Constrictive pericarditis, still a diagnostic challenge: comprehensive review of clinical management

Markus Schwefer\textsuperscript{a}, Rene Aschenbach\textsuperscript{b}, Jan Heidemann\textsuperscript{c}, Celia Mey\textsuperscript{a}, Harald Lapp\textsuperscript{a,*}

\textsuperscript{a} Helios Klinikum Erfurt, Department of Cardiology, Nordhaeuser Straße 74, D-99089 Erfurt, Germany
\textsuperscript{b} Helios Klinikum Erfurt, Department of Radiology, Nordhaeuser Straße 74, D-99089 Erfurt, Germany
\textsuperscript{c} Department of Medicine B, University of Muenster, Albert-Schweitzer Straße 33, D-48149 Muenster, Germany

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Summary

The diagnosis of constrictive pericarditis (CP) continues to be a challenge in the modern era. Understanding the pathophysiology and integrating the results of invasive and non-invasive techniques are important in the differential diagnosis of CP and e.g. restrictive cardiomyopathy. New echocardiographic techniques such as tissue Doppler imaging (TDI) and 2D-speckle tracking, dual-source CT (computed tomographic imaging) and especially tagged cine-MRI (magnetic resonance imaging) with the analysis of phase contrast angiography sequences are promising novel approaches. Pericardiectomy in experienced centers with complete decortication (if technically feasible) is the treatment of choice for CP and it results in symptomatic relief in most patients. However, some patients may not benefit from pericardiectomy and this may be due to myocardial compliance abnormalities, myocardial atrophy after prolonged constriction, residual constriction or other myocardial processes. An important predictor of long-term outcome after pericardiectomy is the etiology of the pericardial disease. The overall mortality in the current literature is nearly 5—6%. Survival with post-surgical CP is worse than with idiopathic CP, but significantly better than with post-radiation CP.

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1. Introduction

Constrictive pericarditis (CP) is defined as impedance to diastolic filling caused by a fibrotic pericardium [1]. The normal pericardium is a thin sac consisting of fibroelastic tissue and contains a small amount of fluid. If larger amounts of fluid accumulate between the epicardium and pericardium (pericardial effusion), a pericardial compressive syndrome (cardiac tamponade) may occur as an acute or chronic process. Cardiac tamponade may be generalized or regional. When the visceral and the parietal pericardial layers become adherent, symmetric CP may result as a consequence of scar formation and loss of elasticity of the tissue. In some cases, the constricting process arises solely from the visceral pericardium (epicardium) [1—4]. Localized variants of constriction may occur as areas or bands of constriction [5,6]. If the constricting process is limited to the right or left ventricle, ventricular interdependence (see below) can be reduced or absent [7]. Hancock described variant forms of CP with the effusive CP, the occult CP, the localized CP and the transient CP [7]. The term effusive CP is used in cases of CP by the visceral pericardium with a tense and sometimes localized pericardial effusion [4,7,8]. The recent development of novel non-invasive imaging techniques will likely be of substantial help in the differential diagnosis of CP and, for example, restrictive cardiomyopathy.

2. Discussion

2.1. History

Pericardial diseases have been acknowledged and described for a long time [1,9—11]: Avenzoar (1113—1162) described serofibrinous pericarditis. Lancisi (1654—1720) noted the clinical consequence of pericardial adhesions. In 1669, Richard Lower described a patient with dyspnea and intermittent pulse. In 1873, Kussmaul coined the term ‘pulsus paradoxus’. In 1896, the concept of Pick’s disease was introduced, which represents patients with CP who had concomitant ascites and hepatomegaly (‘pseudo cirrhosis’). In 1982, Isner et al. demonstrated the value of computed tomography in diagnosing CP [12].
2.2. Etiology

At present, idiopathic or viral pericarditis is the predominant cause in the Western world, followed by cardiac surgery and mediastinal irradiation which are as well major and increasing causes of CP in the developed world [11, 13—15]. Tuberculosis is still a common cause of CP in developing and underdeveloped countries, as well as in immunosuppressed patients [11]. The frequency of causes will be discussed in the different series below (Table 1).

