Rescue Echocardiographically Guided Pericardiocentesis for Cardiac Perforation Complicating Catheter-based Procedures

The Mayo Clinic Experience

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Objectives. The purpose of this study was to determine the safety and efficacy of rescue echocardiographically guided pericardiocentesis as a primary strategy for the management of acute cardiac perforation and tamponade complicating catheter-based procedures.

Background. In this era of interventional catheterization, acute tamponade from cardiac perforation as a complication is encountered more frequently. The safety and efficacy of echocardiographically guided pericardiocentesis in this life-threatening situation and outcomes of patients managed by this technique are unknown.

Methods. Of the 960 consecutive echocardiographically guided pericardiocenteses performed at the Mayo Clinic (1979 to 1997), 92 (9.6%) were undertaken in 88 patients with acute tamponade that developed in association with a diagnostic or interventional catheter-based procedure. Most of the patients were hemodynamically unstable at the time of pericardiocentesis, with clinically overt tamponade in 40% and frank hemodynamic collapse (systolic blood pressure <60 mm Hg) in 57%. Clinical end points of interest were the success and complication rates of rescue pericardiocentesis and patient outcomes, including the need for other interventions, clinical and echocardiographic follow-up findings and survival.

Results. Rescue pericardiocentesis was successful in relieving tamponade in 91 cases (99%) and was the only and definitive therapy in 82% of the cases. Major complications (3%) included pneumothorax (n = 1), right ventricular laceration (n = 1) and intercostal vessel injury with right ventricular laceration (n = 1); all were treated successfully. Minor complications (2%) included a small pneumothorax and an instance of transient nonsustained ventricular tachycardia; all were resolved spontaneously. Further surgical intervention was performed in 16 patients (18%). No deaths resulted from the rescue pericardiocentesis procedure itself. Early death (<30 days) in this series was due to injuries from cardiac catheter-based procedures (n = 3), perioperative complications (n = 2) and underlying cardiac diseases (n = 2). Clinical or echocardiographic follow-up for a minimum of 3 months or until death (if <3 months) for recurrent effusion or development of pericardial constriction was achieved in 87 (99%) of the patients.

Conclusions. Echocardiographically guided pericardiocentesis was safe and effective for rescuing patients from tamponade and reversing hemodynamic instability complicating invasive cardiac catheter-based procedures. For most patients, this was the definitive and only therapy necessary.

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In the era of rapidly advancing technology, catheter-based diagnostic and interventional procedures are now being performed in invasive laboratories with increasing frequency (1–7). An increased incidence of catheter-related complications may be encountered (8). One potentially fatal complication is acute hemorrhagic tamponade secondary to inadvertent cardiac perforation. It is essential that this complication be promptly recognized and treated rapidly and effectively. Although echocardiographically (echo) guided pericardiocentesis has been shown to be safe and effective therapy for management of malignant effusions (9), its use for acute catheter-related perforation and tamponade has not been examined in a large series. In this situation pericardiocentesis must be performed rapidly, often under technically challenging circumstances, including smaller effusion and unstable patient hemodynamics. The purpose of this study is to assess the safety and efficacy of echo-guided pericardiocentesis as a management strategy in this acute life-threatening situation and the outcome of patients who had sustained catheter-induced cardiac perforation and tamponade managed by this technique.

Methods

Data collection. From the Mayo Clinic prospective registry of 960 consecutive echo-guided pericardiocenteses performed...
between February 1979 and November 1997, 92 procedures involving 88 patients in whom pericardial effusion had developed acutely in association with a catheter-based procedure were identified. After approval by the Institutional Review Board, a comprehensive review of the echocardiography database, hospital charts and invasive cardiac laboratory procedure logs was conducted. When necessary, follow-up data were obtained using a survey completed by patients or telephone interviews with patients and their local primary care physicians.

Data from each echo-guided pericardiocentesis procedure entered into a computer registry included patient, age, gender, physical findings, hemodynamics and echocardiographic findings. Indications, technical details, success and complications of the pericardiocentesis procedure, any surgical interventions, clinical and echocardiographic follow-up data and outcome of patients were recorded in detail.

