Review Article

Overview on Congestive Heart Failure Imaging

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ABSTRACT

Background: Heart failure is a complex clinical syndrome that results from a functional or structural heart disorder. Acute heart failure is one of the main diagnostic and therapeutic challenges in clinical practice due to a non-specific clinical manifestation and the urgent need for timely and tailored management at the same time. During the first hours of admission the point-of-care focused on cardiac and lung ultrasound examination that are invaluable tool for rapid differential diagnosis of acute dyspnoea, which are highly feasible and relatively easy to learn.

Objective: The study aimed to investigate the role of several portable and stationary imaging modalities, which are being increasingly used for the evaluation of cardiac structure and function, haemodynamic and volume status, precipitating myocardial ischaemia or valvular abnormalities, and systemic and pulmonary congestion.

Methods: For article selection, the PubMed database and EBSCO Information Services were used. All articles relevant with our topic and other articles were used in our review. Other articles that were not related to this field were excluded. The data was extracted in a specific format that was reviewed by the group members.

Conclusion: Heart failure is a main cause of mortality and morbidity worldwide. Assessment of the case is essential to determine the etiology and the best treatment strategy. For the assessment of HF patients, a variety of imaging techniques are used, each with advantages and disadvantages. For its accessibility, affordability, and utility, echocardiography remains the preferred method. It offers the majority of the data necessary it has been improved with the addition of 3DE and strain for the management and follow-up of patients with HF. In particular cases like ischemic heart disease, other methods may be helpful. It should be noted that the right imaging choice can assist in the management of the patient with HF.

Keyword: Heart, Ischemia, CHF, Imagining, MRI, CT.

Introduction

A functional or anatomical cardiac problem that impairs ventricular filling or blood ejection to the systemic circulation causes heart failure, a complex clinical condition. By definition, it is a failure to satisfy the underlying needs of circulation [1, 2]. Due to a non-specific clinical presentation and the urgent requirement for timely and customized care at the same time, acute heart failure is one of the major diagnostic and therapeutic problems in clinical practice. The differential diagnosis of underlying pathology is difficult yet essential for prompt and individualised care because many co-existing or alternative disorders with differing pathophysiology can produce similar clinical pictures [3, 4].

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The point-of-care focused cardiac and lung ultrasound examination, which is highly practical and comparatively simple to learn. US is an excellent tool for rapid differential diagnosis of acute dyspnea during the initial hours of admission [5]. Imaging modalities are crucial for quick triage and accurate diagnosis in emergency departments, as well as for subsequent clinical decisions during the stabilisation phase. These assessments include the initial routine evaluation (clinical examination, electrocardiogram), as well as laboratory parameters (natriuretic peptides, troponins, D-dimer and inflammation markers) [6, 7]. For the assessment of cardiac structure and function, haemodynamic and volume status, triggering myocardial ischaemia or valve anomalies, and systemic and pulmonary congestion, a number of mobile and stationary imaging modalities are being used more often [8]. New imaging methods that can make an early diagnosis and direct treatment are needed due to the rising prevalence of heart failure. The number of new cases of heart failure is predicted to be 825,000 per year in the US, and by 2030, it is anticipated that this number would have surpassed 8 million [9, 10]. To evaluate the degree of pulmonary congestion and the heart shape, chest radiographs are employed (to determine the presence of cardiomegaly). Chest radiographs may show an enlarged cardiac silhouette, edema at the bases of the lungs, and vascular congestion, all signs of congestive heart failure. On chest radiographs, Kerley B lines can be detected in florid heart failure [11, 12]. Unscheduled short-term readmission may be avoided with proper assessment of heart filling pressures and appropriate prognostication. Advanced imaging techniques such as cardiac magnetic resonance, computed tomography, nuclear studies, and coronary angiography should be taken into account to help with patient management during the pre- and post-discharge phases [13].

Epidemiology and etiology

A previous study from Framingham found that the incidence of HF was between 1.4 and 2.3 per 1000/year among people aged 29 to 79 using standardized criteria [14, 15]. Today, there are more than 5.8 million common instances of heart failure in the U.S., and more than 550,000 new patient reported are diagnosed annually. Medicare hospital cases from 1986 and 1993 were used to compare the rates of initial admission to hospital for HF. The study found an increase in the rate of early hospitalization for HF. The incidence of HF was rising over time, according to data from Henry Ford Health system [16]. While, the trend in deaths or the diagnosis was not clear yet. The incidence of HF in women in the Olmsted County Study [17], And the Framingham Heart Study [18], which both include outpatient HF, remained steady over time [17] or even decreased. One in five women is thought to experience heart failure (HF) by the time they reach the age of 40. In addition, hospitalization rates for HF have risen for women over time while falling for males. Heart failure (HF) is a significant cause of death and morbidity in women. The magnitude and rate of cardiac performance impairment, patient age, which ventricle is initially affected by the disease process, and other variables all have a role in the clinical presentations of HF. HF is typically defined as having heart function impairments ranging in severity from mild to severe. The severity of impairment ranges from the mildest types, which only shows clinical signs under stress, to the most severe types, in which the heart pump function cannot support life on its own [19].