2.3. Clinical characteristics

In a series of 135 patients with CP confirmed at surgery or autopsy and evaluated at the Mayo Clinic from 1985 to 1995 the predominant clinical presentation was chronic heart failure in 90 patients (67%) [13]. Eleven patients stated to have chest pain (8%), 8 had abdominal symptoms (6%), 7 patients showed cardiac tamponade (5%), atrial arrhythmia was found in 6 patients (4%), and frank liver disease in 5 patients (4%). The initial presentation of the other eight patients included postoperative low output, recurrent pleura effusion, transient ischemic attack, and syncope. The median duration of symptoms before pericardiectomy was 11.7 months (range, 3 days—29.1 years). Patients with an indeterminate cause of CP were characterized by chronicity of symptoms (mean, 17.4 months). Finally, the combination of common symptoms in cases of severe CP like ascites (50 patients, 37% [13]; 72 patients, 44% [15]), hepatomegaly (71 patients, 53% [13]; 101 patients, 62% [15]), pleural effusion (47 patients, 35% [13]; 77 patients, 47% [15]), and peripheral edema (103 patients, 76% [13]; 122 patients, 75% [15]) often leads to the misdiagnosis of chronic liver disease. In these patients with cirrhosis the jugular venous pressure is generally normal or quite less (with exception of the patients with tense ascites) than in patients with CP, where the elevated jugular venous pressure is a frequent clinical characteristic (119 patients, 93% [13]; 120 patients, 74% [15]).

2.4. Pathophysiology

The normal pericardium can accommodate physiologic changes in cardiac volume. In CP, the pericardium is scarred and inelastic and total cardiac volume cannot change. Hence, one of the most important pathophysiological findings in case of CP is the lack of transmission of respiratory changes in intrathoracic pressure to the heart chambers. As a result, the venous return to the right heart during inspiration does not increase. The absence of an inspiratory decline of jugular pressure leads to an enhanced central venous pressure and the Kussmaul’s sign, which will be discussed. At this time the pulmonary venous pressure falls with inspiration but not the pressure in the left heart chambers (lack of transmission). Subsequently, a reduction of the left ventricular filling during inspiration follows resulting in reduced left ventricular volume. Because of ventricular interdependence, a typical characteristic of CP, the right ventricle now expands (with ventricular septal shift towards the left ventricle during inspiration) but the total cardiac volume does not change [16]. As another result, the usually uninhibited expansion of the heart chambers during diastole is limited by the thickened and rigid fibrotic pericardial sac with an impeded atrial contribution to mid- and late diastolic filling, while the early diastolic filling at first is unimpeded. The predominant ventricular filling will fall in the first third of diastole. This phenomenon is caused by a rapid and abrupt stop of filling of the heart chambers in the mid- and late diastole when the fixed and stiffened pericardial sac cannot stretch any further. This leads to the hemodynamic signs of dip (the rapid ‘y’- descent in the jugular venous pressure) and plateau during right heart catheterization. This phenomenon is called square root sign. As a consequence of these limitations, there is a diastolic equalization of pressures in the right atrium, right ventricle, and pulmonary wedge pressure, which corresponds to the left heart diastolic pressure (Fig. 1) [1, 7, 10, 11, 16]. Kussmaul’s sign refers to an absence of an inspiratory abatement in jugular pressure. The mechanism...
was often debated. As one explanation, the stiff and inelastic pericardium cannot transmit intrathoracic pressure variations to the cardiac chambers and the increased inspiratory venous return leads to an enhanced central venous pressure because CP does not allow for right atrial expansion during inspiration [1,17]. Another hypothesis is a normal inspiratory increase of intra-abdominal pressure transmitted to a tense overly filled venous system caused by CP [1,18]. This sign was noted in 21% of patients in the Mayo Clinic series [13] and in 13% of patients in the Stanford series [14]. However, Kussmaul’s sign is not specific for CP and may be observed in any condition with elevated right-sided pressures like restrictive cardiomyopathy and tricuspid stenosis for example [11]. Pulsus paradoxus is defined as a decline of the systolic arterial pulse pressure during inspiration greater than 10 mmHg. It was noted in 19% of patients in the Mayo Clinic series [13] and in 16% of patients in the Stanford series [14]. Cases of CP without pulsus paradoxus have been explained by the stiff pericardium isolating the heart from the effects of respiration [1,9]. A pericardial knock (i.e. a third heart sound, often referred to as a rapid filling sound) was observed in 47% of patients in the Mayo Clinic series, while 16% of patients had a pericardial rub [13]. In the Stanford series, only 5% had a pericardial knock and 4% a pericardial rub [14]. As another pericardial compressive syndrome cardiac tamponade has to be discussed. A typical characteristic is the accumulation of pericardial fluid under pressure, which can be acute or chronic. Common pathophysiologic features of CP and cardiac tamponade are enhanced ventricular interaction, likewise elevated central venous, pulmonary venous and ventricular diastolic pressures, the pulsus paradoxus, and diastolic dysfunction. A typical distinctive pathophysiologic feature is the inconstant equalization of right atrial, pulmonary venous and ventricular diastolic pressures throughout the respiratory cycle in case of CP because pulmonary venous pressure falls with inspiration and right atrial pressure does not. Another difference is the obliterated pericardial space in case of CP without any transmission of respiratory variation in intrathoracic pressure through the fluid to the heart in contrast to cardiac tamponade. At length, in cardiac tamponade the systemic venous return increases and enlarges the right heart during inspiration with transfer to the left, in CP the systemic venous return does not increase with inspiration. Finally, the particular case of effusive CP should be mentioned. In this setting, there is a combination of constrictive physiology with a coexisting pericardial effusion and signs of tamponade. Hancock gave us a clearer view of effusive CP [4]. The diagnosis often becomes apparent after pericardiocentesis when elevation of right atrium and pulmonary wedge pressure persists. Non-invasive imaging is not useful in diagnosing effusive CP because the visceral layer of pericardium, which is responsible for constriction in this case typically is too thin to be detected. Thus, if surgery is required, a difficult visceral pericardiectomy must be performed in experienced centers [4].