**Procedures and techniques.** Catheter-based procedures, performed according to usual standards of practice, included diagnostic cardiac catheterization, coronary revascularization (conventional percutaneous transluminal coronary angioplasty, atherectomy, rotational and laser angioplasty), myocardial biopsy, valvuloplasty and both diagnostic and interventional electrophysiology procedures. When cardiac perforation was suspected as a complication of a catheter-based procedure, echocardiographic confirmation of the effusion followed by pericardiocentesis under echocardiographic guidance when clinically indicated was the general practice at the Mayo Medical Center. However, it is possible that a few patients were transferred from the invasive laboratory to the operating room for surgical management without echocardiographic assessment or underwent immediate pericardiocentesis without echocardiographic guidance when this was deemed necessary by the invasive laboratory physician. These patients were not included in this study.

Standard two-dimensional (2D) and Doppler echocardiography images were obtained with commercially available equipment. In emergency circumstances, a goal-directed, abbreviated study was performed to obtain essential information. All pericardiocentesis procedures were supervised by staff echocardiologists. Details of the echo-guided pericardiocentesis procedure and 2D and Doppler criteria for cardiac tamponade have been reported previously (10–15). Briefly, 2D echocardiography allowed the examiner to localize the largest collection of pericardial fluid in closest proximity to the transducer, thereby identifying the ideal entry site (16). The trajectory of the pericardiocentesis needle was defined by transducer angulation. After local infiltration with 1% lidocaine, a polytef-sheathed needle (16 to 18 gauge) was used for the initial pericardial entry. On reaching the pericardial fluid, the steel core of the needle was immediately withdrawn, leaving only the polytef sheath in the pericardial space. In the presence of hemorrhagic pericardial effusion, injection of a small volume of agitated saline as contrast was often used for echocardiographic confirmation of the sheath position. If extended pericardial catheter drainage was selected, a guidewire was introduced through the polytef sheath. The sheath was withdrawn and a standard dilator and introducer (6–7F) advanced over the guide wire. A pigtail angiographic catheter (65 cm, 6–7F) was then introduced into the pericardial space. The fluid was initially drained completely and then intermittently thereafter as clinically indicated. Close observation was maintained for persistent or recurrent drainage, which would indicate inadequate control of hemorrhage. The pericardial catheter remained in place for a variable period and was removed when the patient was completely stabilized without evidence of further intrapericardial bleeding (fluid return <25 ml over 24 h) and follow-up echocardiography showed no significant residual effusion.

**Definition.** Rescue pericardiocentesis was defined as a pericardiocentesis procedure urgently performed to restore hemodynamic stability in patients who sustained cardiac perforation and tamponade from the primary catheter-based procedure. Echocardiographic features of tamponade included 2D findings of right atrial compression during late diastole, right ventricular collapse during early diastole, dilated inferior vena cava with lack of inspiratory collapse and swinging heart. Characteristic patterns of tamponade by Doppler echocardiography included decreased left ventricular filling with inspiration leading to delay of mitral valve opening, lengthening of isovolumic relaxation time and decreased mitral E velocity. Opposite changes occurred on expiration with reciprocal findings on the right side. Inspiratory decrease and expiratory increase in pulmonary venous diastolic forward flow, as well as expiratory increase in hepatic venous diastolic flow reversal, were also characteristic. All patients underwent 2D assessments, but few had Doppler echocardiography.

Pretamponade was defined by the echocardiographic diagnosis of tamponade based on 2D criteria or Doppler criteria, or both, in the absence of overt clinical tamponade as manifested in various combinations of physical findings, such as pulsus paradoxus, tachycardia, hypotension and elevated jugular venous pressure, in the appropriate clinical context. Hemodynamic collapse was defined by the finding of systolic blood pressure <60 mm Hg.

Complications of echo-guided pericardiocentesis were considered major if interventions were required for management. Minor complications included any adverse events that occurred without requirement for any treatment beyond appropriate monitoring or follow-up.

