Inferior Vena Cava Plethora With Blunted Respiratory Response: A Sensitive Echocardiographic Sign of Cardiac Tamponade

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To assess the diagnostic and prognostic value of the respiratory behavior of the inferior vena cava in pericardial effusions, clinical and two-dimensional echocardiographic data of 115 consecutive patients with a moderate or large effusion, including 33 who had cardiac tamponade, were reviewed. Echocardiograms were reviewed for effusion size, inferior vena cava diameter before and after deep inspiration and presence of right atrial and ventricular collapse.

For the 83 patients (72%) with <50% decrease in inferior vena cava diameter after deep inspiration ("plethora"), inferior vena cava diameter decreased from 2.0 ± 0.3 to 1.6 ± 0.4 cm after inspiration (mean ± SD) (mean decrease 18%). For the 32 patients (28%) without plethora, the diameter decreased from 1.6 ± 0.5 to 0.6 ± 0.3 cm (mean decrease 63%). Patients with plethora had significantly higher values for heart rate (111 ± 21 versus 98 ± 20 beats/min), pulsus paradoxus (24 ± 15 versus 12 ± 4 mm Hg), jugular venous distension (14 ± 5 versus 8 ± 3 cm H2O) and right atrial pressure (17 ± 6 versus 12 ± 6 mm Hg) and lower values for systolic blood pressure (109 ± 22 versus 132 ± 27 mm Hg) (all p < 0.05) than did patients without plethora. Plethora was present in 58 (92%) of 63 patients who underwent a pericardial drainage procedure, 14 (88%) of 16 who developed constrictive physiology and 11 (92%) of 12 of those whose hospital death was related to pericardial effusion. Sensitivity and specificity of echocardiographic signs for tamponade were 97% and 40% for plethora, 55% and 68% for right atrial collapse and 48% and 84% for right ventricular collapse, respectively. Plethora also had greater sensitivity than did elevated jugular venous distension on physical examination (97% versus 61%).

Thus, plethora in pericardial effusion is 1) associated with elevated right heart filling pressures; 2) more sensitive but less specific for tamponade than right heart chamber collapse or jugular venous distension; and 3) of prognostic importance.

(Echocardiography is the major clinical tool available to cardiologists for the evaluation of pericardial effusions. Although various echocardiographic signs have been proposed as markers of cardiac tamponade (1-14), right atrial and right ventricular collapse by two-dimensional echocardiography are now favored (5-14). However, reports attest-
patients, 15 were excluded because of technically inadequate cardiac or inferior vena cava imaging and 3 were excluded whose echocardiogram was obtained during positive pressure ventilation, leaving 115 patients for the study.

**Clinical features and definitions.** We reviewed the clinical records of these patients for presenting vital signs, pulsus paradoxus, jugular venous distension by physical examination, hemodynamic status, chest radiograph, cause of effusion, therapy and outcome.

Pericardial effusions were classified as surgical in origin if they were related to cardiothoracic surgery, including perioperative pericardial hemorrhage and postpericardiectomy syndrome. All other effusions were classified as medical in etiology. Malignant effusions were identified by pericardial fluid cytology, pericardial biopsy or autopsy. When patients underwent pericardial drainage, the method of pericardial drainage, amount of fluid removed and vital signs and hemodynamic measurements immediately before and after the procedure were recorded.

For patients in this study, cardiac tamponade was said to be present when either of the following two criteria were met: 1) hemodynamic: elevation (mean pressure >12 mm Hg) and equalization (≤5 mm Hg) of diastolic filling pressures by pulmonary artery catheter (right atrial, right ventricular end-diastolic, pulmonary artery diastolic and pulmonary capillary wedge pressures); or 2) relative hypotension: systolic blood pressure <100 mm Hg that increased by ≥20 mm Hg immediately after pericardial drainage.

Pericardial constriction was defined by history and physical examination (elevated jugular venous pressure and rapid "y descent," pericardial knock, hepatomegaly, edema, ascites) and echocardiography (pericardial thickening, early diastolic septal motion abnormality and "immobility" of the heart within the pericardium). Effusive-constrictive pericardial disease was defined when these findings were associated with a small to moderate pericardial effusion (15).