2.5. Echocardiography

Standard echocardiography can provide important information for the diagnosis of CP and for its differentiation from restrictive cardiomyopathy and should be the initial used non-invasive imaging modality. Hancock described three basic signs [7]. Septal notch denotes a sudden shift in position of the ventricular septum caused by an asymmetry of right and left ventricular filling and therefore by the rapid changes in the pressure differential between the right and left ventricle. Another aspect is the ventricular septal shift with respiration, best seen in two-dimensional echocardiography as described by Nishimura [16] and Himelman et al. [19]. Because of the fixed total volume of the heart chambers in case of CP, increased volume of one ventricle is usually associated with a corresponding decreased volume of the other ventricle. The ventricular septum moves towards the left ventricle with inspiration and towards the right ventricle in expiration. These reciprocal changes in left and right ventricular volumes with respiration are an important aspect of ventricular interdependence as a characteristic of CP. A third sign is a moderate bialtrial enlargement, whereas severe enlargement is more compatible with restrictive cardiomyopathy. D’Cruz et al. discussed the abnormal left ventricular-left atrial posterior wall contour as a characteristic sign in two-dimensional echocardiography in CP [20]. The pericardial thickness is a further parameter to differentiate between CP and restrictive cardiomyopathy. The measurement of pericardial thickness by transthoracic echocardiography (TEE) correlates well with that in chest CT [21]. A total of 143 patients with surgically confirmed constriction underwent pericardiectomy at the Mayo Clinic between 1993 and 1999, 138 of whom underwent transthoracic echocardiography pre-surgery. Increased pericardial thickness was seen in 37%, abnormal septal motion in 49%, and atrial enlargement in 61% of patients. Eighteen percent of patients had normal pericardial thickness in spite of surgically and histopathologically proven CP, confirming that CP can occur in patients with normal pericardial thickness and that pericardectomy should not be denied on the basis of normal pericardial thickness when all other features indicate constriction [22].

