Congestive Heart Failure: A Review of Severity Classification, Imaging, and Pre–Heart Transplant Planning

Alexander N. Diaz[1], Matthew D. Cham

Heart failure is a clinical syndrome in which the heart is unable to pump blood effectively to meet the body's metabolic needs. This inefficiency can result from numerous causes including nonischemic cardiomyopathies, coronary artery disease, and congenital heart disease. Heart failure is a significant public health concern that affects 6.7 million adults in the United States alone. This prevalence is expected to increase due to the aging population and rising rates of conditions that contribute to heart failure, including hypertension, diabetes, and obesity [1, 2]. The prevalence of heart failure varies by age, sex, and race. It is more common in older adults, with a significant increase in incidence and prevalence after age 65. Additionally, heart failure is more prevalent among Black adults compared with White adults; it affects men and women nearly equally [3, 4].

Heart failure can be acute or chronic and may be categorized into left-sided, right-sided, or biventricular heart failure. Left-sided heart failure results from left ventricular dysfunction, which leads to pulmonary edema and dyspnea. Right-sided heart failure occurs with right ventricular dysfunction, resulting in peripheral edema [5]. Management typically involves lifestyle modifications, medications such as angiotensin-converting enzyme inhibitors and β-blockers, and, in chronic severe cases, heart transplant. The goal of management is to alleviate symptoms, improve quality of life, and address underlying causes [6].

Criteria for Heart Failure

Well-established clinical criteria for determining the severity of congestive heart failure (CHF) in adult patients include the New York Heart Association (NYHA) criteria and the American College of Cardiology/American Heart Association (ACC/AHA) criteria. For radiologists, familiarity with these criteria can aid in recognizing imaging findings that may be present in patients with compensated and decompensated CHF and when it may be pertinent to discuss imaging findings relevant to heart transplant planning. For cardiologists, these criteria are useful in determining prognosis, informing treatment strategies, and, in severe cases, establishing the need for heart transplant in patients with CHF [3].

The NYHA criteria, established in 1928 and most recently revised in 1994, focus on the extent to which the patient's functional status is limited by symptoms of CHF. The NYHA criteria split disease into one of four categories (Table 1). Class I disease does not limit the patient's physical activity, class II disease results in slight limitations in physical activity but no symptoms at rest, class III disease causes marked limitations in physical activity but no symptoms at rest, and class IV disease results in inability to perform any physical activity and even symptoms that occur at rest [7].

The ACC/AHA criteria for evaluating and managing CHF were established in 1995 and updated in 2022. The ACC/AHA criteria also split patients into four stages of heart failure, based on clinical features of the disease (Table 2). Patients in stage A are at risk for heart failure but manifest no symptoms and have no evidence of structural or functional heart disease. Risk factors for these patients may include hypertension, coronary artery disease, metabolic disease, genetic predisposition to heart failure, or use of cardiotoxic agents. Patients in stage B are defined as having pre–heart failure; these patients have never experienced symptoms of heart failure but have evidence of structural heart disease, such as elevated left heart filling pressures or cardiomegaly. Patients in stage C have symptomatic heart failure and are either experiencing symptoms of CHF or have had symptoms in the past. Patients in stage D have advanced heart failure, with symptoms that interfere with their daily lives or lead to repeated hospitalization [8].

Imaging Features of CHF

The typical radiographic features of CHF include cardiomegaly and evidence of volume overload, such as pulmonary edema, pleural effusions, pericardial effusion, peripheral edema, and ascites. Early in the disease, cardiomegaly may be the only radiographic feature present (Fig. 1), and echocardiography may be useful in establishing evidence of structural and/or functional heart disease, with findings such as impaired systolic function, abnormal end-diastolic chamber volume, or elevated end-diastolic filling pressures. Later in the course of disease, in patients manifesting clinical symptoms of CHF, imaging findings related to pulmonary edema may become evident [3].

Pulmonary edema in patients with CHF is typically ascribed to increased hydrostatic pressure across the pulmonary capillary bed attributable to increased left-sided heart pressures [9]. Less severe cases manifest with interstitial pulmonary edema, evident radio-

[1]Both authors: Department of Radiology, University of Washington Medical Center, 1959 NE Pacific St Main Hospital #1235, Seattle, WA 98195. Address correspondence to M. D. Cham (mdcham@uw.edu).

