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Role of Multimodality Imaging in the Evaluation of Pericardial Diseases

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Abstract

Pericardial diseases are a heterogeneous category of disorders, including pericardial effusion, cardiac tamponade, acute and recurrent pericarditis, constrictive pericarditis, and pericardial masses, which require a timely and precise assessment because of varying clinical manifestations and potentially dire outcomes. Imaging is required in diagnosis, risk stratification, therapeutic planning, and follow-up. Nevertheless, there is no imaging modality that can be used to exhaustively describe the intricate anatomic, hemodynamic, and inflammatory characteristics of pericardial disease. Multimodality imaging has thus become a vital approach to a holistic evaluation. The first method is the use of echocardiography because it is the most available, can be performed at the bedside, and can provide real-time hemodynamic information particularly in pericardial effusion and tamponade. Computed tomography is specifically useful in pericardial calcification, thickness, and masses or complicated anatomy and has a great spatial resolution. Inflammation, edema, fibrosis and constrictive physiology can only be determined by cardiac magnetic resonance, which is also the best in tissue characterization. Positron emission tomography and hybrid imaging also provide extra diagnostic capabilities and assess metabolic activity of inflammatory and malignant diseases. A stepwise and integrated imaging method enhances the accuracy of the diagnosis, distinguishes between similar clinical syndromes, and allows personalized treatment. The development of new technologies like hybrid imaging and artificial intelligence is likely to improve the assessment of pericardial diseases, and increase accuracy in clinical judgment.

Keywords: Pericardial diseases, Echocardiography, Cardiac MRI, CT, Multimodality imaging, Constrictive pericarditis

1. Introduction

The pericardium is a two-layered fibroserous sac, which wraps around the heart and the proximal great vessels and is made up of an outer fibrous layer and an inner serous layer, which is further divided into parietal and visceral components. Physiologically, the pericardium plays a number of important functions such as restricting acute cardiac distension, ensuring optimal cardiac position within the thorax, decreasing friction during cardiac movement, and acting as a barrier to infection and malignancy. A small quantity of lubricating fluid present in the normal pericardial space and this helps to lubricate the heart as it moves through the cardiac cycle. Any interference in the structure or functioning of the pericardium may cause a range of pathological disorders that are collectively known as pericardial diseases (Kligerman, 2019).

The group of pericardial diseases is broad and heterogeneous and includes acute and chronic pericarditis, pericardial effusion, cardiac tamponade, constrictive pericarditis, and pericardial masses or tumors. The etiologies of these conditions can be varied and include infections, autoimmune diseases, malignancies, metabolic disorders, trauma, or iatrogenic. Two of them, pericardial effusion and constrictive pericarditis, are clinically important but may have overlapping features and have very different management and prognostic implications (Jain & Reddy, 2023; Welch, 2018). Pericardial diseases can present with a rather wide range of clinical manifestations, such as incidental findings, which are asymptomatic and potentially life-threatening, such as cardiac tamponade, which emphasizes the need to diagnose them early and accurately.

Appropriate evaluation of the pericardial diseases is not only essential in the diagnosis of the disease but also in determining the degree of the disease, the choice of treatment and also the response to the treatment. Clinical assessment is often not satisfactory due to non-specific symptoms and similar clinical manifestations with other heart diseases and systemic diseases. Imaging is thus an important part of the diagnostic pathway. Traditionally, echocardiography has served as the first imaging modality of choice due to its universal applicability, noninvasivity and the ability to provide real-time hemodynamic assessment. However, echocardiography too has its share of limitations particularly in the measurement of pericardial thickness, the detection of calcifications and the description of tissue structure (Chetrit et al., 2019).

Similarly, other types of individual imaging such as computed tomography (CT) and cardiac magnetic resonance (CMR) have their respective advantages but cannot operate independently without restrictions. CT has a good spatial resolution and is particularly helpful in the detection of pericardial calcifications and anatomical features, however, it provides limited functional and tissue characterization information. Conversely, CMR can be superior at characterizing tissues and is more effective at measuring inflammation, yet may be less accessible and contraindicated in certain groups of patients. The nuclear imaging protocols, including positron emission tomography (PET) offer an added value because they can be used to evaluate metabolic activity and inflammation, particularly in the instances of complicated or unusual cases (Chetrit et al., 2021).

As the strengths and weaknesses of individual imaging modalities are complementary, an individual technique may only lead to incomplete or inaccurate assessment. This has led to the multimodality imaging technique, which is a combination of the findings of other imaging modalities to provide a comprehensive evaluation of the pericardial structure, functionality and pathology. Multimodality imaging enables clinicians to utilize the advantages of each of the modalities, thus increasing diagnostic accuracy, risk stratification, and enabling tailored management strategies. To illustrate, echocardiography may be used to perform preliminary examination and hemodynamic analyses, CT to define anatomy and detect calcification, and CMR to describe tissue and assess inflammation (Klein et al., 2024).

In recent years, the role of multimodality imaging in pericardial diseases has become even stronger due to the new imaging technologies and the elaboration of standardized imaging protocols. Modern recommendations and consensus statements are moving towards a more integrated imaging approach as a foundation in the assessment and management of these conditions. Such a paradigm shift is indicative of an increasing realization that no single modality can answer all diagnostic and clinical questions in pericardial disease (Chetrit et al., 2021).

Thus, the purpose of this review is to present the overall picture of the role of multimodality imaging in the assessment of the pericardial diseases, to outline the strengths, limitations and clinical use of different imaging methods, and to underline the significance of the combined diagnostic approach.

2. Overview of Multimodality Imaging Techniques

The assessment of pericardial diseases has changed tremendously with the introduction of cardiovascular imaging technologies. Multimodality imaging is a concept that is used to describe the combined application of various imaging modalities to provide complementary data regarding cardiac structure, cardiac function, tissue nature and pathophysiology. Clinicians are moving away from the use of one modality and instead are embracing a synergistic methodology whereby a combination of different imaging modalities is used to get a more accurate and comprehensive diagnosis (Wang & Klein, 2022).