Doppler echocardiography is important for the diagnosis of CP and helps to distinguish between CP and restrictive cardiomyopathy. In CP the variation of early diastolic filling velocity of the two ventricles is reciprocal with respiration. Further, the tricuspid velocity increases in inspiration and the mitral velocity decreases [7,11,16]. This phenomenon represents the enhanced ventricular interaction, which is
an important pathophysiologic feature in CP and is not present in both normal subjects and cases of restrictive cardiomyopathy [7,11,16,23]. In patients with high arterial pressure, the increased respiratory variation of mitral inflow sometimes can be unmasked by preload reduction with head up tilt or administration of diuretics [24]. Numerous Doppler methods exist to aid in the diagnosis of CP [7,23,25,26]. Hancock described a sensitivity and specificity of the Doppler respiratory method between 85% and 90% in experienced hands [7]. The overall sensitivity and specificity for diagnosing CP using tissue Doppler imaging (TDI) incrementally with M-mode, 2D and transmitral flow Doppler by Sengupta et al. is nearly 88.8% and 94.8% [11]. TDI shows a prominent Ea-wave (peak early velocity of longitudinal axis expansion) in CP. In case of restrictive cardiomyopathy, the transmitral E-wave is tall and narrow but the tissue Ea-wave is significantly lower than in patients with CP [25] (Fig. 2). Furthermore, the transmitral flow velocity to mitral annular velocity ratio is inversely proportional to pulmonary capillary wedge pressure in case of CP [27]. The respiratory changes in the transmitral flow velocity curve can aid in the differentiation of CP from restrictive cardiomyopathy [7,11,16,23,26]. However, respiratory variation in transmitral flow velocity can also be observed in patients with chronic obstructive airway disease [28,29]. Furthermore, a considerable proportion of patients with CP will not demonstrate respiratory variation of mitral inflow velocity [23,29]. In these cases, 2D-speckle tracking to detect longitudinal and circumferential myocardial deformation is a useful modality to distinguish constrictive from restrictive pathophysiology [11].

### 2.6. Electrocardiography

Non-specific ST and T-wave changes are common features of CP. In the report of 143 patients of the Mayo Clinic with surgically confirmed CP, 22% of patients had atrial fibrillation and 27% had low voltage in the surface leads [22]. In another series of 135 patients of the Mayo Clinic, 16% of patients had atrial arrhythmia and 27% had low voltage in 12 lead-ECG [13].

### 2.7. Plasma BNP

Leya et al. and Babuin et al. described the efficacy of plasma brain natriuretic peptide (BNP) in differentiating CP from restrictive cardiomyopathy [30,31]. Plasma levels of BNP are usually much higher in patients with restrictive cardiomyopathy than with CP. Over and above that, Babuin et al. emphasized that BNP levels are significantly lower in patients with idiopathic CP, compared to those with post-cardiac surgical or post-radiation CP and restrictive cardiomyopathy. Hence, BNP can help to distinguish CP from restrictive cardiomyopathy when CP is not due to a secondary cause [31].

### 2.8. Magnetic resonance imaging and computed tomography

The pericardium, which is normally only a few millimetres thick, represents an anatomical barrier between the heart and the mediastinum. Some pathologies are associated with characteristic alterations of the pericardium.

In CT and MRI, the healthy pericardium is normally visualized as a fibrous lining surrounding the heart with a minimal fluid layer. According to observations by Edwards, the normal amount of pericardial fluid is 15—50 ml [32]. Using the above-mentioned imaging modalities, the parietal and visceral pericardial layers can usually not be differentiated. In addition, the pericardium can hardly be differentiated from both mediastinum and epicardium due to poor soft tissue resolution in CT. A fine hypo dense lining is visible in the case of orthograde pericardial projection. However, large pericardial effusions and radio contrast agent positive tumors are easily detected with CT. The most recent generation of CT scanners allows for triggered thoracic scans in a single breathing cycle, resulting in enhanced resolution of pericardial structures.

CT is widely used to delineate partial or complete pericardial calcifications [33]. Minimal pericardial calcifications are early detectable in thoracal CT. Further, CT is feasible in patients with contraindications for MRI or in the setting of tumor staging procedures.