**Echocardiography.** Standard two-dimensional echocardiographic views (parasternal, apical and subcostal) were obtained on commercially available equipment. Whenever possible, parasternal and apical views were performed with the patients in the 90 degree left lateral decubitus position, and subcostal views were performed with the patient supine with the knees flexed. In this laboratory, subcostal imaging of the inferior vena cava is a routine part of the echocardiographic examination, especially in the setting of pericardial effusion. End-diastole was defined at the peak of the R wave of the electrocardiogram (ECG); end-systole was defined at the frame just before mitral valve opening.

**Qualitative estimates of effusion size were made as follows:** effusions that demonstrated circumventricular pericardial fluid that did not permit contact between the visceral and parietal pericardial layers in any view were judged to be of moderate size. Effusions that extended beyond the viewing screen, preventing the visualization of both the visceral and parietal pericardial layers in certain views, were judged to be large.

Studies were reviewed for the presence of right atrial and right ventricular diastolic collapse and pericardial loculations. Right atrial collapse was defined as dynamic inversion of the anterosuperior right atrial wall that occurred during late diastole or early systole and varied with respiration. Right ventricular collapse was defined as early diastolic inversion of the right ventricular free wall that varied with respiration. Pericardial loculations were defined by the presence of pericardial fluid localized in discrete compartments or by adhesions from the parietal to the visceral pericardium (Fig. 1).

Plethora of the inferior vena cava ("plethora") was defined as a decrease in proximal vena cava diameter by <50% after deep inspiration or a "sniff." With the use of the trailing edge to leading edge technique, maximal inferior vena cava diameter before inspiration and minimal diameter after inspiration were measured in the subcostal view within the first 2 cm of the entrance to the right atrium (Fig. 2). The vena cava was differentiated from the descending aorta in the subcostal view by its right-sided location and lack of systolic pulsations. The "caval respiratory index" was defined as the percentage decrease in inferior vena cava diameter after inspiration or sniff (Figs. 2 and 3). The caval respiratory index was previously correlated with direct measurement of central venous pressure by flotation catheterization in 89 patients (r = 0.73, p < 0.001, unpublished data).

Two independent readers reviewed the echocardiograms...
Figure 2. Subcostal view in a patient with a large pericardial effusion and plethora of the inferior vena cava. The diameter of the vena cava was 22 mm (A, measured at the arrows) and decreased to 18 mm after deep inspiration (B) for a caval respiratory index of 18% for the presence of right atrial collapse and right ventricular collapse. They also measured inferior vena cava diameter and caval respiratory indexes before and after pericardial drainage or other therapeutic interventions; results of these measurements were averaged for the two readers. When the readers disagreed over the presence of right atrial or ventricular collapse, the opinion of a third reader was sought.

Statistics. Data were evaluated by chi-square analysis, factorial analysis of variance and linear regression analysis. Numbers are listed as mean ± SD. Sensitivity and specificity of clinical and echocardiographic findings for cardiac tamponade were defined in standard fashion (16). For the caval respiratory index, interobserver variability was defined as the average percent difference in indexes between the two readers. The null hypothesis was rejected at the 5% level.

Results

Demographics and etiology. Of the 115 patients in the study, 58 were male and 57 female; the mean age was 53 years. The causes of pericardial effusion were as follows: cardiac surgery in 37 patients (32%), malignancy in 35 (30%), end-stage renal failure in 14 (12%), viral pericarditis in 5 (4%) and other causes in 24 (21%), including unknown origin in 5, perforation due to pacemaker or central venous catheter insertion in 3, endocarditis in 2, mediastinitis in 2, myocardial infarction in 2, purulent pericarditis in 2, trauma in 2 and aortic dissection, carcinoid heart disease, collagen-vascular disease, myxedema, pancreatitis and preeclampsia in 1 patient each.