Multimodality imaging is of particular interest in pericardial diseases due to the complex interactions between anatomical changes, hemodynamic changes, and inflammation. Every imaging modality has its own perceptions; echocardiography is a real-time functional imaging, computed tomography (CT) is a high-resolution anatomic imaging, cardiac magnetic resonance (CMR) is a tissue characterization, and positron emission tomography (PET) is a metabolic activity imaging. The jointness of these modalities enhances diagnostic confidence and improved clinical decision making (Abbara & Kligerman, 2025).

2.1 General Principles for Selecting Imaging Modalities

Various clinical and practical factors determine the imaging modality to be used in pericardial disease. To begin with, the suspected diagnosis and clinical presentation are crucial. To illustrate, echocardiography is the modality of choice in hemodynamically unstable patient with suspected cardiac tamponade because it is fast and can be performed at the bedside. Conversely, CT might be a better option when more detailed anatomical examination or identification of calcification is needed (Terry et al., 2021).

Second, patient-related issues, including renal performance, the capacity to withstand contrast agents, implanted devices, and hemodynamic stability should be taken into account. An example of this is that CMR should not be used in patients with some metallic implantation or severe claustrophobia, and the use of iodinated contrast in CT can be dangerous in patients with renal failure. Third, modality choice is dependent on the availability and expertise because not all imaging methods, including CMR and PET, are equally available (Wang & Klein, 2022).

The incremental value of every modality is another principle. The imaging must be done in a progressive fashion meaning that other modalities should be used only in cases where they add clinically significant information to the original findings. This method prevent unnecessary investigations, save money, and limit patient radiation or contrast exposure to radiation or contrast agents. Finally, multimodality imaging is not aimed at redundancy but complementation with the exploitation of each modality to provide answers to particular clinical questions (Abbara & Kligerman, 2025).

2.2 Echocardiography

Echocardiography is the primary imaging modality that is used in the assessment of pericardial diseases because it has a high availability, is noninvasive, and can be used to provide real-time evaluation of cardiac structure and function. It is especially useful in diagnosing the presence of pericardial effusion, its size and distribution and in determining the presence of cardiac tamponade, including chamber collapse and respiratory variation in transvalvular flow velocities. Doppler echocardiography also allows assessing hemodynamic implications, which is essential in distinguishing between constrictive pericarditis and restrictive cardiomyopathy (Wang & Klein, 2022).

Echocardiography has limitations although there are benefits. The quality of images can be poor in patients with poor acoustic windows, and cannot measure pericardial thickness and calcification. Also the tissue characterization is not possible by traditional echocardiographic methods. Such limitations require additional imaging modalities to be used in some clinical situations.

2.3 Computed Tomography (CT)

Computed tomography is very well resolved in space and is especially applicable in the detailed anatomical assessment of the pericardium. It is the modality of choice to identify pericardial calcifications that are commonly related to chronic constrictive pericarditis. CT may also reliably quantify pericardial thickness and detect related results like masses, loculated effusions, or involvement of nearby structures (Terry et al., 2021).

Recent innovations such as spectral photon-counting CT have also improved the quality of images and tissue differentiation, enabling the better characterization of cardiovascular structures at lower radiation levels (Meloni et al., 2024). Nevertheless, CT has some shortcomings, such as exposure to ionizing radiation and the use of iodinated contrast agents, which may not apply to every patient. Furthermore, CT does not give much functional and hemodynamic information as compared to echocardiography and CMR.

2.4 Cardiac Magnetic Resonance (CMR)

Cardiac magnetic resonance has become a complete imaging modality of pericardial diseases because it has high soft tissue contrast and capability to characterize tissue in detail. CMR is able to measure the pericardial thickness, identify inflammation by late gadolinium enhancement, and measure the pericardial edema by T2-weighted imaging. It also allows functional evaluation, such as ventricular interdependence and septal motion abnormalities, which are crucial in diagnosing constrictive pericarditis (Antonopoulos et al., 2023).

Among the most important benefits of CMR, there is the possibility to distinguish between active inflammatory disease and chronic fibrotic changes which has significant therapeutic consequences. Limitations are however longer acquisition times, high cost, low availability and contraindication in some patient groups. Nonetheless, multimodality assessment of pericardial disease is starting to rely on CMR as a cornerstone modality despite these challenges.

2.5 Positron Emission Tomography (PET)

Positron emission tomography provides functional and metabolic information that supplements anatomical imaging. It is particularly useful in the diagnosis of active inflammation and malignancy of the pericardium. PET, often employed alongside CT (PET/CT), is capable of detecting any metabolic activity that is enhanced by inflammatory or neoplastic processes, thereby facilitating in diagnosis and treatment (Abbara & Kligerman, 2025).

PET is not a routinely used modality, but has an appropriate place in complex or ambiguous cases, such as the differentiation between infectious or inflammatory pericarditis and malignancy.

Limitations are limited availability, expensive and radiation exposure. The major strengths, limitations, and clinical uses of the major imaging modalities employed in pericardial diseases are summarized in Table 1. It emphasizes the complementary nature of echocardiography, CT, CMR and PET in diagnostic assessment.