Dual-source CT as a novel scanner generation featuring two sets of X-ray sources and detector arrays in a single CT gantry allow for full image series cine viewing with high-time resolution. This method makes it possible to quantify potential myocardial impairments caused by pericardial calcifications.
After echocardiography, cardiac MRI is the method of choice for pericardial imaging [34–37]. Due to its fibrous composition, the healthy pericardium shows hypo intense characteristics in both T1w and T2w image gating modalities as compared to the myocardium. However, minimal pericardial effusions can easily be visualized as hyper intense linear signals in T2w image gating. In addition to inflammatory alterations of the pericardium, suspected constrictive and fibrotic alterations of the pericardium represent major indications for cardiac MRI.

Tagged cine-MRI sequence analysis is believed to be most suited for optimal functional imaging in CP [38]. Typical morphological characteristics of CP are global thickening of the pericardial layers (>4 mm in diameter) and late pericardial contrast enhancement, which is known to correlate with acute stages of inflammation (Figs. 3 and 4). A study conducted by Masui et al. has provided evidence that cardiac MRI can aid in the differentiation between restrictive cardiomyopathy and CP. Using intraoperative findings as the gold standard in a small cohort of patients (n = 17), sensitivity and specificity were found to be 88% and 100%, respectively [39].

A novel approach for the differentiation of early stage CP is the analysis of phase contrast angiography sequences, which are widely used in the characterization of hemodynamic parameters such as diastolic function. Similar to echocardiography, E- and A-waves of ventricular filling curves can suggest myocardial impairment before morphological alterations of the pericardium become evident. In contrast to echocardiography, the major advantage of MRI lies in the independence from anatomical patient characteristics. Furthermore, and in contrast to echocardiography, cardiac MRI is fairly observer-independent. Due to rapid imaging processing, cardiac MRI sequences are obtained in a few seconds and can easily be incorporated in routine diagnostic procedure schedules. Systematic studies comparing the diagnostic performance of cardiac MRI and echocardiography have been lacking so far. With the advent of new MRI techniques, the diagnostic yield in hemodynamic characterization of various pericardial and valvular heart conditions are expected to improve [40].

2.9. Hemodynamics

Invasive hemodynamic evaluation is important for the diagnosis of CP [1,7,11,16,41], but it is not always necessary because of the obtained results from other non-invasive imaging modalities like TDI, 2D-speckle tracking and MRI. One of the hallmarks in hemodynamic diagnosis is the equalization of left and right atrial and ventricular diastolic plateau pressure tracings as described above and shown in Fig. 1. The difference has to be less than 5 mmHg at rest. This is more obvious after premature ventricular contraction and one beat after onset of inspiration [1,7]. Nishimura argued that the most useful information obtainable by cardiac catheterization in the diagnosis of CP pertains to the dynamic respiratory variation between the left and right ventricular pressure tracings. During peak inspiration there is a decrease in left ventricular pressure and a concomitant increase in right ventricular pressure, indicating discordance of ventricular pressures (Fig. 5). In patients with restrictive cardiomyopathy and in patients with a normal pericardium, there is a concordance of left and right ventricular pressures [16]. Likewise, the ratio of right ventricular to left ventricular systolic area during inspiration and expiration is a reliable novel invasive criterion for differentiating CP from restrictive cardiomyopathy (Fig. 5). Talreja et al. reported a sensitivity of 97% and a predictive accuracy of 100% for identifying patients with surgically proven CP in about 100 consecutive patients [42]. An asymmetric elevation of left ventricular pressure is more characteristic of restrictive cardiomyopathy. Hancock stated that a comparison of instantaneous end diastolic pressure in the two ventricles is perhaps the most critical way, but a comparison of the mean pressures in the right atrium and the left atrium (or the pulmonary artery wedge pressure) may be the most reliable way to evaluate the diastolic equalization of pressures [7]. If CP is assumed but all diastolic pressures
remained low (occult constrictive pericarditis), a 1-l intravenous fluid bolus can enhance the diastolic pressures and will separate the right and left diastolic pressure by more than 5 mmHg in normal dehydrated patients without CP. As a result of CP the right and left ventricular diastolic pressures may increase but will not disperse after fluid bolus application [43]. Other causes of diastolic equalization of pressure, such as pericardial tamponade, restrictive cardiomyopathy, end stage dilated cardiomyopathy (all pressures high), dehydration (all pressures low), atrial septal defects and hyperinflated lungs (chronic obstructive pulmonary disease, pneumothorax) have to be excluded before diagnosing CP. Of note, restrictive cardiomyopathy with amyloidosis is the most likely to mimic CP [1,44,45]. Other criteria that favor a diagnosis of CP over restrictive cardiomyopathy are a ratio of right ventricular diastolic pressure to systolic pressure of greater than 1–3, as well as right ventricular or pulmonary systolic pressures of less than 55 mmHg, which are commonly found in CP, but not in restrictive cardiomyopathy [1,7,11,16,44,46,47]. However, these criteria may be difficult to apply in individual cases [16,46]. The diastolic dip and plateau (square root sign) and a prominent rapid filling wave are visible during right heart catheterization in CP. Further characteristic findings are Kussmaul’s sign and pulsus paradoxus (exaggeratus) as denoted in the pathophysiological findings section above. Of 143 patients of the Mayo Clinic with surgically confirmed CP, 78 patients underwent cardiac catheterization. Of these patients, 81% had a diastolic equalization of pressures, while a dip and plateau was seen in 77%. Respiratory variation in LV-RV gradient was seen in 44%. The mean atrial pressure was about 21 mmHg [22].