**Clinical end points and outcomes.** Details of clinical status and echocardiographic findings were reviewed. The rescue echo-guided pericardiocentesis was evaluated for its success in fulfilling the emergency therapeutic indication and for the development of any associated complications. Patient out-
comes included the need for surgical intervention, clinical and echocardiographic follow-up findings and survival.

Statistics. Descriptive results were reported as mean ± standard deviation, median with range or as frequency percentages. The 95% confidence intervals (CI) were estimated for binomial parameters, using the exact limits from the binomial distribution.

Results

Estimated incidence of cardiac perforation. As a tertiary care referral facility, the Mayo Medical Center experienced an increase in the utilization of catheter-based procedures over the past 18 years (Fig. 1). Relative to the number of diagnostic and interventional electrophysiology procedures, diagnostic cardiac catheterizations, coronary angioplasties, myocardial biopsies and valvuloplasties totaling 95,130 procedures performed between 1979 and 1997 (Table 1), the estimated overall incidence of cardiac perforation managed by rescue echocardiographically guided pericardiocentesis, 0.08%, was very low. In this series, the highest rate of cardiac perforation and tamponade (1.9%) occurred in association with valvuloplasty, and the lowest with diagnostic catheterization (0.006%). This result is consistent with the findings of other investigators (9).

Patient characteristics and procedures performed. Eighty-eight patients (36 males, 52 females) with a mean age of 63.6 ± 21 years (median, 69.8 years; range, 1 day to 91 years) underwent 92 echo-guided pericardiocenteses (1979 to 1997) for acute cardiac perforation and tamponade that occurred in association with catheter-based procedures. The catheter-based procedures consisted of 25 (27%) electrophysiologic studies, 7 (8%) radiofrequency ablations, 11 (12%) temporary pacemaker insertions, 6 (7%) permanent pacemaker implantations, 4 (4%) diagnostic catheterizations, 11 (12%) coronary interventional procedures, 17 (18%) myocardial biopsies, 9 (10%) valvuloplasties, 1 (1%) atrial septostomy and 1 (1%) left ventricular puncture for measuring aortic valve gradient.

For 84 patients, single rescue pericardiocentesis was performed. Three patients underwent a second pericardiocentesis on the same day, and one patient had two pericardiocenteses for tamponade during radiofrequency ablation on two occasions 9 months apart.

At the time of the rescue pericardiocentesis, pretamponade without overt hemodynamic instability was identified in only three cases (3%). Clinical status was unstable in the remaining 89 cases (97%). In 52 instances (57%), patients were in frank hemodynamic collapse (systolic blood pressure < 60 mm Hg), and in 37 (40%), the patients had overt tamponade, albeit without cardiovascular collapse (Fig. 2). Cardiopulmonary resuscitation was required in 16 (17%) procedures. Protamine sulfate was administered to patients in 33 (94%) of 35 cases for reversal of heparin anticoagulation when cardiac perforation was recognized. Most pericardiocenteses (59, or 64%) were performed during or at the conclusion of the catheter-based procedure while the patient was still in the invasive laboratory. The remaining 33 (36%) were performed within 48 h of the invasive procedure, predominantly within the first 24 h (21, or 23%).

Transthoracic echocardiography confirmed a pericardial effusion in all patients of this study before initiation of the rescue pericardiocentesis. Tamponade was documented by 2D criteria in 62 (67%), by Doppler in 4 (4%) and by both in 4 (4%). For 22 (24%), definitive echocardiographic features of tamponade were not all present, although all had hemody-
namic embarrassment. The detection of a new pericardial effusion in association with hemodynamic instability after an invasive cardiac catheter-based procedure was considered sufficient impetus for urgent rescue pericardiocentesis.