The 35 patients with a malignant effusion had the following primary tumors: lung tumor in 12 (34%), lymphoma in 5 (14%), breast tumor in 4 (11%), adenocarcinoma of unknown primary site in 3 (9%), leukemia in 2 (6%), melanoma in 2, ovarian tumor in 2 and other tumor in 5 (14%). Of the 37 patients whose pericardial effusion was due to cardiac surgery, the responsible surgical procedures included aortic valve replacement in 16 (43%), coronary artery bypass grafting in 11 (30%), mitral valve replacement in 9 (24%) and ablation of atrioventricular bypass tract in 1 (3%). Of these 37 effusions in cardiac surgery patients, 7 (19%) were associated with the postpericardiotomy syndrome and the rest with perioperative intrapericardial hemorrhage.
Vital signs and hemodynamics. For all 115 study patients, heart rate was 107 ± 21 (mean ± SD), systolic blood pressure 116 ± 25 mm Hg, diastolic blood pressure 72 ± 14 mm Hg, pulsus paradoxus 22 ± 14 mm Hg and jugular venous pressure 13 ± 5 mm Hg. Of the 115 pericardial effusions, 60 (52%) were estimated by two-dimensional echocardiography to be large and 55 (48%) moderate in size. Chest radiography revealed an enlarged cardiac silhouette in 74 patients (64%).

Invasive hemodynamic evaluation was performed in 32 patients (28%); 20 demonstrated elevation and equalization of diastolic filling pressures. Twenty-five patients (21%) developed relative hypotension, having a minimal systolic blood pressure of <100 mm Hg that increased by >20 mm Hg after pericardial drainage. Overall, 33 patients (29%) met criteria for cardiac tamponade. Comparison of clinical, hemodynamic and echocardiographic data in patients with and without cardiac tamponade is shown in Table 1.

Therapy and outcome. Pericardial drainage procedures were performed in 63 patients (55%); open surgical drainage in 47 (41%), pericardiocentesis in 31 (27%) and both in 15 (13%). Four patients who had a malignant effusion underwent tetracycline sclerosis. The average amount of pericardial fluid drained was 812 ± 484 ml (range 150 to 2135). Pericardial fluid was drained for therapy of known cardiac tamponade in 31 patients (2 with diagnosed tamponade refused drainage), for relief of symptoms in 24 patients without proven tamponade and for purely diagnostic purposes in 8.

Seventeen patients (15%) either presented with effusive-constrictive pericarditis or developed effusive-constrictive or constrictive pericardial disease during the follow-up period. In 12 patients (10%), pericardial effusion was a factor contributing to death during the hospitalization. Causes of death in these 12 patients included malignant cardiac tamponade associated with cardiopulmonary arrest in 5 patients, pericardial hemorrhage after cardiac surgery requiring open drainage in 4, aortic dissection with cardiac tamponade in 1, purulent pericarditis associated with bacterial sepsis in 1 and right ventricular laceration secondary to pericardiocentesis in 1.

Echocardiographic signs. Plethora was noted in 83 patients (72%), right atrial collapse in 46 (40%) and right ventricular collapse in 42 (37%). In the 83 patients who had plethora, inferior vena cava diameter decreased from 2.0 ± 0.3 to 1.6 ± 0.4 cm after inspiration, showing a mean caval