2.10. Endomyocardial biopsy

This diagnostic method can be helpful when echocardiographic, hemodynamic and other imaging modalities have failed to establish a diagnosis of CP [48,49]. Hancock emphasized that the major role of endomyocardial biopsy in distinguishing CP from restrictive cardiomyopathy was to show other entities such as cardiac amyloidosis (the most frequent simulator of CP), hemochromatosis, eosinophilic cardiomyopathy or other forms of specific infiltrative disease [7].

2.11. Mayo Clinic series

A contemporary spectrum of constrictive pericarditis in 135 patients evaluated at the Mayo Clinic from 1985 through 1995 was compared with that of a historic cohort of 231 patients from 1936 through 1982 [13]. Notable trends were an increasing frequency of CP due to cardiac surgery and mediastinal radiation (patients who had received radiotherapy most commonly had Hodgkin’s lymphoma or breast cancer) and presentation in older patients (median age, 61 vs 45 years). The frequency of various causes is listed in Table 1. Perioperative mortality decreased significantly as compared to the historic cohort (6% vs 14%, p = 0.011), but late survival was inferior to that of an age- and sex-matched US population (57 ± 8% at 10 years) and was not as good as expected. The median duration of symptoms before pericardiectomy was 11.7 months. The long-term outcome was predicted independently by age, NYHA class, and most powerful by a post-radiation etiology. Ninety late survivors had an improved functional status after pericardiectomy with 83% being free of clinical symptoms (latest follow-up after 10 years). The authors conclude that although pericardiectomy is often performed in patients with CP, it may not offer a cure or good long-term result for patients with post-radiation or long standing CP. Postoperative prognosis and functional outcomes remain good for most other patients with CP and excellent for younger patients without post-radiation CP. According to the authors’ opinion, cardiac transplantation should be considered in selected patients without evidence of tumor recurrence and with good pulmonary reserve, particularly if severe valvular disease coexists [13].

2.12. Stanford series

In a series from the Stanford University, 95 patients with CP from 1970 through 1985 were reviewed [14]. The diagnosis was documented at the time of surgery. A trend similar to the Mayo Clinic series, cited above, was seen regarding post-surgical CP, which emerged as an important etiology only after 1980, constituting 29% of cases during 1980–1985. The frequency of various causes is listed in Table 1. In cases of post-radiotherapy CP, the more recent cases from 1980 to 1985 had a longer latent period than the patients between 1970 and 1980 (11 vs 4.75 years). The operative mortality was 12% overall, lower in the idiopathic group (8%) and higher in the post-radiotherapy group (21%).