Details of echo-guided pericardiocentesis procedures and pericardial catheter utilization. All echo-guided pericardiocenteses in this series were performed on an urgent basis for therapeutic indications, and the procedure was successful in 91 cases (99%; 95% CI, 94 to 100%). In two cases, no significant pericardial fluid return was obtained, although relief of tamponade was achieved rapidly by fluid decompression into the left pleural space, evident by the development of a left pleural effusion on subsequent chest radiographs. In one procedure, entry into the pericardial space could not be achieved. A single needle passage was effective in 79 procedures (86%; 95% CI, 77 to 92%). Two attempts were necessary in five procedures and more than two attempts in eight. The ideal entry site selected by 2D echocardiography was located on the chest wall in 62 (67%), and the subcostal position was identified as most suitable in only 22 (24%). The ideal entry site was not specified or documented in eight (9%) (Fig. 3). The mean hemorrhagic fluid volume withdrawn was 221 ml (range, 8 to 1,700 ml). A pericardial catheter was placed concomitantly in 53 (58%) of the procedures and remained indwelling for a mean of 2.5 days (range, 1 to 5 days). An additional mean volume of 130 ml (range, 0 to 830 ml) of fluid was aspirated before removal of the catheter.

Outcome measures. Complications of rescue pericardiocentesis. No deaths (95% CI, 0 to 4%) occurred as a result of rescue pericardiocentesis. There were three (3%; 95% CI, 0.7 to 9.2%) major complications: 1) pneumothorax requiring chest tube reexpansion, 2) intercostal vessel injury with right ventricular laceration and 3) isolated right ventricular laceration. Surgical repair was successful for the latter two complications. The two (2%; 95% CI, 0.3 to 7.6%) minor complications were a small pneumothorax conservatively treated in one patient and nonsustained ventricular tachycardia with spontaneous resolution suspected to have been provoked by the pericardiocentesis procedure in another patient.

Surgical interventions. For the 88 patients in this series, 65 had a rescue pericardiocentesis immediately in the invasive laboratory, 20 after leaving the laboratory but within 24 h, and 3 between 24 and 48 h of the catheter-based procedure. For 72 patients (82%; 95% CI, 72 to 89%), rescue pericardiocentesis was the definitive and only treatment required for the management of cardiac perforation and tamponade. No surgical intervention was necessary. The remaining 16 patients (18%; 95% CI, 11 to 28%) required surgical attention within 48 h of the initial catheter-based procedure (Table 2). Thirteen underwent surgery on the same day after immediate pericardiocentesis in the laboratory, and the other three patients who had pericardiocentesis after leaving the laboratory underwent surgery between 24 and 48 h of the catheter-based procedure. Indications for surgery included failed pericardiocentesis (1 patient), complications as a result of the pericardiocentesis procedure (2 patients) and exploration for possible repair of suspected bleeding sites or injuries introduced by the initial catheter-based procedure and evacuation of intrapericardial hematoma (13 patients). However, no significant pericardial effusion or hematoma or active bleeding sites were found intraoperatively in 2 of these 13 patients.

Clinical and echocardiographic follow-up. At least one follow-up echocardiogram was obtained before hospital dismissal in 75 instances (82%). Complete resolution of pericardial effusion was documented by echocardiography in 28 cases (30%), and a tiny residual effusion was present in 44 (48%). In the remaining three cases (3.3%), patients underwent a repeat pericardiocentesis on the same day for a moderate effusion identified on repeat echocardiography. All three did not have pericardial catheter placement with the index procedure. A pericardial catheter was placed in one of these patients during the second procedure. Resolution of the effusion was documented in all three patients before dismissal. In 87 patients (99%), subsequent follow-up, clinically or echocardiographically, for a minimum of 3 months unless death occurred, did not reveal residual pericardial effusion or development of pericardial constriction.

Survival. No deaths were associated with the rescue pericardiocentesis procedure itself. Seven deaths (8%) occurred within 30 days of the catheter-based procedure. Three of these were directly attributed to the initial injury from the catheter procedure (one each from percutaneous transluminal coronary angioplasty, electrophysiologic study and septostomy). Two deaths were related to postoperative complications and two were primarily due to underlying cardiac disease.