Table 1. Comparison of Imaging Modalities in Pericardial Diseases

Modality	Strengths	Limitations	Best Clinical Use	Reference
Echocardiography	Widely available; real-time imaging; excellent hemodynamic assessment; bedside applicability	Limited tissue characterization; suboptimal in poor acoustic windows; limited evaluation of pericardial thickness	Initial evaluation; pericardial effusion; cardiac tamponade; hemodynamic assessment	(Wang & Klein, 2022)
Computed Tomography (CT)	High spatial resolution; उत्कृष्ट detection of calcification; accurate assessment of pericardial thickness and anatomy	Ionizing radiation; contrast-related risks; limited functional information	Pericardial calcification; anatomical delineation; masses and complex effusions	(Terry et al., 2021)
Cardiac Magnetic Resonance (CMR)	Superior tissue characterization; assessment of inflammation and fibrosis; no radiation; functional evaluation	Limited availability; longer acquisition time; contraindications in certain patients	Constrictive pericarditis; inflammatory pericardial disease; tissue characterization	(He et al., 2023)
Positron Emission Tomography (PET)	Evaluation of metabolic activity; detection of inflammation and malignancy; complementary to CT/MRI	High cost; limited availability; radiation exposure	Inflammatory pericarditis; malignancy assessment; complex diagnostic cases	(Abbara & Kligerman, 2025)

3. Echocardiography in Pericardial Diseases

Echocardiography is considered the first-line imaging tool in the assessment of pericardial diseases because it is accessible, portable, cost-effective, and offers real-time evaluation of the cardiac structure and functions. It is a key component of the initial diagnosis, hemodynamic assessment, and follow-up of patients with suspected pericardial pathology. Echocardiography can be used quickly and at the bedside, which is why it is essential in the emergency and critical care setting (Chiabrando et al., 2020).

3.1 Role in Pericardial Effusion

The main tool to identify and measure the pericardial effusion is echocardiography and it presents as a space with no echoes between the visceral and parietal pericardial layers. It enables categorization of efficiency of the effusion (small, moderate, large) and distribution (circumferential or loculated). Moreover, echocardiography may give information on the etiology by revealing related results like fibrin strands, septations, or echogenic material which may indicate exudative or hemorrhagic effusions (Perez et al., 2023).

Serial echocardiogram analysis can be particularly helpful in the course of effusion progression or resolution and in the management of therapeutic treatments like pericardiocentesis. Echocardiography can also reveal the presence of sustained constrictive physiology in the presence of fluid removal, which can be important in dynamic assessment in cases of effusive-constrictive pericarditis (Kim et al., 2018; Maisch, 2018).

3.2 Role in Cardiac Tamponade

The diagnosis of cardiac tamponade is one of the most urgent uses of echocardiography as it is a life-threatening condition with elevated intrapericardial pressure resulting in impaired cardiac filling. The echo changes in tamponade are right atrial and right ventricular diastolic collapse, exaggerated respiratory variation of transvalvular flow velocities and inferior vena cava (IVC) dilation with lesser respiratory collapse. Notably, echocardiography can be used not only to evaluate structure but also hemodynamics, which can be used to distinguish between tamponade physiology and large and hemodynamically insignificant effusions. This differentiation is essential to make clinical decisions and intervention timely (Chiabrando et al., 2020).

3.3 Role in Constrictive Pericarditis

The use of Echocardiography is also central to the assessment of constrictive pericarditis, which is an ailment that is typified by a stiff pericardium, which limits diastolic filling. Echocardiography can not necessarily directly observe the pericardial thickening, but it includes important indirect data in the form of typical hemodynamic patterns.

The most important echocardiographic findings are: Septal bouncing or interventricular dependence, Diaphragm variability of inflow velocities of the mitral and tricuspid valves, Hepatic vein diastolic reversal, and preserved or increased medial mitral annular velocity. The results aid in the distinction between constrictive pericarditis and restrictive cardiomyopathy that shares the same clinical presentation but with different management approaches. Other imaging modalities can be used to complement echocardiography in complex cases to establish the diagnosis (Karmali et al., 2024; Kim et al., 2018).

3.4 Doppler and Hemodynamic Assessment

One of the key advantages of echocardiography is that it offers in-depth Doppler-based hemodynamic evaluation. Pulsed-wave and continuous-wave Doppler methods permit measuring transvalvular flow velocities, whereas tissue Doppler imaging gives information on myocardial motion and diastolic function.

Both constrictive pericarditis and tamponade have the characteristic of respiratory variation in Doppler inflow velocities, which is an indication of increased ventricular interdependence. Tissue Doppler imaging also helps to differentiate between constrictive pericarditis and myocardial diseases in that the annular velocities in constriction are preserved or even increased, as opposed to slower velocities in restrictive cardiomyopathy. These hemodynamic values are critical to proper diagnosis and informing clinical care (Karmali et al., 2024).

3.5 Advantages and Limitations

Echocardiography has a number of strengths such as being noninvasive, having no radiation effects, is real-time, and is widely available. It is especially useful in acute conditions where quick diagnosis is needed. Moreover, it enables the repetition of the assessment to track the disease progress and therapy response.

Nonetheless, echocardiography has significant shortcomings. Obese patients, patients with lung disease, or chest wall abnormalities may have their image quality compromised. It is less effective to measure pericardial thickness and identify calcifications and does not allow detailed characterization of tissues. Moreover, interpretation can be operator-dependent and this can create variability in findings.

In spite of these shortcomings, echocardiography is the staple of pericardial imaging and the platform on which multimodality imaging strategies are based. It can be combined with complex imaging modalities to improve diagnostic precision and deliver a more detailed analysis of pericardial diseases (Maisch, 2018). Echocardiography is still the initial imaging mode used in the diagnosis of pericardial effusion and evaluation of hemodynamic impairment in cardiac tamponade. The important structural and Doppler results as shown in Figure 1 demonstrate its applicability in real-time functional assessment.