| Table 1. Clinical, Hemodynamic, Radiographic and Echocardiographic Data on 115 Patients With a Moderate or Large Pericardial Effusion |
|---------------------------------------------------------------|----------------|--|----------------|----------------|
| No. of patients                                             | Tamponade | No Tamponade | Plethora | No Plethora |
| Vital signs                                                 |           |              |         |            |
| Heart rate (beats/min)                                      | 117 ± 25  | 103 ± 18     | 111 ± 21| 98 ± 20†   |
| SBP (mm Hg)                                                 | 90 ± 16   | 125 ± 21     | 109 ± 22| 132 ± 27†  |
| Pulsus paradoxus (mm Hg)                                    | 28 ± 9    | 18 ± 8       | 22 ± 15 | 18 ± 4‡    |
| JVD (cm H₂O)                                                | 16 ± 4    | 12 ± 5       | 14 ± 5  | 10 ± 3†    |
| Hemodynamics                                               |           |              |         |            |
| RAP (mm Hg)                                                 | 18 ± 5    | 12 ± 8       | 17 ± 6  | 12 ± 6†    |
| PAD (mm Hg)                                                 | 20 ± 6    | 17 ± 6       | 19 ± 6  | 19 ± 6     |
| PCWP (mm Hg)                                                | 20 ± 6    | 19 ± 8       | 20 ± 7  | 22 ± 5     |
| Diast equal (patients)                                      | 20        | 0*           | 19      | 1†         |
| Chest radiograph                                            |           |              |         |            |
| Cardiomegaly (patients)                                     | 23        | 51           | 61      | 13‡        |
| Two-dimensional echocardiography                            |           |              |         |            |
| Large effusion (patients)                                   | 22        | 38           | 52      | 8†         |
| RAC (patients)                                              | 18        | 28           | 41      | 5†         |
| RVC (patients)                                              | 16        | 26           | 38      | 4‡         |
| Resp cav index (%)                                          | 16 ± 15   | 33 ± 23      | 18 ± 12 | 63 ± 14‡   |
| Therapy                                                    |           |              |         |            |
| Drainage of eff.                                            | 31        | 32*          | 58      | 5†         |
| Outcome (patients)                                          |           |              |         |            |
| Constr/eff-constr                                          | 7         | 10           | 15      | 2          |
| Death due to Eff.                                           | 8         | 3*           | 11      | 1          |

*p < 0.05 vs. patients with cardiac tamponade; †p < 0.05 vs. patients with plethora. Constr = pericardial constriction; Diast equal = diastolic equalization of ventricular filling pressures; Eff = pericardial effusion; eff-constr = effusive-constrictive pericardial disease; JVD = jugular venous distention; PAD = pulmonary artery diastolic pressure; PCWP = pulmonary capillary wedge pressure; Plethora = blunted response of inferior vena cava to respiration; RAC = right atrial collapse; RAP = right atrial pressure; Resp cav index = respiratory caval index; RVC = right ventricular collapse; SBP = systolic blood pressure.
respiratory index of 18 ± 12%; in the 32 patients without plethora, diameter decreased from 1.6 ± 0.5 to 0.6 ± 0.3 cm, showing an index of 63 ± 14%. For the caval respiratory index, interobserver variability was 8%. The caval respiratory index had a modest correlation with jugular venous distension (r = -0.55, p < 0.01) and with right atrial pressure (r = -0.43, p < 0.05).

Right atrial diastolic collapse was noted most commonly in the apical four chamber view, whereas right ventricular diastolic collapse was noted most commonly in the parasternal views. The two readers disagreed in 5 cases over the presence of right atrial collapse and in 4 over right ventricular collapse. Pericardial loculations were noted in 26 effusions (23%).

Compared with the 32 patients with a responsive vena cava (no plethora), the 83 patients with plethora had significantly higher values for heart rate, jugular venous distension, right atrial pressure and pulsus paradoxus and lower values for systolic blood pressure (Table 1). In addition, patients with plethora more often had cardiomegaly by chest radiography, large effusions by echocardiography, right atrial and right ventricular collapse and pericardial drainage procedures (Table 1). Although pericardial effusions in patients with plethora led to constrictive or effusive-constrictive disease or death more often than in patients without plethora, these differences were not significant (Table 1).

In addition to pericardial disease, other diagnoses associated with elevated central venous pressure in this study included right ventricular failure due to left ventricular dysfunction in nine patients, pulmonary hypertension in six, moderate to severe tricuspid insufficiency in five and right ventricular myocardial infarction in one.

