Perforations of right heart chambers associated with diagnostic electrophysiology catheters and temporary transvenous pacing leads

Tanısal elektrofizyoloji kateterleri ve geçici kalp pili elektrotları ile ilişkili sağ kalp boşluklarının perforasyonu

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ABSTRACT

Objectives: Perforation of heart chambers is one of the rare complications observed during electrophysiological studies and placement of pacemaker leads. In this study, we performed a retrospective evaluation of patients with catheter-related right heart perforation, aiming to determine its incidence and clinical course.

Study design: We reviewed cases with catheter-relater cardiac perforations observed at our institution from June 2002 to November 2007.

Results: During the study period, a total of 2,385 procedures were performed (1,287 electrophysiologic studies, 1,098 temporary nonballoon-floating pacing lead placements). Eight cardiac perforations were diagnosed, with the overall procedure-based and catheter-based incidences of 0.34% (8/2,385) and 0.14% (8/5,603), respectively. Three of these perforations were related to diagnostic electrophysiology catheters, and five were related to temporary (1 permanent) transvenous pacemaker leads. Seven perforations involved the right ventricle and one involved the right atrium. Three patients in whom right ventricular perforation was detected at a late stage died suddenly after pacemaker lead implantation. One patient underwent surgical exploration because of right atrial perforation. Two patients underwent coronary bypass operation and, in one of these patients, perforation was detected during surgery. Two patients were managed conservatively.

Conclusion: Although right ventricular perforations detected early have a relatively benign course, those detected late and right atrial perforations require emergent surgical exploration and may have catastrophic consequences.

ÖZET

Amaç: Kalp boşluklarının delinmesi, elektrofizyolojik çalışma ve geçici kalp pili takılmasının nadir rastlanan bir komplikasyonudur. Bu çalışmada, kateterle ilişkili sağ kalp delinmesi gelişen hastalar geriye dönük olarak incelenerek bu komplikasyonun sıklığı ve klinik seyri araştırıldı.

Çalışma planı: Haziran 2002 ile Kasım 2007 tarihleri arasında kurumumuzda kateterle ilişkili kalp delinmesi tanısı konan hastalar çalışmaya alındı.

Bulgular: Çalışma dönemi içinde toplam 2385 uygulama gerçekleştirildi (1287 elektrofizyolojik çalışma, 1098 balonsuz geçici kalp pili uygulaması). Sekiz olguda kalp delinmesi tanısı kondu. Bu komplikasyonun sıklığı işlem sayısı açısından %0.34 (8/2385), kullanılan kateter sayısı açısından %0.14 (8/5603) bulundu. Kalp delinmesi üç olguda elektrofizyolojik çalışma sırasında, diğer olgularda geçici (1 olguda kalıcı) kalp pili elektrodunun yerleştirilmesi sırasında meydana geldi. Etkilenen boşluklar yedi olguda sağ ventrikül, bir olguda sağ atriyum idi. Kalp pili yerleştirilmesinden sonra sağ ventrikül delinmesinin geç evrede saptandığı üç hastada ani ölüm gelişti. Sağ atriyum delinmesi saptanan bir hastaya cerrahi eksplorasyon yapıldı. İki hastaya koroner baypass ameliyatı uygulandı, bunların birinde delinme ameliyat sırasında görüldü. İki hasta ise konservatif olarak izlendi.

Sonuç: Erken saptanan sağ ventrikül delinmelerinde prognoz nispeten daha iyi olsa da, geç saptanan delinmeler ve sağ atriyum delinmeleri acil girişim gerektiren durumlardır ve sonuçları çok kötü olabilir.

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Cardiac perforation is one of the rare and potentially disastrous complications observed during intracardiac catheter manipulations. The true incidence of this event is not well-established due to the possible asymptomatic course in some patients. Many case reports present patients with catheter-related perforations, but there is lack of information on management of this condition. In this study, we performed a retrospective evaluation of patients with catheter-related right heart perforation, aiming to determine its incidence and clinical course. Based on our data, we also intended to propose a classification system for catheter-related cardiac perforations to contribute to the management of this complication.