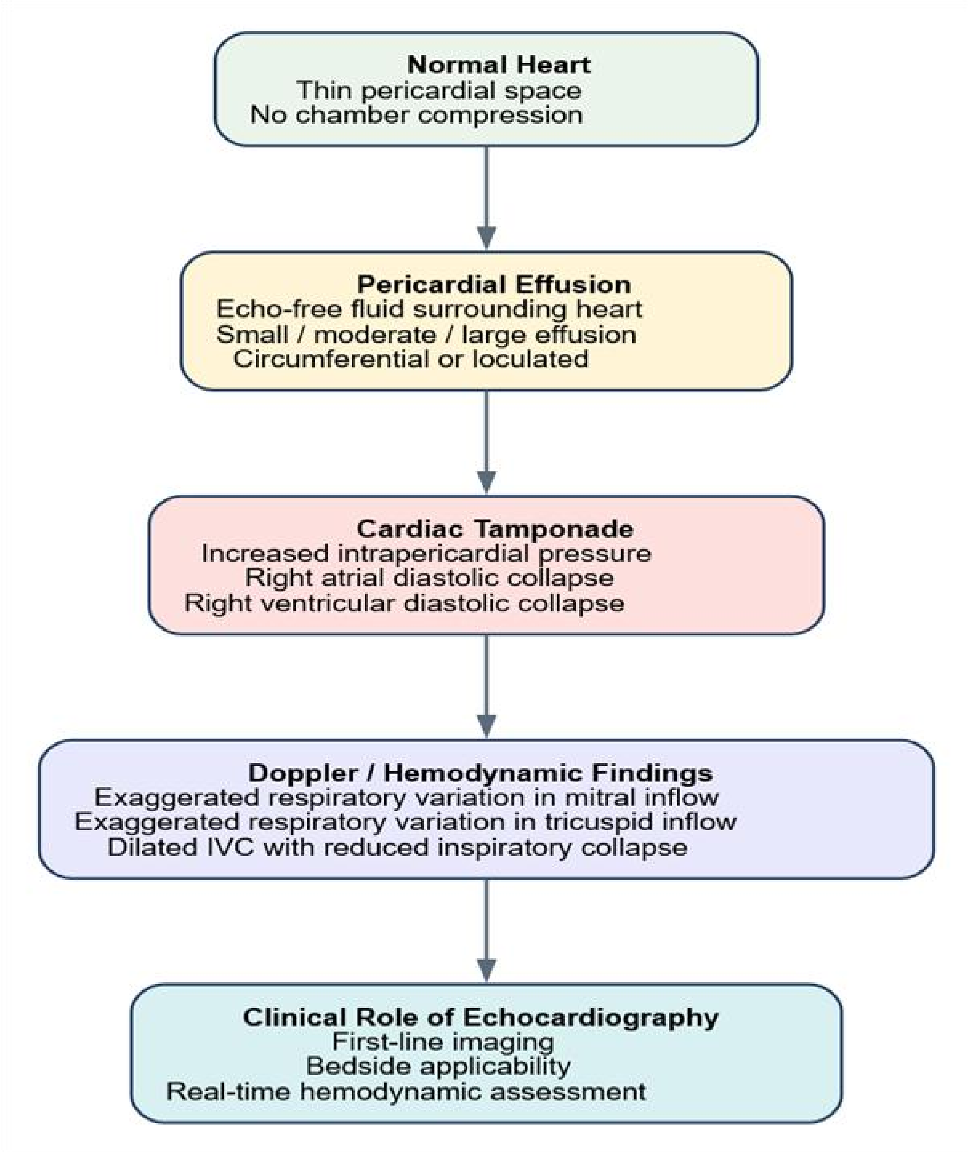

Figure 1. Echocardiographic Findings in Pericardial Effusion and Tamponade

4. Advanced Imaging: CT and Cardiac Magnetic Resonance

High-level imaging modalities, particularly computed tomography (CT) and cardiac magnetic resonance (CMR) play a crucial role in the general evaluation of pericardial diseases. Although echocardiography is the first-line modality, CT and CMR offer better anatomical and tissue characterization, respectively, which compensate for the important diagnostic gaps. The modalities come in handy especially in complex cases where structural abnormalities, inflammation or distinction between similar clinical entities must be drawn at the point of precision (Antonopoulos et al., 2023).

4.1 Computed Tomography (CT)

One of the imaging modalities that have been found to be most useful in assessing the anatomy of the pericardium is computed tomography because it has a high spatial resolution and requires less time to be taken. One of its key strengths is that it is able to identify pericardial calcification which is a feature of chronic pericardial disease particularly constrictive pericarditis. CT is far more sensitive than echocardiography to delimit and characterize calcific deposits, which can be both localized and diffuse and contribute to an important role in impaired diastolic filling (Terry et al., 2021).

Besides calcification, CT enables precise measurement of pericardial thickness, and a value exceeding 4 mm is typically regarded as abnormal. It allows detailed anatomical visualization of the pericardial anatomy with the presence of loculated effusions, pericardial masses, or adhesions. This renders CT especially helpful in preoperative planning, specifically in patients under consideration of pericardiectomy.

CT is also significant in the assessment of the pericardial involvement in trauma and malignancy. CT can be used to quickly identify hemopericardium and other thoracic trauma in a traumatic environment. It is useful in oncologic cases to determine whether the pericardium has been infiltrated, whether the disease is metastatic or an end in itself, and whether the disease has spread to other structures. Moreover, CT with contrast enhancement can identify vascular involvement and direct biopsy or intervention as necessary (Al-Kazaz et al., 2024).

4.2 Cardiac Magnetic Resonance (CMR)

In pericardial diseases, cardiac magnetic resonance has become a gold standard in the characterization of tissue. Its potential to give comprehensive data on the composition of the pericardium, inflammation, and functional implications of the same qualifies it to be an inseparable part of multimodality imaging. In contrast to CT, CMR lacks radiation and has better soft tissue contrast, providing the opportunity to distinguish normal, inflamed, and fibrotic pericardial tissue (Fogante et al., 2025).

Pericardial inflammation has been identified as one of the most crucial uses of CMR. T2-weighted imaging techniques are able to detect edema, whereas late gadolinium enhancement (LGE) allows locating active inflammation and fibrosis. The characteristics come in handy especially when diagnosing acute and recurrent pericarditis and in the determination of disease activity, which directly affects treatment choices (El Roumi et al., 2026).

CMR can also be used to quantify extracellular volume (ECV), which can indicate tissue composition and may be used to identify diffuse fibrosis or inflammatory changes. Active disease processes have been linked to increased ECV values and add more diagnostic and prognostic data (Lurz et al., 2018). This is especially useful in the differentiation between reversible inflammatory diseases and irreversible fibrotic constriction.