TABLE 1: NYHA Criteria for Determining CHF Severity

Class	Limitations on Physical Activity	Presence of Symptoms at Rest
I	None	No
II	Slight	No
III	Marked	No
IV	Significant and physical activity results in worsening symptoms	Yes

Note—NYHA = New York Heart Association, CHF = congestive heart failure.

TABLE 2: ACC/AHA Criteria for Determining CHF Severity

Stage	Heart Failure or Structural or Functional Heart Disease
A	Risk factors present but no signs or symptoms
B	Evidence of structural or functional heart disease but no symptoms of CHF (current or previous)
C	Current or previous symptoms of CHF
D	Symptoms of CHF interfere with daily life, result in repeated hospitalization, or both

Note—ACC = American College of Cardiology, AHA = American Heart Association, CHF = congestive heart failure.

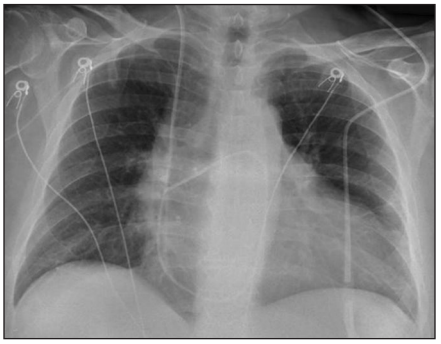

Fig. 1—Upright chest radiograph shows cardiomegaly, with heart measuring greater than 50% of width of chest cavity. Splaying of carina and dual contour of right heart border also suggest left atrial enlargement. Swan-Ganz catheter is present, with tip in distal right pulmonary artery.

graphically as blurriness of the segmental and subsegmental pulmonary vasculature, presence of Kerley B lines, and possibly small pleural effusions (Fig. 2A). As hydrostatic pressure increases, the lobar and central vasculature approaching the hilum appear increasingly prominent [10] (Fig. 2B). On CT, these findings are evident as smooth interlobular septal thickening and bronchial wall thickening (Fig. 2C). In more severe cases, when fluid drainage from the lymphatic and interstitial compartment is at its limit, alveolar flooding ensues as fluid escapes into the alveoli to decompress the intravascular compartment. At this point, nodular or fluffy pulmonary opacities are evident on radiographs and ground-glass opacification is apparent on CT scans (Fig. 2D). If the pressure increase is sufficiently high, these opacities become confluent consolidations on radiography and CT and in severe cases, the pressure increase may be sufficient to induce damage to the surface epithelium of the alveoli, further increasing alveolar permeability, which can progress to acute respiratory distress syndrome. Pleural and pericardial effusions of increasing size may accompany these findings [10].

Imaging and Planning Before Heart Transplant

Heart transplant is the surgical replacement of a diseased heart with a healthy donor heart. It is reserved for patients with end-stage heart failure or severe heart disease when other treatments are no longer effective or are contraindicated. The procedure involves complex evaluations to ensure the donor heart's suitability and the recipient's readiness. Heart transplant is a multidisciplinary procedure that demands rigorous planning and coordination. Radiologists play a crucial role in this process by providing essential imaging data that influences the decision-making and surgical considerations. This chapter covers the multifaceted role of radiologists in heart transplant planning, focusing on imaging techniques, their applications, and the integration of imaging findings with clinical management.

Indications for Heart Transplant

Specific clinical criteria must be met for heart transplant listing [2, 11, 12] (Tables 3 and 4). Specific cardiac diseases that account for the majority of heart transplants include end-stage nonischemic cardiomyopathy, end-stage ischemic cardiomyopathy, congenital heart disease, and myocarditis.

End-Stage Nonischemic Cardiomyopathy

This broad category encompasses myocardial diseases that can result in severe cardiac dysfunction in the context of nonobstructive or absent coronary artery disease. End-stage nonischemic cardiomyopathy is the leading cause of heart failure in transplant candidates and accounts for about 58% of heart transplants [13].

About 51% of heart transplants are due to a nonischemic dilated cardiomyopathy (DCM). DCM is characterized by dilation and impaired contraction of the left or both ventricles (Fig. 3A). DCM may be the result of genetics, viral infections, alcohol abuse, and idiopathic causes. Patients with DCM typically present with progressive heart failure, arrhythmias, and exercise intolerance. The diagnosis of DCM is often made on the basis of echocardiography, blood tests, and genetic screening. The initial treatment approach for DCM includes heart failure medications, lifestyle modifications, and implantable devices. Heart transplant is indicated when DCM is severe, refractory to treatment, and significantly impacts quality of life.