PATIENTS AND METHODS

We examined our database and reviewed cases with cardiac perforations observed from June 2002 to November 2007. All electrophysiological procedures were recorded on a digital computer-based program, and data on perforations were derived from this digital archive. Identification of patients who sustained a cardiac perforation related to temporary transvenous pacemaker implantation was made manually by screening hospital records.

RESULTS

During the study period, a total of 2,385 procedures were performed (1,287 electrophysiological studies, 1,098 temporary pacemaker implantations). The number of diagnostic and ablation catheters used during electrophysiological studies and ablation procedures was 4,505, and the total number of catheters and temporary pacing wires was 5,603. Among these procedures, cardiac perforations occurred in eight cases (5 with temporary transvenous pacing catheters, 3 with diagnostic electrophysiology catheters). Seven of these perforations involved the right ventricle and one involved the right atrium. All the catheters associated with ventricular perforation were introduced through the femoral vein and were placed at the right ventricular apex. Atrial perforation occurred at the lateral wall of the high right atrium, with a catheter introduced through the left femoral vein.

The incidence of right heart perforation was 0.23% (3/1287) when the number of electrophysiological studies was considered and 0.07% (3/4,505) when the number of catheters used was taken into account. The incidence was 0.46% (5/1098) for temporary pacemaker lead implantations. The overall procedure-based and catheter-based incidences were 0.34% (8/2,385) and 0.14% (8/5,603), respectively (Table 1).

Abbreviations:

AV *Atrioventricular*
HRA *High right atrium*

Temporary pacing electrodes were more frequently associated with cardiac perforations (0.46% *vs.* 0.07%), but this difference was not statistically significant (chi-square test, $p>0.05$).

Mortality occurred in three patients who developed massive pericardial effusion after implantation of a temporary or permanent transvenous pacemaker lead.

Brief presentation of the cases

Case 1 (Age 82 years, male) – The patient was admitted with recurrent syncope and third-degree atrioventricular block and escape rhythm with wide QRS complexes at a rate of 25-30 beats/min. He had a history of hypertension and paroxysmal atrial fibrillation. Digitalis intoxication was diagnosed based on daily digoxin intake and digoxin level of 3.3 μg/dl. Echocardiographic examination showed mild enlargement of the right heart chambers and moderate pulmonary hypertension, with preserved left ventricular systolic function. Temporary transvenous pacemaker lead was introduced via the right femoral vein. Pacemaker implantation was scheduled one week later to allow elimination of digitalis effect. On the fifth day, the patient developed sudden cardiac arrest (sudden bradycardia followed by electromechanical dissociation). Echocardiographic examination performed during resuscitation revealed massive circumferential pericardial effusion. The patient died despite pericardiocentesis and all resuscitation efforts.

Case 2 (Age 32 years, male) – The patient was admitted with the diagnosis of acute inferior myocardial infarction and third-degree AV block. A temporary transvenous pacemaker lead was placed via the right femoral vein and successful reperfusion of the right coronary artery was achieved with administration of streptokinase. However, AV block persisted until the seventh day, at which time the patient developed sudden cardiovascular collapse. Bedside echocardiography revealed large pericardial and left pleural effusions. The pacing lead was visualized beyond the right ventricular wall. Despite emergent bedside pericardiocentesis, placement of chest tube, and cardiopulmonary resuscitation, the patient died.

Case 3 (Age 89 years, female) – The patient was admitted with symptomatic Mobitz type II second-degree

Table 1. Procedure-based and catheter-based incidences of right heart perforations

	Electrophysiological study	Transvenous temporary pacemaker	Total
No. of procedures	1,287	1,098	2,385
No. of catheters	4,505	1,098	5,603
No. of right heart perforations	3	5	8
Incidence of perforations			
Procedure-based	0.23%	0.46%	0.34%
Catheter-based	0.07%	0.46%	0.14%

AV block. Her medical history included insulin-dependent diabetes mellitus, systemic hypertension, ischemic stroke, and use of digitalis for five years. Admission echocardiography showed only mild aortic stenosis and left ventricular hypertrophy. Permanent pacemaker lead implantation was performed through the right femoral vein one after temporary pacemaker implantation. On the third day, the patient developed sudden cardiac arrest and all resuscitation efforts were unsuccessful. Echocardiographic examination performed during resuscitation showed massive pericardial effusion.