2.13. Cleveland Clinic Foundation series

One of the largest current series investigating the survival after pericardiectomy was published by the Cleveland Clinic [15]. A total of 163 patients who underwent pericardiectomy for surgically confirmed CP over a 24-year period at a single surgical center were studied between January 1977 and
December 2000. The overall mortality (defined as death either within the hospital or within 30 days of surgery) was 6%. The survival in the post-surgical group (mortality 8.3%) was inferior to the excellent idiopathic group (mortality 2.7%), but significantly higher than in the post-radiation group (mortality 21.4%). The median duration between pericardiectomy and preceding surgery was 16 months. The median duration between pericardiectomy and preceding radiation was 11 years (range, 2–30 years) [15]. The frequency of various causes is listed in Table 1. Predictors of poor overall survival will be discussed below.

2.14. Treatment and outcome

If patients with CP are largely asymptomatic or the symptoms are mild or in cases with mixed restrictive—restrictive disease, diuretics can be initially used as treatment, even in case of severe and end-stage disease, when perioperative mortality seems to be unacceptably high. Not all of these patients may benefit from surgical pericardiectomy. The problem of additional myocardial damage and myocardial compliance abnormalities and its relevance regarding perioperative outcome and remaining right-sided heart failure will be discussed. Otherwise, pericardiectomy in experienced centers with complete decortication (if technically feasible) is the accepted treatment of choice for CP. Most patients have relief of symptoms after successful pericardiectomy. Different surgical approaches have been discussed controversially, especially partial versus total pericardiectomy and median sternotomy versus lateral thoracotomy and the need for cardiopulmonary bypass [2,3,15,50–55]. In the Cleveland Clinic Foundation series of 163 patients who underwent pericardiectomy for CP over a 24-year period, there is no clear benefit for any particular surgical approach with regard to perioperative mortality or long-term survival [15]. Total pericardiectomy should be looked for. Chowdhury et al. published a large series of 395 patients undergoing pericardiectomy for CP between 1985 and 2004 [55]. The perioperative mortality was 7.6%. Total pericardiectomy was defined as wide excision of the pericardium with the phrenic nerves defining the posterior extent, the great vessels including the intrapericardial portion of superior cava-right atrium junction defining the superior extent, and the diaphragmatic surface including the inferior vena cava-right atrium junction defining the inferior extent of the pericardial resection. Constricting layers of the epicardium were removed if possible. Any excision less than total was defined as partial. Total pericardiectomy (338 patients, 85.6%) was associated with lower perioperative mortality, less post-operative low output syndrome, abbreviated hospitalization, and better long-term survival than partial pericardiectomy [55]. The majority of patients in the Mayo Clinic series (117 patients, 89%) [13] and in the Cleveland series (119 patients, 73%) [15] underwent complete pericardiectomy. The favored surgical approach was median sternotomy (146 patients, 90% [15]; 300 patients, 75.9% [55]). Chowdhury et al. achieved total pericardiectomy in all patients through median sternotomy. This approach provides a good exposure of the right atrium and the superior and inferior vena cava and enables a good clearance of the diseased pericardium [55,56]. On the other hand, left anterolateral thoracotomy should be used for purulent pericarditis to avoid sternal infection [55,56]. Cardiopulmonary bypass during pericardiectomy should not be a necessary adjunct for total pericardiectomy and employed only in special circumstances, inadvertent excessive bleeding for example [55]. Thirty patients (18.4%) of the Cleveland series underwent an on-pump procedure [15]. Chowdhury et al. noted that cardiopulmonary bypass was used in only seven cases (1.8%) because of massive bleeding [55].