Restrictive cardiomyopathy (RCM) accounts for about 4% of heart transplants. RCM is characterized by diastolic dysfunction and impaired ventricular filling. It is often a result of systemic diseases including amyloidosis, sarcoidosis, and hemochromatosis (Fig. 3B). Patients typically present with dyspnea, fatigue, and symptoms of heart failure. Diagnosis is made on the basis of echocardiography, cardiac MRI, and, in some cases, biopsy. Treatment options focus on managing symptoms and underlying conditions. Heart transplant is

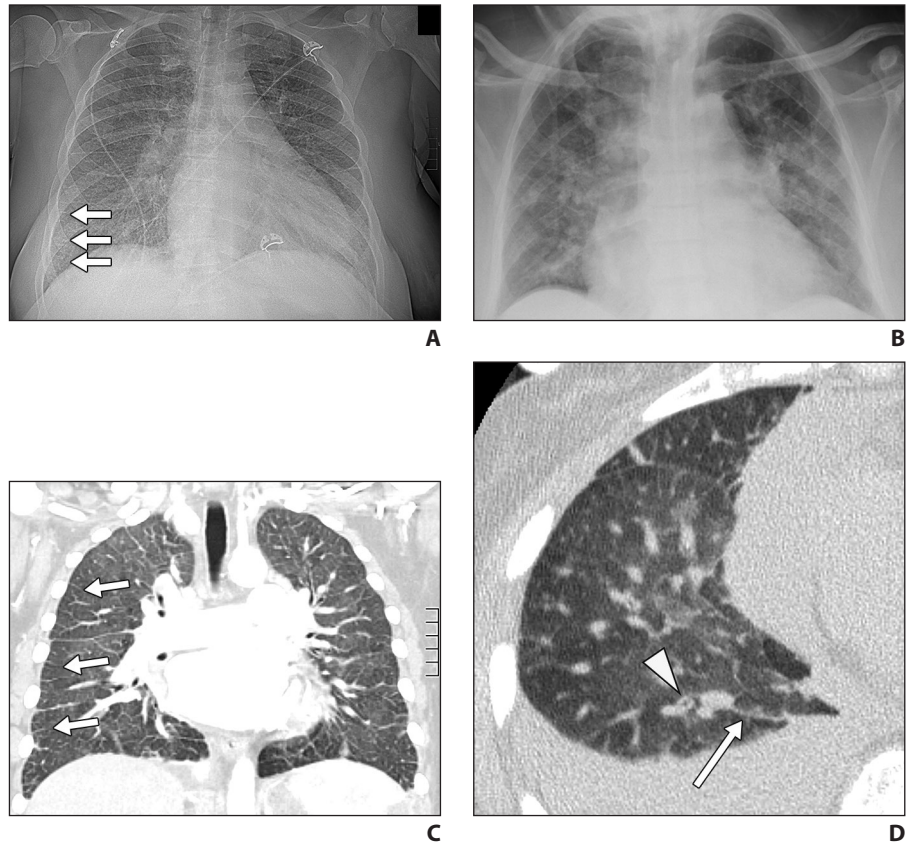

Fig. 2—Pulmonary edema.
A, Anteroposterior chest radiograph shows Kerley B lines (*arrows*), suggestive of mild pulmonary edema, in patient with cardiomegaly and small bilateral pleural effusions.
B, Chest radiograph shows cardiomegaly, fluffy perihilar opacification, and prominent indistinct central pulmonary vasculature, all suggestive of pulmonary edema.
C, Coronal CT image of chest shows subtle diffuse ground-glass opacification and smooth interlobular septal thickening (*arrows*) in patient with interstitial pulmonary edema.
D, Axial CT image of right lower lobe shows ground-glass opacification, smooth interlobular septal thickening (*arrow*), and bronchiole wall thickening (*arrowhead*) in this patient with pulmonary edema and medium-sized pleural effusion.

considered for advanced RCM that is unresponsive to treatment and severely affects cardiac function.

Hypertrophic cardiomyopathy (HCM) is the underlying pathology in about 3% of heart transplants. HCM is characterized by asymmetric thickening of the myocardium, often involving the ventricular septum (Fig. 3C). It is most often genetic, although some genetic markers have yet to be identified. Patients with HCM present with dyspnea, chest pain, and syncope. The diagnosis of HCM is typically made from echocardiography, genetic testing, or cardiac MRI. Initial treatment options for HCM include medications, lifestyle modifications, and surgical or minimally invasive interventions. Heart transplant is considered for patients with severe refractory symptoms despite treatment or those with end-stage heart failure.