Case 4 (Age 54 years, female) – The patient was admitted with chest pain, syncope, and third-degree AV block with narrow QRS escape rhythm. There were no electrocardiographic signs of acute myocardial infarction, without any increase in cardiac biomarkers during 24 hours of observation period. On admission, a temporary transvenous pacemaker was placed via the right femoral vein. Coronary angiography performed on the third day revealed severe three-vessel coronary artery disease. The patient was submitted to coronary artery bypass grafting surgery. During surgical exploration, the pacing lead was observed within the pericardial space and minimal pericardial effusion was observed. A fragile and necrotic tissue was noted around the pacing lead. Suture closure of the defect, coronary grafting, and placement of an epicardial pacing wire were performed. Complete AV block resolved on the second postoperative day and the patient had an uneventful recovery.

Case 5 (Age 54 years, male) – The patient had two episodes of syncope and was admitted with third-degree AV block. A temporary pacing catheter was passed into the right ventricle through the right femoral vein. Coronary angiography performed one day later revealed apparent right ventricular perforation (Fig. 1) and three-vessel coronary artery disease. As the perforation was relatively new (<24 hours), the

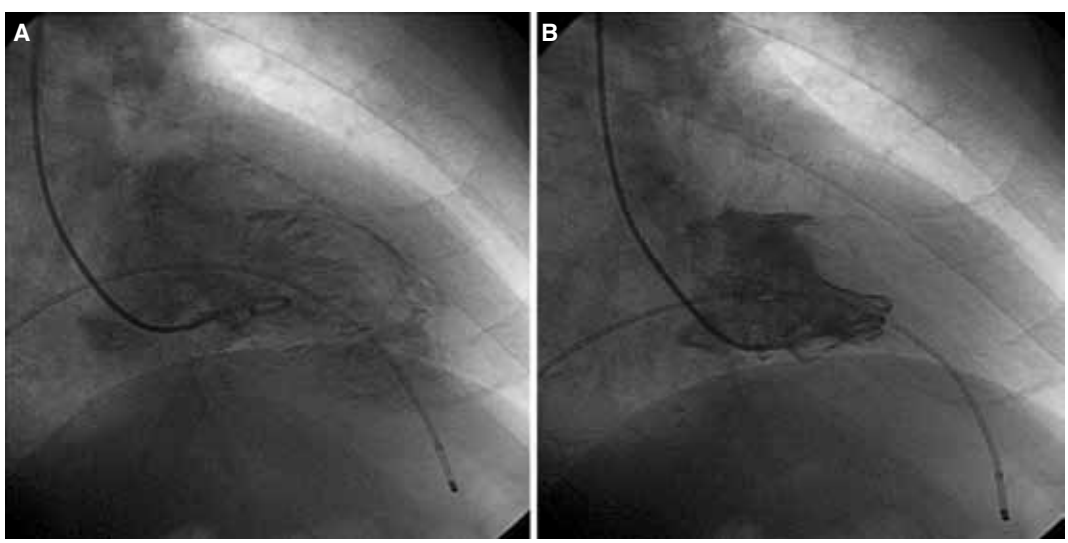

Figure 1. Left ventriculograms in the right anterior oblique view showing apparent right ventricular perforation during **(A)** diastole and **(B)** systole.

catheter was withdrawn and the patient was submitted to coronary bypass surgery. Daily echocardiographic evaluations during preoperative follow-up showed no pericardial effusion. Surgery was performed on the third day, during which no signs of pericardial effusion were noted, but there was a clear demarcation at the site of the perforation.