Resolution of echocardiographic signs. Of the 63 patients who underwent pericardial drainage, 34 (54%) had a follow-up echocardiogram within 48 h. In this group, the caval respiratory index increased from 22 ± 15 to 57 ± 26% after drainage (p < 0.001). After pericardial drainage, resolution of plethora occurred in 21 (70%) of 30 patients (Fig. 4), right atrial diastolic collapse in 18 (90%) of 20, and right ventricular diastolic collapse in 17 (94%) of 18. Of the nine patients who did not demonstrate resolution of plethora after pericardial drainage, four had effusive-constrictive pericarditis. Of 13 other study patients who developed effusive-constrictive or constrictive pericardial disease over the ensuing days to weeks, repeat echocardiography revealed plethora at that time in 10 patients.

Sensitivity and specificity for cardiac tamponade (Table 2). Plethora was by far the most sensitive (97%) but least specific (40%) echocardiographic sign of cardiac tamponade. Right atrial collapse was intermediate in both sensitivity (55%) and specificity (68%), and right ventricular collapse was the least sensitive (48%) but most specific (84%) sign. The combination of right atrial and ventricular collapse increased sensitivity at the expense of specificity. In comparison, the presence of jugular venous distension >10 cm H2O was 61% sensitive and 74% specific for cardiac tamponade. For pulsus paradoxus >10 mm Hg, these values were 67% and 69%, respectively.

Medical versus surgical effusions. Tamponade was present in 21 (27%) of 78 patients who had a medical cause of effusion and 12 (32%) of 37 who had a surgical cause. Plethora had the highest sensitivity for tamponade in both groups; right-sided chamber collapse was more sensitive in medical than in surgical patients (Table 2). Of the 26 localized pericardial effusions in the study, 16 were in the surgical group versus 10 in the medical group (p < 0.01). Six of 11 patients with surgical tamponade versus 2 of 21 with medical tamponade had loculations (p < 0.05).

Discussion

Previous investigations. Although the role of echocardiography in the diagnosis and quantitation of pericardial effusion is well established (17,18), the determination of the hemodynamic significance of an effusion by echocardiography remains problematic. Previous studies using M-mode

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Abbreviations as in Table 1.
echocardiography have indicated a number of findings in patients who have cardiac tamponade, including reciprocal respiratory variation in right and left ventricular size (1), inspiratory reductions in mitral D-E excursion and E-F slope (2), systolic notching of the right ventricular wall (3,4) and right ventricular expiratory end-diastolic compression (5). None of these echocardiographic signs has proven to be optimally sensitive or specific in the diagnosis of cardiac tamponade.

With the advent of two-dimensional echocardiography, dynamic collapse and inversion of the right atrial and right ventricular free walls have become the favored signposts of tamponade (6-14). In experimental studies (9,11) where graded acute cardiac tamponade is induced by saline infusion by way of a pericardial catheter, these signs correlate with hemodynamically significant effusions. Although in most clinical studies (6,7,13,14) right atrial and right ventricular collapse have been found to be early indicators of tamponade, cardiac tamponade has not always been clearly defined, small numbers of patients have been studied and pericardial effusions related to cardiothoracic surgery have not been included.

**Plethora versus right chamber collapse in cardiac tamponade.** In our 115 study patients with a moderate or large pericardial effusion, we found that plethora was often the first echocardiographic sign to appear during the course of tamponade and the last to resolve after pericardial drainage. This sign was defined as a decrease in inferior vena cava diameter by <50% after deep inspiration or sniff. Compared with the patients who had a responsive inferior vena cava, those with plethora had a higher heart rate, lower systolic blood pressure, larger pericardial effusion and more severe hemodynamic abnormalities (Table 1). As an echocardiographic marker of cardiac tamponade, plethora was far more sensitive but less specific than right-sided chamber collapse (Table 2).

The number of patients with right atrial or right ventricular diastolic collapse and plethora exceeded the number with cardiac tamponade. Because a pulmonary artery flotation catheter was not placed in all patients, our definition of cardiac tamponade may have excluded some patients with systolic blood pressures >100 mm Hg who would have demonstrated elevation and equalization of diastolic filling pressures by catheter. However, it is more likely that the two-dimensional echocardiographic signs evaluated in this study can be present in patients with a moderate or large effusion who do not manifest hypotension or hemodynamic criteria of tamponade. As noted earlier, right chamber collapse has been reported to be a marker of "early" or "incipient" tamponade (3,6-14); our data suggest that plethora may also be a sensitive early sign of a hemodynamically significant pericardial effusion.