Diagnosis

The majority of HF diagnoses are clinical, based on recognizable signs and symptoms. However, assessment of the left ventricular ejection fraction (LVEF), which is also beneficial for patient care and risk assessment, is necessary for classification and verification. Although echocardiography is typically the initial imaging modality utilized for LVEF, other methods exist and may also have unique benefits in some circumstances. Further imaging may be necessary to determine the epidemiology and diagnosis of HF to direct subsequent clinical therapy.

1. Echocardiography

In cases with CHF, echocardiography is the chosen test due to its low cost and being non-invasive technique. To assess cardiac output, pulmonary artery and ventricular filling pressures, as well as systolic and diastolic left ventricular (LV) performance and two-dimensional and Doppler echocardiography may be utilized [20]. To detect valve disease that is clinically significant, echocardiography may also be performed [21, 22]. Although, echocardiography is straightforward and noninvasive, it is ineffective in about 10% of instances, and patients with lung illness may have difficulties in comprehending their results. High levels of reliability and low rates of false-positive and false-negative results are attributes of echocardiography being used the most. Three-dimensional (3D) echocardiography has been made possible by recent developments in ultrasound equipment and computerization, ushering in a new era in cardiovascular imaging [23]. Since the heart is a complicated 3D structure, study of the heart in motion in all three or four dimensions can help and improve echocardiography's diagnostic powers. The development of 3D echocardiography is ongoing giving a clearer characterization of the intra cardiac interaction of the structures and a better knowledge of the topographical elements of disease [24]. Additionally, it may offer a novel index, such as commissural calcification, that 2D echocardiography was unable to detect and improve the accuracy of the ones that are already available, such as patients with mitral valve diseases whose assessment is challenging and difficult using 2D echocardiography [25]. Using echocardiography to detect Systolic activity where the most popular strain-based indicator of LV global systolic performance is global longitudinal strain (GLS), which is frequently assessed by speckle-tracking echocardiography and reflects the change in the length of the LV myocardium between end-diastole and end-systole. Additionally, it is estimated that a healthy person will have a peak GLS in the neighbourhood of 20%. Results from chemotherapy patients reveal that minor ejection fraction (EF) abnormalities precede early cardiac deformation changes [26, 27]. An early reduction in GLS of 10% to 15% is the most accurate indicator of cardiotoxicity, which is defined as a decline in LVEF or HF during therapy [28]. Additionally, by showing a relative "apical sparing" pattern, regional differences in LS from base to apex, and lower basal strain, 2D imaging may be helpful in distinguishing cardiac amyloidosis from other leading cause to cardiac hypertrophy. In order to properly assess suspected HF, a thorough diastolic assessment is necessary. LV diastolic pressures in certain people has normal value at rest but then become abnormal after activity. The maximal tricuspid regurgitant velocity and the E/e' ratio are usual echocardiographic measurements taken during or right after exercise. While, their sensitivity is just 76%, these characteristics have a high specificity of 96%. Increased rise in the E/e' ratio during physical exercise is indicative of both LV end-diastolic pressures and a worsening prognosis [29, 30]. When compared to other imaging techniques, echocardiography is less effective at identifying the cause with hypertrophic cardiomyopathy or mitral regurgitation in doubtful circumstances, stress echocardiography is particularly interesting due to its dynamic character and its ability to rule out ischaemia [31].

2. Computed tomography (CT)

Cardiac CT imaging seeks to reduce scan durations and radiation exposure by utilising ECG and cutting-edge technology. Multidetector CT (MDCT) can determine infarct size with exact results in patients with non-MRI conditional pacemakers or defibrillators in correlation to measurements obtained using cardiac MRI [32, 33]. Due to its greater negative predictive accuracy and ability to identify obstructive CAD6, even in populations with heart failure, CT is regarded as the best examination technique for patients with coronary artery disorders. Additionally, it offers information on cardiac structure, chamber sizes, and extra-cardiac outcomes that may be useful for patients who have heart failure brought on by complicated coronary pathologies or multisystem diseases such rheumatoid arthritis and chronic lung illness [34]. Rochite et al. [35] prospectively evaluated the diagnostic efficacy of myocardial CT perfusion for the diagnosis of obstructive coronary artery disorder (CAD) to invasive catheter angiography with a comparable perfusion deficit using single photon emission tomography/myocardial perfusion scanning (SPECT/MPS). In this investigation of 381 patients from 16 centres, the authors were able to demonstrate a sensitivity of 80% and a specificity of 74% for obstructive CAD when compared to the gold standard of ICA + SPECT/MPS. Radiation exposure and delivery of contrast are the procedure's two main dangers. Patients who are contraindicated for receiving iodinated contrast injection cannot undergo cardiac CT. Moderate to severe renal failure and prior contrast allergy are two more related contraindications.