Case 6 (Age 78 years, female) – The patient was referred to our hospital for electrophysiological evaluation of possible sick sinus syndrome after an inconclusive noninvasive evaluation. Electrophysiological study was performed via the left femoral approach with placement of three diagnostic catheters at the HRA, His bundle position, and right ventricular apex, respectively. Pacing capture was achieved with pacing from the right atrium and right ventricle. During the procedure, the patient developed chest pain accompanied by loss of capture with right ventricular pacing. There was no hemodynamic compromise. Then, the right ventricular capture was achieved by a slight pull-back maneuver and electrophysiological study was completed successfully. Approximately 30 minutes later, the patient developed symptomatic hypotension and was treated with aggressive fluid resuscitation and dopamine infusion. Echocardiographic examination showed pericardial effusion of less than 1 cm localized around the right ventricle. Blood pressure was normalized and dopamine infusion was stopped on the fifth hour. She was discharged on the third day.

Case 7 (Age 65 years, female) – The patient was referred for assessment of frequent episodes of supraventricular tachycardia and underwent invasive electrophysiological evaluation. Three 6 F and one 8 F introducer sheaths were placed via the left and right femoral veins, respectively. Diagnostic catheters were placed at the right ventricular apex, His bundle position, coronary sinus, and HRA. During manipulations with the HRA catheter, the patient complained of chest pain due to withdrawal of the HRA catheter to the inferior vena cava, resulting in hypotension. Fluid resuscitation and dopamine infusion were started. Echocardiographic evaluation showed pericardial effusion resulting in collapse of the right atrium. Emergent surgical exploration was performed and the patient had an uneventful recovery period.

Case 8 (Age 52 years, male) – The patient was referred to our hospital for electrophysiological evaluation of supraventricular tachycardia. Three 6 F diagnostic catheters were placed to the HRA, His bundle position, and right ventricular apex though the left femoral vein, and one 8 F coronary sinus catheter was introduced through the right femoral vein. Pacing capture was achieved from the right atrium and right ventricle. During the procedure, the patient complained of chest pain and we observed loss of capture with the right ventricular pacing. There was no hemodynamic compromise. The right ventricular capture was restored by a slight pull-back maneuver. Electrophysiological study was aborted and all the catheters were pulled out, but the patient developed symptomatic hypotension. Echocardiographic examination showed pericardial effusion of less than 1.5 cm localized around the right ventricle and right atrium with minimal collapsing of both right heart chambers. Pericardiocentesis was not attempted and the patient was transferred to the intensive care unit and treated with fluid and dopamine infusion. Dopamine infusion was stopped at 12 hours when blood pressure became normal. The patient was discharged one week after the procedure.

DISCUSSION

Cardiac perforation is one of the most catastrophic catheter-related complications. It is generally difficult to estimate the exact frequency of this complication due to the asymptomatic clinical course in some patients. In a prospective regional survey, it was shown that almost one-third of transvenous temporary pacing procedures were associated with various complications, and the incidence of cardiac perforation was about 3%.[1] Lower perforation rate in our patients undergoing placement of temporary transvenous pacing leads may be attributed to the retrospective nature of our study. However, the incidence of cardiac perforations is lower for electrophysiological studies, being about 0.1-0.2%, which is compatible with our findings.[2,3]

In our study, all catheters were introduced and placed under fluoroscopic guidance. Considering that all diagnostic catheters and nonballoon-floating temporary pacing leads associated with perforation were 6 F in diameter, we concluded that the mechanism of perforation was similar in patients undergoing temporary transvenous pacing lead placement or electrophysiological study. Although the management of patients with cardiac perforations should be handled on an individual basis, our experience suggests that catheter-related right heart perforations can be classified as primary or secondary and, by the same way, as early or late (Table 2).

Another important question that must be answered is which cardiac chamber has been perforated? We suggest that the answer to this question will affect the strategy for the management of individual patients.