TABLE 3: Indications for Referral to Heart Transplant Listing

Type of Indication	Indications
Absolute	Cardiogenic shock requiring continuous IV ionotropic or mechanical circulatory support for organ perfusion
	Persistent NYHA functional class IV heart failure refractory to optimized medical and surgical therapy
	Nonischemic cardiomyopathies with NYHA class III to IV heart failure plus other criteria
	Severe angina due to coronary artery disease not amenable to revascularization
	Congenital heart disease in an adult with NYHA class IV heart failure, severe symptomatic cyanotic heart disease, or potentially irreversible pulmonary hypertension, not amenable to medical or surgical therapies
	Intractable life-threatening arrhythmias unresponsive to medical, catheter-based, surgical, and implantable cardioverter-defibrillator therapies
Relative	Heart failure that severely limits daily activities despite medical therapy
	Recurrent unstable ischemia despite other interventions
	Recurrent fluid imbalance despite medical compliance
Inadequate	Reduced left ventricular ejection fraction
	Functional NYHA class III or IV heart failure
	Peak maximal oxygen consumption > 55% of predicted or > 15 mL/kg/min

Note—NYHA = New York Heart Association.

End-Stage Ischemic Cardiomyopathy

Heat transplant is indicated for end-stage ischemic cardiomyopathy or when coronary artery bypass grafting or percutaneous interventions are not feasible. This accounts for about 32% of heart transplants [13]. Ischemic cardiomyopathy is heart failure resulting from coronary artery disease (CAD), leading to myocardial ischemia and infarction. Patients typically present with chest pain, dyspnea, fatigue, and arrhythmias. Imaging tests to diagnose CAD include coronary CTA, nu-

clear imaging, echocardiography, and cardiac MRI. Treatment strategies typically begin with medications, lifestyle modification, and coronary revascularization procedures. Heart transplant is considered when CAD is severe and unresponsive to treatment and left ventricular function is significantly impaired.

TABLE 4: Contraindications to Heart Transplant

Type of Contraindication	Contraindications
Absolute	Systemic illness with life expectancy < 2 y despite heart transplant
	Irreversible pulmonary hypertension, with some exceptions that vary by institution
	Multisystem disease with severe extracardiac organ dysfunction, such as some cases of amyloidosis
	Clinically severe symptomatic cerebrovascular disease
	Active substance misuse including drugs, tobacco, or alcohol
	History of chronic medical noncompliance
Relative	Age > 70 y, with some exceptions that vary by institution
	BMI > 35
	Diabetes mellitus with hemoglobin A1c level > 7.5% despite optimal effort or some cases of end-stage organ damage
	Irreversible renal dysfunction with eGFR < 30 mL/min/1.73 m^2
	Neoplastic or infectious history, determined on a case-by-case basis
	Acute pulmonary embolism within 8 wk
	Tobacco use or substance misuse within 6 mo
	Cognitive-behavioral disability or deficient social support would lead to medical noncompliance
	Conditions that limit tolerance of immunosuppression

Note—eGFR = estimated glomerular filtration rate.