One of the critical clinical uses of CMR is to distinguish between constrictive and restrictive cardiomyopathy and pericarditis, which are clinically and hemodynamically similar conditions that need different treatment approaches. CMR is able to show typical results of constrictive pericarditis, such as pericardial thickening, bouncing of the septum, and interdependence of the ventricles. Moreover, the presence of pericardial enhancement is an indicator of active inflammation which can be addressed with medical treatment, but the lack of enhancement can be a sign of chronic fibrotic disease that needs surgical treatment (Imazio et al., 2025).

In addition, CMR offers detailed functional evaluation, such as ventricular volumes, ejection fraction and real-time cine imaging, which is needed to determine the effect of pericardial disease on cardiac performance. This combined structural and functional assessment renders CMR the only technique that is most appropriate for diagnosis as well as longitudinal follow-up.

Nonetheless, CMR does not have limitations. It is not as common as echocardiography and CT, takes more time to acquire, and is contraindicated in patients with some implants or severe claustrophobia. Also, gadolinium contrast agents should be used with caution in patients with acute renal failure. Pericardial disease has been studied with computed tomography and cardiac magnetic resonance, offering a combination of anatomical and tissue characterization. Figure 2 shows the unique but complementary positions of CT and CMR in advanced imaging evaluation.

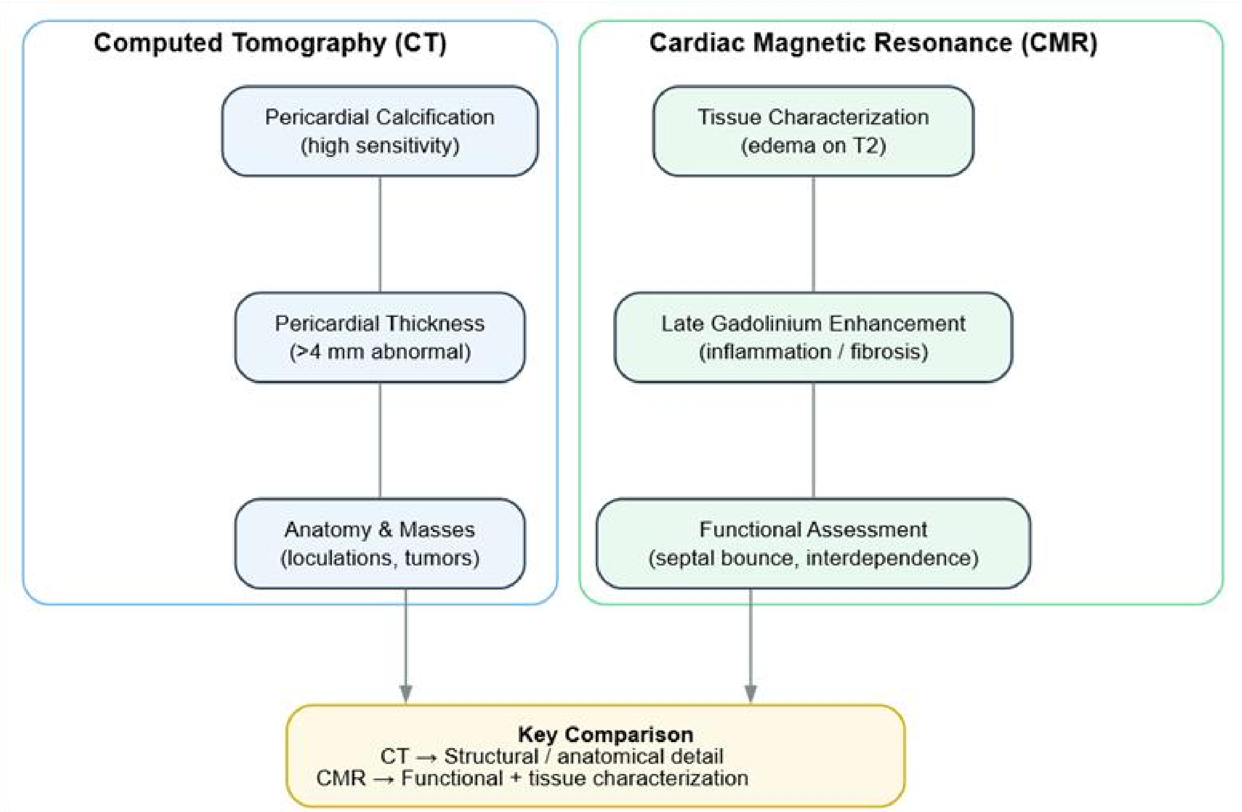

Figure 2. CT and CMR Features of Pericardial Disease

5. Multimodality Imaging in Specific Pericardial Conditions

Multimodality imaging could be especially useful in the assessment of a particular pericardial condition, where various imaging modalities could offer complementary information regarding anatomy, hemodynamics, and tissue features. The combination of echocardiography, CT, CMR, and nuclear imaging allow making a more accurate diagnosis and provide a way to manage the condition.

5.1 Pericardial Effusion and Cardiac Tamponade

One of the most frequent manifestations of pericardial disease is pericardial effusion which can be incidental or lead to life-threatening cardiac tamponade. Echocardiography is the leading modality of effusion detection, size, distribution and hemodynamic effects measurement. It is especially useful when it comes to determining tamponade physiology via such characteristics as right atrial and ventricular collapse and respiratory variation in transvalvular flow (Baggish et al., 2020).

CT and CMR however add information in complicated cases. CT can be used to detect loculated effusions, hemorrhagic collections, or related thoracic pathology, whereas CMR can be used to describe the composition of pericardial fluid and to identify related inflammation. Multimodality imaging can be used to identify the underlying etiology and inform therapeutic choices in instances of recurrent or unusual effusions (Fogante et al., 2025).

5.2 Constrictive Pericarditis

A characteristic of constrictive pericarditis is the inability to fill the ventricles because of a stiff pericardium. Echocardiography is important in primary examination, which shows characteristics of septal bounce, respiratory fluctuations in inflow velocities, and ventricular interdependence. It has limited capability to measure pericardial thickness and calcification, however CT is also useful in the diagnosis of pericardial calcification and in the measurement of thickness, which are crucial in diagnosing the disease. In its turn, CMR provides crucial information on pericardial inflammation and fibrosis through techniques, such as late gadolinium enhancement. This distinction is clinical, in that inflammatory constriction is amenable to medical therapy, whereas chronic fibrotic constriction often requires surgical pericardiectomy (Welch, 2018).