Table 2. Proposed classification, definition, and management of catheter-related right heart perforations

Stages of perforation	Definition	Management	Prognosis
Primary stage	Primary heart chamber perforation during or immediately after catheter manipulation or catheter dislodgement.	1. Withdrawal of the catheter 2. Aggressive fluid replacement 3. Vasopressor or inotropic drugs 4. Vagolytic agent (atropine) 5. Surgery should be considered in patients with thin ventricular wall (e.g., Arrhythmogenic right ventricular dysplasia, severe dilatation of the right ventricle) and in those with perforation of the atrial wall.	Prognosis is good in case of ventricular perforation, but surgery should be considered in cases with atrial wall perforation.
Intermediate or inflammatory stage	This stage is characterized by necrotic process in tissue surrounding the catheter causing heart chamber perforation.	Open cardiac surgery must be the preferred therapeutic strategy. Withdrawal of the catheter should be avoided at this stage, especially in the presence of even a small amount of pericardial fluid.	Individualized approach should be employed, although surgery can be preferred at this stage.
Secondary stage	Rupture of the necrotic heart tissue surrounding the catheter.	Emergent surgical intervention is mandatory.	Poor

Primary or early perforations generally occur during intracardiac catheter manipulations or during dislodgement of intracardiac catheters. It can be suspected by the patient's complaint of sudden chest pain, diaphragmatic stimulation, changes in paced QRS axis or morphology, sudden increases in pacing threshold/failure to pace, or only positional failure to pace during the procedure or follow-up. Another sign of ventricular perforation is long latency between the stimulus artifact and paced QRS complexes, but this sign was reported in only one of the historical case reports.[4] However, it should be realized that the above-mentioned signs may be absent in some patients. For example, failure of ventricular pacing may not be recognized when the tip of the pacing lead lies close to the epicardial surface of the heart, or change in QRS axis may not be observed when the perforating catheter is only minimally advanced.[4] This phase can also seem to be asymptomatic especially in critically ill patients who already have other confounding factors such as elder age, ongoing chest pain due to myocardial infarction, or impaired consciousness. We suggest that this stage can be managed simply by withdrawal of the catheter and symptomatic treatment of hypotension or cardiogenic shock. Pericardial effusion seems to occur during the first seconds, following catheter withdrawal, because we did not observe increases in the size of pericardial effusion during subsequent echocardiographic evaluations. We suggest that symptoms occurring during or after this stage can be attributed to myocardial perforation, diaphragmatic stimulation, pericardial irritation, or to postcardiac injury syndrome.[5] Hemodynamic deterioration must not be attributed solely to the presence of cardiac tamponade and we suggest that increase in vagal tone due to the perforation of the right ventricle or direct irritation of pericardial vagal fibers are important contributing factors. As seen in our patients in whom perforation was detected early, clinical signs of cardiogenic shock can be observed without an obvious increase in pericardial fluid volume and in the absence of echocardiographic signs of tamponade. Spontaneous closure of the defect with myocardial contraction is likely to occur immediately after catheter withdrawal. However, there are several conditions that catheter removal might not result in spontaneous closure of perforation site, including arrhythmogenic right ventricular cardiomyopathy, dilatation of the right heart chambers together with increase in pressure within the right heart, elder age, use of warfarin, infusion of glycoprotein IIb/IIIa inhibitors, or thrombolytic agents, right atrial perforation, and acute or convalescent phase of acute myocardial infarction.

Compared with younger myocardium, aging myocardium has fewer myocytes, highly collagenized connective tissue and, in some individuals, amyloid deposition.[6] As was observed in our cases, elderly patients may be more susceptible to catheter-related perforations because of age-related changes observed in the myocardial structure, requiring more gentle catheter manipulations.

Right atrial perforation is another important issue requiring consideration of several factors. Compared to the ventricular myocardium, the atrial myocardium consists of fewer myocytes and therefore has a limited ability of spontaneous closure following perforation. Atrial perforation can result in a localized pericardial effusion behind the right atrium, with only local compression of the right atrium and subsequent development of cardiac tamponade.[7] This type of tamponade, despite its low volume, is a life-threatening condition with important hemodynamic consequences requiring emergent surgical exploration; moreover, it may be impossible to reach a space behind the right atrium either by surgical creation of a pericardial window or by performing percutaneous pericardiocentesis. This type of localized tamponade can be observed especially in patients with a history of cardiac surgery, radiotherapy, and recurrent and/or constrictive pericarditis.