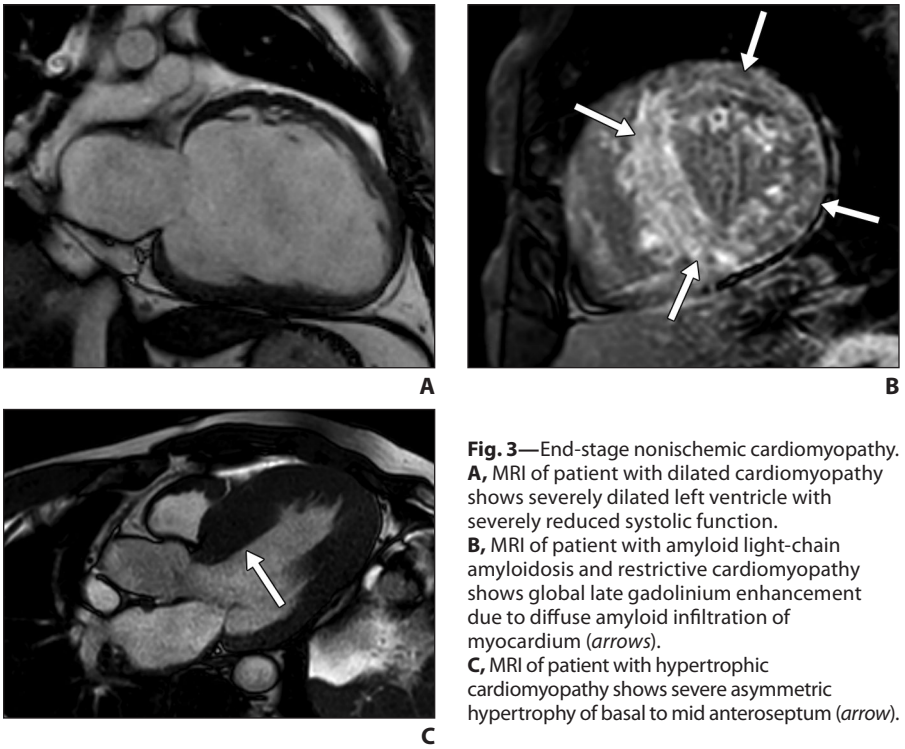

Fig. 3—End-stage nonischemic cardiomyopathy.
A, MRI of patient with dilated cardiomyopathy shows severely dilated left ventricle with severely reduced systolic function.
B, MRI of patient with amyloid light-chain amyloidosis and restrictive cardiomyopathy shows global late gadolinium enhancement due to diffuse amyloid infiltration of myocardium (*arrows*).
C, MRI of patient with hypertrophic cardiomyopathy shows severe asymmetric hypertrophy of basal to mid anteroseptum (*arrow*).

Congenital Heart Disease

Heart transplant is also necessary for some cases of complex congenital heart disease when cardiac dysfunction is severe and no longer surgically correctable or medically manageable. Approximately 3% of heart transplants are performed in patients with congenital heart disease (CHD) [13]. Combined heart-lung transplant is most commonly performed for complex CHD with nonidiopathic pulmonary hypertension (Eisenmenger syndrome), comprising approximately 38% of heart-lung transplants, followed by idiopathic pulmonary hypertension (28%) and cystic fibrosis (15%) [14].

CHD includes a range of structural heart defects present from birth, such as tetralogy of Fallot, transposition of the great arteries, and single ventricle defects [15, 16] (Fig. 4). The clinical signs and symptoms can vary widely depending on the specific cardiac lesion(s), including cyanosis, heart failure, and exercise intolerance. Diagnosis is typically made with echocardiography, cardiac MRI, and occasionally genetic testing. Initial treatment options include surgical correction, catheter-based interventions, medications, and supportive care. Heart transplant is considered when CHD leads to progressive heart failure, CHD is not amenable to further surgical correction, or the patient's quality of life is significantly compromised.

Myocarditis

Myocarditis is the indication in about 1% of heart transplants [17]. Myocarditis is inflammation of the heart muscle, which can be primary (idiopathic or autoimmune) or secondary to viral infections, medications, or systemic diseases (Fig. 5). Patients typically present with chest pain, fever, heart failure symptoms, and arrhythmias. Diagnosis is often performed on the basis of clinical history, blood tests, echocardiography, cardiac MRI, and, rarely, endomyocardial biopsy. Initial treatment options are aimed at addressing underlying causes, antiinflammatory medications, and supportive care. Heart transplant is considered when myocarditis leads to severe refractory heart failure and when other treatments are ineffective.

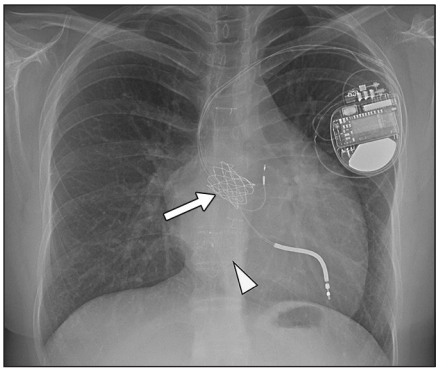

Fig. 4—37-year-old woman who had undergone atrial switch repair (Mustard operation) for dextrotransposition of great arteries. Patient presented with progressive decline in maximal oxygen consumption and worsening symptoms corresponding to New York Heart Association class III and underwent heart transplant evaluation process. Superior vena cava (*arrow*) and inferior vena cava (*arrowhead*) stents were implanted to treat baffle stenoses.

Importance of Imaging Before Heart Transplant

Imaging before heart transplant is fundamental in evaluating cardiac conditions and in surgical planning. Ensuring that both the donor and recipient are suitable for transplant is critical. This includes assessing cardiac anatomy, function, and potential comorbid conditions that could affect the outcome. Radiologists provide critical data that help in assessing cardiac structure, function, and any abnormalities that could impact transplant. Radiologists play key roles in optimizing anatomic and physiologic information for the surgical team.