An important predictor of long-term outcome is the etiology of the pericardial disease [13–15]. Furthermore, the perioperative mortality is highly dependent on the pre-operative NYHA status. In a series of 313 patients from the Mayo Clinic between 1936 and 1990, the overall mortality was 14% (in NYHA Class IV it was 46%, in Class III 10%, in Class I and II 1%) [1,2]. In another series of 135 patients evaluated at the Mayo Clinic from 1985 to 1995, the 30-day perioperative mortality was 6%. In the late survival analysis (10 years of follow-up) independent predictors of late survival were age, NYHA class and previous radiation. Again, independent predictors of late cardiac-related deaths were previous radiotherapy, NYHA class III to IV symptoms and age. Previous radiotherapy was the most powerful predictor of all outcome measures [13]. In the Cleveland Clinic Foundation series with 163 patients between 1977 and 2000 the perioperative overall mortality was 6%. This corresponds to a perioperative mortality of about 5–7.6% in recent studies [13, 15, 52, 55, 57–60]. The most frequent cause of death in the perioperative period of the Cleveland Clinic Foundation series was low-output heart failure, as described in most other prior studies [3,13–15,50,51,55,60]. Idiopathic CP had the best prognosis with 7-year Kaplan–Meier survival of 88% followed by post-surgical CP with 66% and post-radiation CP with 27%. Predictors of poor overall survival were prior radiation, impaired renal function, high pulmonary artery systolic pressure, abnormal left ventricular systolic function, low serum sodium level, and old age. Pericardial calcification had no impact on survival [15]. Bertog et al. assumed that the higher mortality associated with pericardiectomy for post-radiation (21.4%) and post-surgical constriction (8.3%) is related to the fact that constriction is not the sole factor producing heart failure in these subgroups. Myocardial atrophy after prolonged constriction, residual constriction or a concomitant myocardial process can lead to prolonged cardiac failure in spite of successful pericardiectomy [15]. Nishimura noted that some patients have a large degree of ventricular discordance during the respiratory cycle. These patients benefit most from pericardiectomy. Conversely, if the severity of diastolic pressure increase is disproportionate to a mild degree of ventricular discordance the major pathophysiological process is a myocardial compliance abnormality and signs and symptoms of right-sided heart failure can remain after pericardiectomy [16]. Likewise, patients with abnormal left ventricular contractility and relaxation abnormalities incur higher operative mortality and poor long-term outcome after pericardiectomy [61]. On the other hand, in the particular case of transient CP, originally described by Sarraña-Sauleda et al. in 1987 [62], symptoms and constrictive physiologic features can resolve spontaneously or with medical treatment alone. In 1980,
Hancock already described the elastic and the rigid form of pericardial constriction [17]. The elastic form represents the acute or subacute phase of constriction and appears to be reversible [63]. Sagristá-Sauleda et al. reported 16 of 177 patients (9%) with effusive acute idiopathic pericarditis and signs of constriction with recovery under medical treatment and observation. The authors suggested a three-phase pattern of this form of transient constriction [62]. In a review of the Mayo Clinic echocardiography database 212 patients with echocardiographic findings of CP were identified between 1988 and 1999 [63]. In 36 of these patients (17%) follow-up echocardiograms showed resolution of the constrictive hemodynamics without pericardiectomy after a mean of 2.1 months (2.7 months in the study by Sagristá-Sauleda et al. [62]). The most common cause of transient CP in these 36 patients was pericardial inflammation after pericardiectomy (9 patients, 25%), but transient constrictive physiologic features can generally appear in any condition that causes chronic CP with exception of radiation therapy [63]. The medical treatment of the 36 patients with transient CP of the Mayo Clinic contained anti-inflammatory agents (non-steroidal drugs, 56%), steroids (44%), antibiotics (11%), angiotensin converting enzyme inhibitors plus diuretics (6%) and chemotherapy (3%), 5 patients (14%) received no therapy. The authors concluded that patients who have constrictive features early in the course of their illness and are hemodynamically stable should be considered for a trial of conservative and medical treatment with the expectation of an average recovery time of three months before pericardiectomy is recommended [63]. Finally, in contrast to the postoperative outcome of post-radiation and postsurgical CP and in absence of transient CP, the excellent survival for idiopathic CP after pericardiectomy in the large series cited above emphasizes pericardiectomy as a safe treatment of pericardial constriction in this specific entity.

In conclusion, this case report and review emphasizes that the diagnosis of CP and its individual predictive ranking continues to be a challenge. Understanding the pathophysiology of CP and integrating the results of non-invasive and invasive techniques are the Rosetta Stone in the differential diagnosis of CP and related disorders such as restrictive cardiomyopathy. New echocardiographic techniques like TDI and 2D-speckle tracking, dual-source CT and especially tagged cine-MRI with the analysis of phase contrast angiography sequences as discussed above are promising novel approaches. Systematic studies are warranted to confirm these results in larger controlled trials.

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