**Echocardiography in cardiac surgery patients.** Compared with plethora, right-sided chamber collapse was a less sensitive marker for tamponade, especially in surgical patients. Several factors may contribute to this lack of sensitivity in cardiac surgery patients. First, pericardial loculations were far more prevalent in surgical than medical patients. Loculations have previously been reported (19) to develop commonly after pericardiotomy; in animal models (20), the combination of mild serosal injury and spilled blood consistently leads to the formation of extensive postoperative pericardial adhesions within days to weeks. When adhesions form around the right atrium and ventricle, these chambers may no longer collapse, despite hemodynamic evidence of cardiac tamponade.

Second, right heart chamber diastolic collapse did not develop at the time of cardiac tamponade in three patients who underwent mitral valve replacement for severe mitral stenosis associated with pulmonary hypertension. Because of elevated right heart intracavitary pressures and decreased wall compliance, the right atrium and ventricle are known to be relatively resistant to collapse in the setting of right ventricular hypertrophy or pulmonary hypertension (7,9,21).

Third, technical problems with imaging are often troublesome in surgical patients. After cardiothoracic surgery, it may be difficult to obtain high quality parasternal or apical views because of the presence of mediastinal blood and air, chest bandages, drainage tubes, mechanical ventilation and decreased patient mobility. Because chamber inversion is often seen in only one view (11), this can significantly limit the usefulness of the test. Right ventricular collapse has been previously reported to be most prominent in the short-axis view through the right ventricular outflow tract, where the free wall is most compressible (10). In this study, collapse of the right ventricle could be appreciated in the parasternal views, whereas collapse of the right atrium could be seen in the apical four chamber view. In contrast, the inferior vena cava was imaged and measured in the subcostal view.

**Specificity of plethora.** Many patients in this study with a moderate or large pericardial effusion had abnormally elevated central venous pressures but did not meet the criteria for cardiac tamponade. For example, of the patients without cardiac tamponade, mean right atrial pressure was 12 mm Hg and mean jugular venous distension 12 cm H2O (Table 1). Although plethora is usually present when right atrial pressure is >10 mm Hg, the respiratory caval index does not reliably distinguish between moderately and severely elevated levels of central venous pressure (unpublished data). This difficulty may help contribute to the low specificity of plethora for cardiac tamponade.

**Other false positive criteria for plethora included right ventricular failure (secondary to left ventricular dysfunction, right ventricular myocardial infarction, pulmonary hypertension or tricuspid insufficiency) and inability to inspire deeply because of decreased mentation, respiratory muscle weakness, severe breathlessness or pleuritic chest pain. Subsequently, we have found that the latter problem can occasion-
ally be alleviated by having patients “sniff” while the inferior vena cava is imaged. Although we did not quantitate the degree of respiratory effort, in cooperative patients a hand-held manometer can be utilized to measure the force of graded, sustained inspirations (22). Positive pressure ventilation causes dilation of the inferior vena cava; thus patients who were mechanically ventilated during the echocardiogram were excluded from the study.

Because plethora is a nonspecific marker of elevated central venous pressure, this sign should be applied in an appropriate clinical setting (that is, the presence of a moderate or large pericardial effusion without right ventricular failure). However, the caval respiratory index may be most useful to exclude cardiac tamponade because the absence of this sensitive echocardiographic sign effectively rules out a hemodynamically significant effusion that requires immediate pericardial drainage.