3. Magnetic resonance imaging (MRI)

Cardiovascular magnetic resonance (CMR) has developed as a more effective imaging modality when conventional imaging modalities like echocardiography are unable to pinpoint the cause of HF. Additionally, CMR is essential for determining prognosis and guiding therapy choices [36, 37]. CMR is not a part of the assessment procedure in acute HF due to limited monitoring capacity, patient intolerance of lying flat, and lower picture quality. CMR is often used in the treatment of HF patients. The majority of the time, CMR is advised for myocarditis and cardiomyopathy examination as well as risk stratification in cases of suspected ischaemia, according to the European CMR registry [38]. Magnetic resonance imaging generates the image signal by "stimulating" hydrogen nuclei that are oriented to the scanner's field with radiofrequency wave pulses (MR). Energy is lost as the excited nuclei recover to equilibrium magnetization. The breakdown of the longitudinal and transverse components of magnetization is described by T1 relaxation and T2, respectively. Because T2* relaxation also takes into consideration dephasing that is hastened by localised inhomogeneities in the global magnetic field, it happens more quickly than T2 relaxation. Only dephasing brought on by random proton-proton interaction is taken into consideration by T2. By assessing LV performance, CMR is the main imaging method used to evaluate myocarditis in medically stable patients. The CMR with T2* technique gives a conclusive diagnosis in patients diagnosed with HF and potential iron overload. When there is cardiac amyloidosis, short T1, high blood pool wash-out, insufficient myocardial nulling, and elevated myocardial gadolinium enhancement are frequently seen on CMR [15]. In conclusion, CMR uses the wealth of information from quantitative volumetric analysis and T1, T2, and T2* mapping sequences to characterise the cardiac tissue in order to help with diagnosis, risk classification, therapy recommendations, and prognosis [39- 41]. Recent research has connected gadolinium-based contrast agents (GBCA) with nephrogenic systemic fibrosis, a rare multisystemic fibrosing condition. It has been demonstrated that late gadolinium enhancement (LGE) patterns can distinguish between non-ischemic cardiomyopathy (NICM) and ischaemic cardiomyopathy (ICM) [30]. There is no known treatment for this sickness, and symptoms may not appear for months or even years after exposure in patients with severe renal insufficiency. Therefore, GBCA should be avoided in high-risk patients unless the diagnostic information is absolutely necessary and is not accessible through non-contrast enhanced CMR or other imaging modalities [42]. Other non-invasive imaging methods can't compare to CMR's precision, repeatability, limitless field of vision, radiation abatement, and capacity to differentiate heart tissue. In order to assess LV volumes and EF [43]. One example of a CMR tissue characterisation technique is the evaluation of diffuse fibrosis using extracellular volume (ECV) measurements and T1 mapping. The aetiology of cardiomyopathy was identified with 100% sensitivity and 96% specificity in a recent study on the diagnostic use of CMR. For assessing ischaemia or viability in HF patients, CMR has a very strong safety track record [44–46].