Discussion

The implementation of rapidly evolving and expanding catheter-based technologies over the past 2 decades has revolutionized the nonsurgical management of many cardiovascular diseases. Electrophysiologic diagnostic studies now permit accurate localization and definition of specific arrhythmical substrates, directing radiofrequency ablation for eradication of the responsible mechanism. The large increase in the number of percutaneous intracoronary revascularization procedures performed (6) has been accompanied by development of
multiple versions and variations of conventional angioplasty, such as directional and rotational atherectomy, laser angioplasty and stent implantation. One catastrophic complication that may result from these catheter-based procedures is cardiac perforation and tamponade. The incidence of this complication has increased in recent years (8). The exact frequency of such occurrences, however, is difficult to quantify. The incidence of cardiac perforation has been reported to be 1.5% to 4.7% for valvuloplasty (8,17), about 0.2% to 1% for radiofrequency ablation (18,19), 0.1% to 0.2% for electrophysiologic study (20,21), 0.5% for cardiac biopsy (7), 0.03% for coronary angioplasty (22) and 0.01% for diagnostic catheterization (8).

Recognition of cardiac perforation in the invasive laboratory. Most commonly, cardiac perforation was recognized when acute hypotension or cardiovascular collapse developed during, or immediately after, a catheter-based procedure. In some patients, this was accompanied by chest or back pain. In this series, a significant proportion of patients (17%) required cardiopulmonary resuscitation. For those with a less dramatic presentation, perforation could be inferred by confirmation of a new pericardial effusion by echocardiography, and immediate assessment of tamponade physiology could be accomplished concurrently. In this series, pericardial fluid was identified in all patients before pericardiocentesis. Diagnostic criteria for tamponade by limited echocardiography was not documented in all instances. For 24% of the cases, there were no definitive 2D echocardiographic features of tamponade reported, although hemodynamic stability was immediately restored by rescue pericardiocentesis. The finding of a new pericardial effusion in association with acute hemodynamic instability during a catheter-based procedure provided sufficient impetus for rescue pericardiocentesis.

Management strategies for cardiac perforation: safety, efficacy and patient outcome. By the study inclusion criteria, all patients in this series underwent echo-guided pericardiocentesis as the immediate treatment strategy. The procedure was successful in fulfilling the therapeutic indication and in providing rapid relief of hemodynamic embarrassment in all but one patient. The single patient for whom pericardiocentesis failed was transferred to the operating room immediately for pericardial window surgery, at which time active bleeding had already stopped and no other repair was necessary. For two patients, no significant amount of fluid was withdrawn at pericardiocentesis; however, the pericardiocentesis attempt resulted in decompression of the effusion into the pleural space, which was effective in reversing the hemodynamic instability.

Table 2. Patients Who Underwent Surgery after Rescue Pericardiocentesis for Perforation Secondary to a Catheter-based Procedure

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Catheter-based Procedure</th>
<th>Hemodynamics</th>
<th>Complication From Echo-guided Pericardiocentesis</th>
<th>Surgery Performed</th>
<th>Patient Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>F</td>
<td>Myocardial biopsy</td>
<td>Collapse</td>
<td>No</td>
<td>Exploratory thoracotomy; RV puncture spontaneously closed</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>75</td>
<td>M</td>
<td>EP study</td>
<td>Collapse</td>
<td>No</td>
<td>LV perforation, repaired</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>68</td>
<td>F</td>
<td>EP study</td>
<td>Collapse</td>
<td>No</td>
<td>Pericardial window; clot evacuation</td>
<td>Died secondary to injury from primary procedure</td>
</tr>
<tr>
<td>24</td>
<td>M</td>
<td>Myocardial biopsy</td>
<td>Collapse</td>
<td>No</td>
<td>Epicardial bleeder ligated</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>70</td>
<td>F</td>
<td>EP study</td>
<td>Collapse</td>
<td>No</td>
<td>Evacuation of clots</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>85</td>
<td>F</td>
<td>EP study</td>
<td>Collapse</td>
<td>No</td>
<td>Evacuation of clots</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>33</td>
<td>F</td>
<td>EP study, ablation</td>
<td>Collapse</td>
<td>No</td>
<td>No perforation found</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>78</td>
<td>F</td>
<td>EP study</td>
<td>Collapse</td>
<td>No</td>
<td>LV perforation, repaired</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>2 days</td>
<td>M</td>
<td>Diagnostic catheterization</td>
<td>Collapse</td>
<td>No</td>
<td>Evacuation of clots; aortic valve tear repaired</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>1 day</td>
<td>M</td>
<td>Atrial septostomy; hypoplastic left heart</td>
<td>Collapse</td>
<td>No</td>
<td>Attempted repair of atrial tear</td>
<td>Died secondary to injury from primary procedure</td>
</tr>
<tr>
<td>69</td>
<td>F</td>
<td>Diagnostic catheterization, temporary pacemaker insertion</td>
<td>Collapse</td>
<td>No</td>
<td>Exploratory performed; no perforation found</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>87</td>
<td>F</td>
<td>EP study</td>
<td>Collapse</td>
<td>Yes (RV laceration)</td>
<td>RV repair; removal of clots</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>79</td>
<td>F</td>
<td>Diagnostic catheterization</td>
<td>Collapse</td>
<td>No</td>
<td>Repair of right atrial tear</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>59</td>
<td>F</td>
<td>EP ablation</td>
<td>Collapse</td>
<td>Yes (perforated intercostal vessel and RV laceration)</td>
<td>Intercostal vessel and RV repair</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>75</td>
<td>F</td>
<td>EP ablation</td>
<td>Collapse</td>
<td>Unsuccessful pericardiocentesis</td>
<td>Pericardial window</td>
<td>Discharged alive</td>
</tr>
<tr>
<td>44</td>
<td>M</td>
<td>Pulmonary valvuloplasty</td>
<td>Collapse</td>
<td>No</td>
<td>Pulmonary valvotomy</td>
<td>Died of underlying heart disease</td>
</tr>
</tbody>
</table>

