the patient's indication for study or failed to respond to routine therapy. Thus, not all arrhythmias induced during these studies were considered complications.

In one patient being evaluated for syncope and suspected AV conduction disturbance, complete AV block occurred during catheter placement. AV conduction did not return and a permanent pacemaker was implanted. Syncope has not recurred in the 15 months since pacemaker implantation.

In four patients, ventricular fibrillation that was not relevant to the patient's indication for study was initiated by programmed stimulation. In each patient, the arrhythmia was initiated by double extrastimuli (triple extrastimuli were used only in patients undergoing evaluation for ventricular arrhythmias and in such patients, ventricular fibrillation was not considered a complication). In all patients, a single countershock restored sinus rhythm and there were no sequelae.

In 14 patients who had a history of sustained ventricular tachycardia or cardiac arrest and who were in stable condition without frequent episodes of malignant arrhythmia, incessant ventricular tachycardia occurred during electrophysiologic studies. In each patient, the incessant arrhythmia followed the initiation of ventricular tachycardia by programmed stimulation. In two patients, this event occurred during the initial study when the patient was not receiving antiarrhythmic drugs. In the other 12 patients these events occurred during drug evaluations (oral flecainide in three; intravenous procainamide in three; intravenous indecainide, intravenous pirmenol, intravenous amiodarone, oral disopyramide with intravenous mexiletine, oral amiodarone and oral amiodarone and procainamide in one each). These episodes required prolonged treatment with fluids, pressor agents, other antiarrhythmic agents, and pacing or cardioversion, or both. All patients survived and there were no permanent sequelae. This complication, development of incessant ventricular tachycardia during electrophysiologic drug evaluation, occurred in 12 (3%) of 397 patients with a sustained ventricular tachyarrhythmia who underwent drug studies. These 12 episodes represent 1% of the 1,081 drug evaluations performed in patients with inducible sustained ventricular tachyarrhythmias.

Atrial fibrillation that was not related to the patient's clinical arrhythmia history and required drugs or cardioversion for restoration of sinus rhythm was initiated by catheter manipulation or programmed stimulation in 10 patients. The patients were not severely symptomatic; however, if the atrial fibrillation prevented completion of the stimulation protocol or persisted for several hours, it was converted with drugs (seven patients) or cardioversion (three patients).

Cardioversion. Electrical cardioversion was required to terminate induced arrhythmias in 217 patients. In addition to the three patients with atrial fibrillation noted earlier, cardioversion was required for 289 episodes of sustained ventricular tachycardia (in 166 patients) and 83 episodes of ventricular fibrillation (in 48 patients). In the 372 episodes of ventricular tachycardia or fibrillation, cardioversion was successful on the first shock in 275 (74%), the second shock in 77 (21%) and the third shock in 14 (3.5%). In six patients, more than three shocks were required to terminate the tachyarrhythmia. Because of the difficulty in determining the efficacy of cardioversion in patients with incessant ventricular tachycardia, the patients with this arrhythmia (supra vide) are not included in this analysis.

In patients with inducible sustained ventricular tachycardia or fibrillation, cardioversion was required in 179 (53%) of 339 initial studies. In 80 of these 179 patients, cardioversion was not required during any subsequent drug evaluations. On the other hand, it was required at least once during follow-up drug studies in 35 patients in whom it was not necessary during the initial study.

Discussion

The usefulness of clinical cardiac electrophysiologic studies has been well established (1–9). They have been used to diagnose previously undocumented arrhythmias and evaluate pharmacologic, device and surgical therapies in patients with supraventricular and ventricular tachyarrhythmias (2–9,11–15). Although many patients who undergo these studies have serious organic heart disease, the risk of serious complication is low. Particularly in patients with malignant ventricular tachyarrhythmias, in whom the impact of recurrent arrhythmia is significant, the risks and complications of electrophysiologic testing are acceptable.

Comparison with previous studies. In general, our results confirm the report of DiMarco et al. (16) that electrophysiologic studies carry an acceptably low incidence of serious complication. The major differences in our approaches involve the use of indwelling electrode catheters and systemic anticoagulation.

Dimarco et al. (16) and other laboratories (6) favor the use of indwelling catheters to facilitate serial drug testing.

Because of consideration for patient comfort, these catheters were frequently inserted by way of the subclavian route. This practice was associated with a small risk of pneumothorax (1.6%). Moreover, indwelling catheters pose a risk of local and systemic infection, also reported by DiMarco et al. (16). We chose not to employ indwelling catheters and thus avoid these complications. Moreover, our routine use of stimulation of the right ventricular outflow tract in patients with ventricular tachyarrhythmias was not readily accomplished with an indwelling catheter. Nonetheless, the superiority of either approach has not been clearly demonstrated.

To avoid significant thromboembolic complications we have routinely used systemic anticoagulation during studies. DiMarco et al. (16) used heparin only when the left atrium or ventricle was catheterized. Whether the use of heparin or the avoidance of indwelling catheters explains the lower incidence of venous thromboembolic complications in our series (0.6 versus 2.5%) is uncertain.

In a retrospective survey from six active electrophysiology laboratories (17), the incidence of major complications related to the mechanical aspects of this procedure were similar to those reported by DiMarco et al. (16) and those in the present study. Although the cooperative study was retrospective and included data from laboratories using differing techniques and protocols, it confirms the safety of clinical electrophysiologic studies.

We have reported a higher incidence of artery injury than others. This may be related to the frequent insertion of two catheters in the same femoral vein, which may increase the chance of inadvertently injuring the adjacent femoral artery.

Deaths during electrophysiologic studies. Few deaths have been reported in previous clinical cardiac electrophysiologic studies. In addition to the four deaths reported in the multicenter study (17) and the death in the present series, only one other well described case has been mentioned (18). The patients who died typically were severely ill with marked ventricular dysfunction, and several were at the point of death at the time of study. However, the potential lethality of perforation, embolism and proarrhythmia should not be underestimated.

Arrhythmic complications. Although the arrhythmic complications of electrophysiologic studies have been reported (6,19) they have not been emphasized. The risk of death is low but not absent and the proarrhythmic effects of antiarrhythmic drugs present an additional hazard. In our series, 12 (3%) of 397 patients with inducible malignant ventricular tachyarrhythmias who underwent drug evaluations had a severe proarrhythmic event, incessant ventricular tachycardia. Although none of these patients died, that possibility was very real. Moreover, 35 patients who did not have cardioversion during initial studies had ventricular tachycardia that required cardioversion during drug studies. Although the benefits of serial drug evaluations are appreciable, their risks should not be minimized.

Comparison with angiographic catheterization. The risks and complications of electrophysiologic studies reported by us and others (16–20) are generally comparable with those reported for coronary arteriography and cardiac catheterization (21–28). Although the specific types of complications are somewhat different and mortality may be higher for cardiac catheterization, the overall risk of both procedures is acceptable. Data on complications of cardiac catheterization have been compiled in large groups of patients (5,000 to 50,000) in both university centers (23,26–28) and community hospitals (24–27). Similar large groups from diverse types of hospital facilities are required before we can confidently assess the risks of electrophysiologic studies in all hospital settings.

Conclusions. The incidence of catheterization-related and arrhythmic complications of electrophysiologic studies is low and acceptable. The roles of systemic anticoagulation and indwelling catheters remain to be clarified although it does appear that the incidence of thromboembolic complications can be reduced from that in previous reports. The present data were collected in a university center tertiary care facility and can be applied to similiar medical institutions; however, similiar data should be obtained from other settings in which electrophysiologic studies may be performed.

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