4. Radionuclide multiple-gated acquisition (MUGA) scan

Nuclear imaging techniques like multigated acquisition (MUGA) scanning let doctors assess the dynamic and structural characteristics of the heart. In order to produce a composite video of several cardiac cycles and display it in 2 dimensions on the computer. MUGA scans involve taking numerous images of the heart at various periods in time. This helps the medical professional evaluate particular heart characteristics at rest and under pressure. Knowing these factors is very helpful, especially for cancer and heart patients, as both cardiovascular disorders and cardiotoxic cancer therapy have significant mortality rates. The MUGA scan offers a better understanding of heart structure and dynamics, improved diagnostic and prognostic accuracy, and cardiac function tracking for patients. MUGA scans use radioactive isotopes that are given to and linked with RBCs. The purpose of labeling RBCs with radioisotopes or detectors is to use a gamma camera to collect photons released by these isotopes. These cameras have a sodium iodide crystal connected to photomultipliers, which aid in transforming the energy of the acquired photon into a picture. Since the heart receives enough radiation to be detected by the gamma camera and technetium-99m (Tc-99m) that has a half-life of six hours [47]. It is the radioisotope of choice for MUGA scans. Additionally, being renal eliminated and excreted in the urine make it the ideal radioisotope. The patients' blood is initially taken from an IV line and combined with the radioactive isotope before being given back to them through the same IV line. It takes the tracer about 15 minutes to balance in the circulation. In first-pass MUGA scanning, when a radioisotope bolus is administered over a longer initial intravenous push and the patient is photographed right away, this is adjusted. In non-first pass MUGA scanning, the ECG rhythm is assessed for appropriate R-R progression once the tracer achieves equilibrium, and once this is confirmed, the gamma camera is utilized to take pictures. When evaluating wall motion and left ventricle EF, at least 16 pictures per R-R interval are typically collected. The most typical application of MUGA scanning is the repeated evaluation of patients receiving cardiotoxic chemotherapy regimens. Anthracyclines are often used chemotherapeutic drugs for the treatment of cancer. Anthracyclines have been demonstrated to result in congestive heart failure in a dose-dependent and cumulative manner (AIC). In cases of systolic cardiac failure, the MUGA scan can also be clinically useful. In these situations, the accurate assessment of LVEF is essential in deciding whether to proceed with implantable cardioverter-defibrillators (ICD) or not, and it is accomplished with the least amount of variance using MUGA scan [48]. Patients who have a multigated acquisition (MUGA) scan run very little risk. The scan does, however, use radioactive isotope tracers, thus there is a risk of radiation exposure even if the overall radiation exposure to the patients is very low [49]. There is a danger of bleeding near the injection site and an adverse reaction to the substance infused, as with any substance infused in the body. In conclusion, the MUGA scan is not applied very frequently due to the extensive use of echocardiography and the growing use of magnetic resonance imaging for evaluating LVEF and diastolic function. It still has a purpose, nonetheless, in determining the myocardial function of patients receiving cardiotoxic chemotherapy and in situations when an accurate, repeatable, and interpreter-free evaluation of LV function is required.

5. Electrocardiogram (ECG)-gated myocardial perfusion imaging

Nowadays, single-photon emission computer tomography (SPECT) that is ECG-gated for myocardial perfusion is a widely utilised technology, and composite data on perfusion and function have been employed for both diagnostic and prognostic purposes. Since the 1990s, there has been a lot of research on quantifying SPECT, and it has been discovered that functional measurements like ejection fraction (EF) and left ventricular (LV) volume have a strong correlation with outcomes from left ventriculography, gated blood-pool studies, and MRI. Additionally, these parameters are fairly repeatable across different institutions [50]. Commonly acknowledged as an evidence-based, non-invasive method for detecting myocardial ischemia and stress SPECT MPI. Stress perfusion is frequently aberrant in myocardial ischemia, and rest perfusion either returns to normal in full or in part. Recently, stress or stress/rest MPI for the diagnosis of obstructive CAD has been studied using deep learning and other artificial intelligence techniques. However, many patients are unable to undergo stress MPI due to a number of stress test constraints. Only 30% of all patients suspected of having CAD displayed abnormal resting perfusion which wasn't really sensitive. The sensitivity of wall motion and resting perfusion for the diagnosis of CAD increased but remained poor at 46.8%. Increasing the accuracy of resting MPI for the identification of obstructive CAD has significant clinical consequences [50]. Gated SPECT has become increasingly popular as a result of advancements in imaging hardware, computer engineering, and the creation of novel radioisotopes. The 99mTc-based perfusion tracers enable measurement of myocardial wall motion and thickening across the cardiac cycle due to their greater count rates and stable myocardial distribution over time. Its prevalent use has also been facilitated by the creation of automated algorithms that quantitatively measure the size of the left ventricle (LV) and its ejection fraction (EF), as well as performing all of this quickly, accurately, and with negligible operator interaction.

6. Iobenguane scanning

Heart failure is characterized by elevated myocardial sympathetic activity, which is frequently accompanied by deteriorating symptoms, reduction in left ventricular function, and abrupt cardiac death. Norepinephrine (NE) storage and absorption are reduced as a result of this increase. Iobenguane offers a way to evaluate the neuronal capacity for NE uptake and storage. Imaging with iobenguane employs the heart to mediastinum (H/M) ratio to evaluate the efficiency of the sympathetic nerves, whereas existing prognostic tests focus on the impact of the condition on heart tissue and blood circulation. The identification of sympathetic nervous system dysfunction using 123I may be possible to identify early poor clinical outcomes by using iobenguane myocardial scintigraphy (MIBG), which has been shown to be a valid predictor of sudden cardiac SCD death in individuals with CHF [50].

Conclusion

Heart failure is a main cause of mortality and morbidity worldwide. Assessment of the case is essential to determine the etiology and the best treatment strategy. For the assessment of HF patients, a variety of imaging techniques are used, each with advantages and disadvantages. For its accessibility, affordability, and utility, echocardiography remains the preferred method. It offers the majority of the data necessary it has been improved with the addition of 3DE and strain for the management and follow-up of patients with HF. In particular cases like ischemic heart disease, other methods may be helpful. It should be noted that the right imaging choice can assist in the management of the patient with HF.

Conflict of Interest

None

Funding

None

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