Multimodality imaging is also necessary to distinguish between constrictive pericarditis and restrictive cardiomyopathy, which share clinical manifestations but demand different treatment.

5.3 Acute and Chronic Pericarditis

Acute pericarditis is a clinical diagnosis, although imaging is used to support the diagnosis of inflammation and complications. Echocardiography can be used to identify related pericardial effusion, but it is less sensitive to inflammation.

CMR has become the most sensitive modality to detect pericardial inflammation, showing pericardial edema on T2-weighted images and enhancement on late gadolinium sequences. The findings have been especially effective in diagnosing recurrent or chronic pericarditis as well as in response to therapy. The continuous improvement can be a sign of inflammation persistence, and its disappearance can be an indicator of successful treatment (Imazio et al., 2025).

Pericardial thickening and enhancement can also be seen on CT, but is less sensitive than CMR to identify active inflammation. In some specific instances, PET imaging may also evaluate metabolic activity, especially in inflammatory or infectious etiologies.

5.4 Pericardial Masses and Tumors

Pericardial masses are rather uncommon but of clinical importance because they can be malignant. They can be either primary tumors like mesothelioma or secondary invasion by metastasis. Masses can be incidentally identified by echocardiography but has little capacity to characterize the masses.

CT can be used to give detailed anatomic data, such as lesion size, location, and relation to adjacent structures. It is specifically beneficial in detecting calcifications and determining invasion into adjacent tissues. CMR is better in characterization of soft tissues, and the benign and malignant lesions are differentiable based on the intensity of the signal and the enhancement patterns. Also, CMR is able to assess functional effects on cardiac chambers. PET/CT could be applied to measure metabolic activity in a few cases to help differentiate between benign and malignant lesions and to plan the biopsy or treatment (Imazio et al., 2025).

5.5 Congenital Pericardial Abnormalities

Pericardial abnormalities that are congenital like partial or total absence of the pericardium are uncommon and in most cases silent but can be incidentally observed. Echocardiography can create suspicion, either due to abnormal cardiac positioning, or atypical motions, but is often not adequate to make a definite diagnosis.

The modalities that are preferable in confirming congenital abnormalities are CT and CMR. They give a clear visualization of pericardial structure and are capable of detecting related complications like cardiac herniation or compression of the surrounding structures. Specifically, CMR provides functional examination and is capable of examining the physiological effect of such abnormalities (Antonopoulos et al., 2023). Table 2 describes the typical imaging appearances of the various pericardial conditions and their ideal modalities. This helps in selection and interpretation of imaging in a disease-oriented mode.

Table 2. Imaging Findings in Different Pericardial Diseases

Condition	Key Imaging Features	Preferred Modality	Reference
Pericardial Effusion	Echo-free space; quantification of size; loculations; associated fibrin strands	Echocardiography	(Wang & Klein, 2022)
Cardiac Tamponade	Right atrial/ventricular collapse; exaggerated respiratory variation; dilated IVC with reduced collapse	Echocardiography	(Chiabrando et al., 2020)
Constrictive Pericarditis	Septal bounce; ventricular interdependence; pericardial thickening and calcification; LGE on CMR	Echocardiography + CT + CMR	(El Roumi et al., 2026)
Acute/Chronic Pericarditis	Pericardial edema (T2); late gadolinium enhancement; associated effusion	CMR	(Slart & Brouwer, 2021)
Pericardial Masses/Tumors	Mass lesion; invasion of adjacent structures; contrast enhancement; metabolic uptake (PET)	CT + CMR ± PET	(Imazio et al., 2025)Abbara & Kligerman (2025)
Congenital Pericardial Abnormalities	Partial/complete absence of pericardium; abnormal cardiac position; possible herniation	CT / CMR	(Mavrogeni et al., 2023)

6. Role of Nuclear Imaging and Emerging Techniques

Nuclear imaging and the emerging technologies are broadening the diagnostic scope of pericardial diseases to offer functional, metabolic and computational information that complements the traditional anatomical imaging. Although echocardiography, CT, and CMR continue to be the main foundation of assessment, new methods, including positron emission tomography (PET), hybrid imaging, and artificial intelligence (AI) are increasingly becoming an important part of the clinical picture in cases of complexities and ambiguity.

6.1 PET/CT in Inflammation and Malignancy

Positron emission tomography, especially with CT (PET/CT), allows one to determine the activity of metabolism and inflammation that cannot be directly observed using other types of imaging. Fluorodeoxyglucose (FDG) is the most prevalent tracer that is concentrated in inflammatory and malignant tissues with high metabolic activity and gives an opportunity to detect active inflammation of the pericardium.

PET/CT is capable of detecting an augmented FDG uptake in the pericardium, which is a sign of active inflammation in the cases of acute or recurrent pericarditis. This is especially applicable in cases where traditional imaging results are inconclusive or in cases where active inflammation and chronic fibrotic disease need to be distinguished. Besides, the PET/CT can also be significant in assessing the pericardial involvement of malignancy and differentiate between benign and malignant processes, as well as determine the biopsy or treatment approach (Kwiecinski, 2025; Slart & Brouwer, 2021). Moreover, PET can be used to detect systemic inflammatory or infectious diseases that can involve the pericardium, thus offering a more comprehensive diagnostic view. Although PET/CT has its benefits, it is not commonly adopted as a primary modality because of its cost, lack of accessibility, and radiations.

6.2 Hybrid Imaging

PET/CT and PET/MRI are examples of hybrid imaging methods that have made a major breakthrough in cardiovascular imaging, with the integration of structural and functional information in a single scan. PET/CT combines metabolic data of PET with anatomy of CT whereas PET/MRI has the added advantage of better soft tissue characterization with no extra radiation dose.