Prognostic and therapeutic value of plethora. In addition to its sensitivity as a marker of cardiac tamponade, plethora was of prognostic and therapeutic value. Pletora was present in 92% of patients who underwent a pericardial drainage procedure, 88% of those who developed constric­tive physiology and 92% of those whose hospital death was related to pericardial effusion (Table 1). The development of pericardial constriction during the resolution phase of effusive pericarditis or after cardiac surgery has been previously reported (23,24). In our experience, the persistence or recurrence of plethora after pericardiocentesis suggests pericardial constriction, effusive-constrictive disease or a hemodynamically significant residual effusion.

Mechanisms for echocardiographic markers of tamponade. Collapse of right-sided heart chambers occurs when intrapericardial pressures transiently exceed intracardiac pressures in early diastole (11,12). Because of the greater compliance of the right atrial wall, the right atrium usually collapses before the right ventricle in the course of cardiac tamponade, (6,13,14). However, when cardiac tamponade develops in the setting of chronic pulmonary hypertension, right heart diastolic collapse may not occur because intrapericardial pressures must rise sufficiently to overcome the effects of elevated right heart intracavitary pressures and decreased right atrial and ventricular compliance. Likewise, in the setting of pericardial adhesions or loculations, right heart collapse may not occur because of a “tethering effect” (Fig. 1).

The wall of the inferior vena cava is even thinner and more compliant than that of the right atrium; thus, changes in the diameter of this structure with inspiration closely reflect changes in right ventricular filling pressure (22,25,26). In this study, patients with plethora had significantly higher jugular venous and right atrial pressures than did patients with a responsive inferior vena cava (Table 1). In the normal patient, the development of negative intrapleural pressure with inspiration creates a pressure gradient between the abdominal inferior vena cava and the right atrium, which promotes collapse of the inferior vena cava as blood rapidly moves into the right atrium (27–29). In the patient who has early tamponade, elevation of pericardial pressure inhibits right ventricular filling, preventing the collapse of the inferior vena cava. Because plethora can occur when pericardial pressure exceeds the transdiaphragmatic pressure gradient but is still below right heart filling pressures, this sign often develops before right-sided chamber collapse.

Caval respiratory index versus other indexes of right atrial pressure. In this study, the correlations between caval respiratory index and jugular venous pressure or right atrial pressure were modest. Although the determination of jugular venous pressure is valuable in the clinical assessment of cardiac tamponade, this assessment may be inaccurate or impossible in critically ill patients (30). In this study, plethora had greater sensitivity than elevated jugular venous pressure for the detection of tamponade, perhaps in part owing to the difficulties encountered in the physical examination of tachypneic, edematous, hypotensive or postoperative patients.

The correlation of caval respiratory index with right atrial pressure in this study could possibly have been improved by performing sonospirometry (22) or including patients with low or normal right atrial pressure (25). We have previously evaluated critically ill patients with a wide range of right atrial pressures (0 to 35 mm Hg); the coefficient of correlation between the caval respiratory index and right atrial pressure measured by flotation catheter was 0.73 (unpublished data). For a caval respiratory index <50%, the predictive value for a right atrial pressure $\geq 10$ mm Hg was 87%; for an index $\geq 50\%$, the predictive value for a right atrial pressure $<10$ mm Hg was 82%.

Recommendations. On the basis of results of two-dimensional echocardiography, the following scheme describes our initial clinical approach to patients who have a moderate or large pericardial effusion:

1) Plethora absent (medical or surgical): Because plethora is a sensitive sign for a hemodynamically significant pericardial effusion in surgical or medical patients, those who lack this sign have a low probability of tamponade and do not require pericardial drainage at this time.

2) Plethora present (medical): Because plethora is not specific for tamponade, pericardial drainage in medical patients is not justified without confirmatory echocardiographic findings, such as right atrial or ventricular diastolic collapse.

3) Plethora present (surgical): Because of the presence of pericardial loculations, pulmonary hypertension and technical difficulties with imaging, right atrial and ventricular collapse are often lacking in surgical patients with cardiac tamponade. In this setting, hemodynamic data may be necessary to confirm the presence of cardiac tamponade before pericardial drainage is attempted.
We are indebted to the technicians and cardiology fellows in the echocardiography laboratory, who performed the majority of the studies.

References