The presence of acute myocardial infarction also merits special mention. Patients with myocardial infarction involving the right ventricle and/or treated with thrombolytic agents are especially prone to catheter-related perforations. Because involvement of the right ventricle during myocardial infarction is often associated with various degrees of AV block, the possibility of cardiac perforation should be kept in mind in these patients, and maximally gentle catheter maneuvers must be employed during placement of temporary transvenous pacing leads. Yet, it is not clear how to manage cardiac perforations in patients who concomitantly receive thrombolytic therapy, infusion of glycoprotein IIb/IIIa inhibitors, and other types of antiplatelet agents. Whether we have to wait in minimally symptomatic patients or perform emergent surgical exploration in this high-risk group is not clear and the answer to this question will probably not be available and we will have to manage this condition intuitively.

The intermediate stage is the inflammation period that can be visualized either intraoperatively or histopathologically. This stage is characterized by the presence of necrotic tissue surrounding the catheter, which itself leads to perforation of the heart chamber during the secondary stage. From a pathological point of view, this inflammation process begins in the tissue surrounding the perforation zone as soon as the catheter perforates the ventricular or atrial wall. Inflammation serves to destroy, dilute, or wall off the injurious agent and sets a series of events into motion, which contribute to healing and reconstitution of the damaged tissue. This process completes only after the injurious agent has been neutralized or completely removed. During repair, the injured tissue is replaced through regeneration of native parenchymal cells and by filling the defect with fibrous tissue, or most commonly by a combination of these two processes.[8,9] We speculate that pericardial effusion that appears in this stage mainly occurs as a result of blood leakage from microperforations in tissue surrounding the catheter.

During the secondary stage, necrotic tissue surrounding the catheter ruptures either spontaneously or by catheter movement and leaks through the widened perforation zone, which is an indication for surgical intervention. Massive bleeding into the pericardial space leading to cardiac tamponade is the main cause of mortality. Pericardiocentesis can be tried to stabilize the patient, only when emergent surgical intervention can be performed immediately thereafter.

Finally, we suggest that serial echocardiographic and radiographic monitoring is critical in the follow-up of patients with temporary transvenous pacemakers. Detection of even a small pericardial effusion should be considered to be a sign of possible perforation. Early ventricular perforations can be managed by catheter withdrawal; however, ventricular perforations detected at a late stage and atrial perforations have very high mortality rates. Emergent surgical intervention is mandatory in this latter group.

In conclusion, despite the fact that catheter-related cardiac perforations are a well known complication and each patient suffering this condition needs an individualized approach, there is no concise information on the management of these cases, and surgical approach is generally preferred in most cases. However, as shown in our cases, cardiac perforations do not always necessitate surgical exploration. In this article, we presented our cases with perforation of right heart chambers, suggested possible mechanisms, proposed a system for classification of right heart perforations and a possible case-based approach for management of this important clinical condition. Additionally, we proposed only a pathological basis, autopsy and subsequent pathological evaluation was not performed in any of the cases. On the basis of intraoperative find-

ings observed in two patients, we could describe the intermediate stage of perforation. We are aware that the number of patients is not enough to make a conclusive decision, but one must also understand the difficulty to conduct a study with enrollment of a large number of patients with cardiac perforation. Despite its retrospective nature and limitations, we believe that our experience will provide further insight into the management of patients with catheter-related right heart perforations.

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Key words: Electrodes, implanted/adverse effects; electrophysiologic techniques, cardiac/adverse effects; heart catheterization; heart injuries/etiology; pacemaker, artificial/adverse effects; pericardial effusion/etiology; wounds, penetrating/etiology.

Anahtar sözcükler: Elektrot yerleştirme/yan etki; elektrofizyolojik teknik, kardiyak/yan etki; kalp kateterizasyonu; kalp yaralanması/etyoloji; kalp pili/yan etki; perikart efüzyonu/etyoloji; yaralanma, delici/etyoloji.