Hybrid imaging is especially useful in inflammatory heart diseases, such as pericarditis, where it is necessary to evaluate inflammation, tissue composition, and anatomical variations simultaneously. An example is PEt/MRI, which can be used to correlate FDG uptake with CMR-based parameters (edema and fibrosis), enhancing the accuracy of the diagnosis and providing the opportunity to characterize the disease more accurately (Dweck et al., 2018; Fogante et al., 2025).

They also find application in oncologic assessment where they have the ability to measure tumor metabolism, extent of disease as well as response to therapy in a single imaging session. Nonetheless, cost, availability, and technical complexity are currently limiting the widespread use of hybrid imaging.

6.3 Artificial Intelligence Applications

The field of cardiovascular imaging, such as the assessment of pericardial diseases, is changing quickly due to artificial intelligence. AI methods, especially machine learning and deep learning, facilitate automatic image analysis, pattern recognition, and predictive modeling, which increases the accuracy and efficiency of the diagnosis. Deep learning algorithms have demonstrated to be capable of analyzing difficult imaging data, improving image quality, and assisting in segmenting and quantifying cardiac structure. They are particularly relevant to multimodality imaging, where much information across different modalities should be synthesized and interpreted (Litjens et al., 2019).

Recent advances have also shown that AI can automatically assess cardiac activity, including ventricular volumes and ejection fraction, with high accuracy and reproducibility. These instruments reduce interobserver error and provide greater efficiency to clinical practice (He et al., 2023; Ho et al., 2021).

Besides, machine learning models can be used to perform risk stratification and outcome prediction, using both clinical and imaging data to inform individual management strategies. E.g. the definition of patients who are at greater risk of developing constrictive pericarditis or recurrent disease can be based on predictive models (Tamarappoo et al., 2021).

6.4 Future Trends

The future of pericardial imaging is multimodality imaging with sophisticated computational techniques. The improvements in PET tracers to specific inflammatory pathways, the improvement of hybrid imaging systems, and the increased use of AI-based analytics are bound to give more precise diagnostics and clinical decision-making (Abouzeid et al., 2024).

The novel technologies that might enable the characterization of the disease activity in a non-invasive manner at a molecular level may also enable the early diagnosis and monitoring of therapeutic response. It is likely that these inventions will assume centre stage in individualized medicine to patients with pericardial diseases as it becomes more accessible.. The combination of positron emission tomography and CT makes it possible to evaluate the metabolic activity, especially in inflammatory and malignant pericardial diseases. Figure 3 demonstrates that PET/CT particularly comes in handy in the distinction of active disease versus chronic fibrosis.

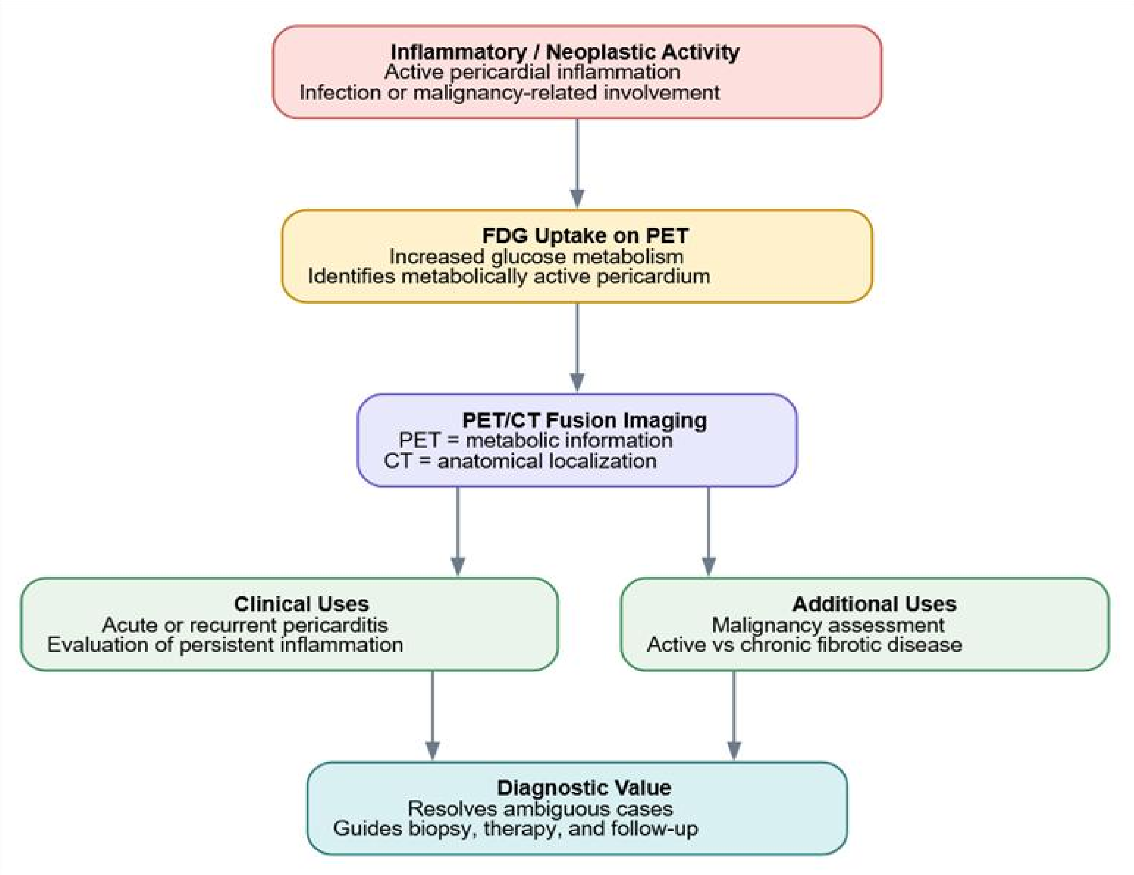

Figure 3. Role of PET/CT in Pericardial Inflammation

7. Clinical Integration and Diagnostic Approach

To diagnose and treat pericardial diseases, they must be assessed in a systematic and combined approach, including clinical examination and multimodality imaging. The pericardial conditions are heterogenous, and can occur in overlapping fashion, so a step-by-step imaging technique might be required to optimize the diagnostic outcome and minimize unnecessary tests and spending (Klein et al., 2024).