EP = electrophysiologic; F = female; LV = left ventricular; M = male; PTCA = percutaneous transluminal coronary angioplasty; RV = right ventricular.
Complications associated with echo-guided pericardiocentesis were infrequent. Most important, there were no deaths as a result of pericardiocentesis. Major complications (3%) were quickly recognized and successfully managed. Minor complications (2%) were not associated with any sequelae and did not require further intervention. These results represent a substantial improvement over the previously reported 5% to 25% incidence of major complications, including death, associated with blind subxiphoid pericardiocentesis (23,24).

Overall outcome was favorable for this group of patients despite their initial instability before rescue pericardiocentesis. Echo-guided pericardiocentesis was the only necessary intervention for the management of acute cardiac perforation in 82% of the patients in this series. All patients requiring surgical intervention were operated on within 48 h of the initial catheter-based procedure. This 48-h window was critical for close supervision of any persistent bleeding or rebleeding. Thirty-day survival was 93% for this series. No patient died from rescue pericardiocentesis. The causes of death within 30 days of the primary procedure were directly or indirectly related to the initial catheter-based procedure itself (3%), perioperative complications (2%) or the underlying cardiac disease (2%).

Limitations. This study was subject to the limitations and biases inherent in all investigations with a prospective-retrospective design. In addition, because all patients in this series were identified from the echo-guided pericardiocentesis database, it is possible that a small number of patients who sustained cardiac perforation did not have echocardiographic assessment or echo-guided pericardiocentesis and were not identified. As a result, the incidence of cardiac perforation secondary to catheter-based procedures could also be underestimated. The strengths of this study include utilization of data from the comprehensive prospective registry of consecutive echo-guided pericardiocenteses performed during the study period and the near 100% follow-up of all patients in the series.

Conclusions. Emergency rescue echo-guided pericardiocentesis is a safe, effective and readily accessible management strategy for cardiac perforation and tamponade secondary to invasive catheter-based procedures. Despite the marked hemodynamic compromise that frequently accompanies the acute injury, stabilization can be rapidly achieved with a low rate of complications. Pericardial catheter placement allows complete drainage and monitoring of further hemorrhage into the pericardial space. Rescue echo-guided pericardiocentesis is the only treatment required for the majority of these patients. Surgical exploration or intervention is indicated when complete control of the bleeding is in question or when hemodynamic stability is not rapidly restored with rescue pericardiocentesis alone. In the era of interventional catheterization, echo-guided rescue pericardiocentesis assumes a critical role in the initial management of catheter-induced cardiac perforation and tamponade.

References