7.1 Stepwise Imaging Strategy

The first stages of the diagnostic pathway are typically a clinical examination and initial imaging with echocardiography to allow quick assessment of pericardial effusion, hemodynamic jeopardy, and macro-structural abnormalities. Echocardiography suffices in the diagnosis and initial treatment in most of the cases except in simple pericardial effusion or acute pericarditis.

Second-line imaging modalities (CT or CMR) are but employed in case of inconclusive results of echocardiography or when additional anatomical or tissue characterization is required. CT is the most suitable option, in the case of a necessity to determine the specific anatomical data, including pericardial calcification or thickness, but CMR is the more appropriate option to determine inflammation, fibrosis, and functional outcomes. This stepwise methodology make sure that imaging is specific to the clinical question (Osei et al., 2025).

More complex or refractory cases, particularly those that involve suspected malignancy or chronic inflammation, can also entail more advanced imaging such as PET/CT to identify the extent of metabolic activity and guide further treatment. The progressive increase in imaging modalities is a pointer of trade-off between the accuracy of diagnostic and resource consumption.

7.2 Decision-Making Algorithms

The use of algorithm-based clinical decision-making in pericardial diseases is becoming more and more dependent on imaging results, clinical and laboratory data. These algorithms can be used to standardize care, minimize variability, and provide timely diagnosis and intervention. As an example, the suspected constrictive pericarditis patients are first examined with echocardiography and then CT or CMR to determine the presence of pericardial thickening, calcification, or inflammation. Active inflammation on CMR could be an indication of a trial of anti-inflammatory therapy, and evidence of chronic fibrotic constriction could be a reason to refer to surgical pericardiectomy (Al-Kazaz et al., 2024).

Likewise, imaging is an important element of diagnosing persistent inflammation and informing treatment choices, including targeted therapeutics like interleukin-1 inhibitors, in recurrent pericarditis. Management strategies guided by imaging have been found to enhance the results and minimize the chances of recurrence (Imazio et al., 2023; Klein et al., 2021).

7.3 When to Escalate Imaging

Further imaging is justified in several clinical situations: Inconclusive or suboptimal echocardiography results, suspected constrictive physiology or restrictive cardiomyopathy, Recurrence of pericarditis or refractory pericarditis, suspected pericardial mass or malignancy, Preoperative imaging before pericardiectomy.

CT and CMR in these situations can be vital in providing complementary data which can help in narrowing diagnosis and management. The escalation of imaging must be a personal choice, grounded on clinical suspicion, and the potential effect on patient care (Osei et al., 2025).

7.4 Cost-Effectiveness Considerations

Although multimodality imaging has great diagnostic benefits, its application should be weighed against cost-efficiency and the use of resources. Unwarranted or unnecessary imaging may add to the overall healthcare expenditure with no patient outcome enhancement. Consequently, an evidence-based and specific approach is needed. The most affordable first modality is still the Echocardiography because it is affordable and is available everywhere. Only cases where advanced imaging methods like CMR and PET add diagnostic value should be used. Structured diagnostic algorithms are beneficial to optimize resource utilization by making sure that every imaging modality is utilized most appropriately and efficiently (Klein et al., 2024).

Furthermore, the right choice of imaging may save downstream costs through avoiding misdiagnosis, unnecessary invasive procedures, and timely intervention. An example is that proper distinction of constrictive pericarditis and restrictive cardiomyopathy would help avoid improper treatment and enhance patient outcomes (Al-Kazaz et al., 2024). Table 3 introduces a multimodality imaging algorithm step-by-step evaluation of pericardial diseases. It incorporates clinical situations and the suitable imaging pathways to aid decision-making.

Table 3. Suggested Multimodality Imaging Algorithm for Pericardial Diseases

Clinical Scenario	First-Line Imaging	Second-Line Imaging	Advanced Imaging	Reference
Suspected pericardial effusion/tamponade	Echocardiography	Not routinely required	Not indicated	(Klein et al., 2024)
Suspected constrictive pericarditis	Echocardiography	CT / CMR	PET (if inflammation	(Al-Kazaz et al., 2024)

			unclear)	
Recurrent pericarditis	Echocardiography	CMR	PET (selected cases)	(Imazio et al., 2023)
Suspected pericardial mass	Echocardiography	CT / CMR	PET/CT	(Klein et al., 2024)
Pre-surgical evaluation	Echocardiography	CT / CMR	Not routinely required	(Al-Kazaz et al., 2024)

8. Conclusion

The multimodality imaging is now playing a significant role in the overall assessment of pericardial diseases, overcoming the shortcomings of each specific imaging method, and providing a more precise and subtle diagnosis. The modalities used to determine cardiac structure, hemodynamics, tissue properties and metabolic activity (echocardiography, computed tomography (CT), cardiac magnetic resonance (CMR), and positron emission tomography (PET) provide different and complementary information. A combination of these modalities allows a more accurate evaluation of disease etiology, severity, and progression. Echocardiography continues to be the foundation of the initial assessment especially in identifying pericardial effusion and the hemodynamic compromise. The complex conditions like constrictive pericarditis and restrictive cardiomyopathy require detailed anatomical and tissue characterization which is offered by advanced imaging modalities like CT and CMR. Nuclear imaging also enhances the diagnostic potential by identifying active inflammation and malignancy, especially in challenging or atypical cases. A stepwise, systematically designed, based on clinical presentation and diagnostic requirement, and maximising the utilisation of resources and optimising diagnostic yield imaging process. New technologies, such as hybrid imaging and artificial intelligence, contribute to the further optimization of diagnostic pathways and help to implement individual management strategies. In conclusion, a multimodality imaging model can not only be used to improve the accuracy of diagnostic but also to provide prompt and sufficient therapeutic decisions, which ultimately lead to improved patient outcomes in pericardial diseases.

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