Imaging Techniques and Their Applications

Chest Radiography

Chest radiography provides initial information on heart size, pulmonary vasculature, and potential lung pathology. Key findings include cardiomegaly, pulmonary edema, and pleural effusion [18].

Transthoracic Echocardiography

Transthoracic echocardiography (TTE) assesses overall cardiac function, chamber sizes, and valve function. Important parameters include left ventricular ejection fraction, wall motion abnormalities, and valve pathology [19].

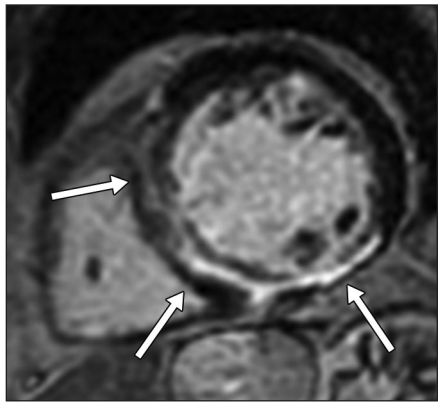

Fig. 5—MRI of patient with myocarditis shows extensive midwall late gadolinium enhancement (*arrows*) in mid anteroseptum, inferoseptum, and inferior walls.

Transesophageal Echocardiography

Transesophageal echocardiography (TEE) provides detailed images of the heart's internal structures, useful for assessing intracardiac thrombi or masses. TEE is particularly helpful when TTE is insufficient or detailed imaging is required [19].

Cardiac MRI

Cardiac MRI offers high-resolution cine imaging of myocardial tissue and detailed analysis of cardiac and valvular function. It includes late gadolinium enhancement imaging for tissue characterization and assessment of myocardial scar or infiltration. It is particularly effective in quantifying myocardial fibrosis, inflammation, or infiltration [20].

Cardiac and Coronary CTA

Coronary CTA evaluates coronary artery anatomy, aortic root, and major thoracic vessels. Its primary benefit is the noninvasive assessment of coronary arteries and surgical planning. It can identify and quantify coronary artery disease, aortic abnormalities, and anatomic issues that can affect the surgical approach [21].

Nuclear Imaging

SPECT and PET are used to evaluate myocardial perfusion and viability and may include both stress testing and myocardial perfusion imaging. They can identify areas of reduced perfusion and indicate areas of myocardial viability [22]. Despite its lower spatial resolution compared with cardiac MRI, nuclear imaging remains particularly effective in patients with implanted devices that degrade or preclude cardiac MRI.

Chest CT

Recipient chest CT can also be used in the pre–heart transplant evaluation process, although it is not as essential as other modalities such as echocardiography or cardiac MRI. Chest CT can identify significant pulmonary or aortic pathologies that can adversely affect surgical success [23].

Head CT

Recipient head CT is not routinely used as a primary imaging modality for pre–heart transplant evaluation but may be valuable for specific cases in which neurologic conditions are suspected or need to be ruled out (Fig. 6). It can be used to detect prior strokes, intracranial hemorrhage, or metastatic disease that could affect the patient's suitability for transplant surgery [24].

Clinical Considerations in Donor Heart Evaluation

Radiologists should be familiar with the battery of clinical tests that donor hearts undergo before transplant. Each donor heart must meet several criteria to ensure that the heart will function well and improve the recipient's quality of life [25, 26].

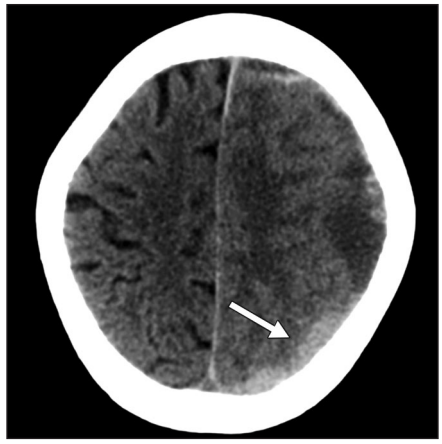

Fig. 6—Head CT of patient being considered for heart transplant and who developed headache shows acute subdural hematoma (*arrow*) with midline shift. Patient's neurologic status and recovery affects determination of whether heart transplant can proceed.

Patient History

Hearts from younger donors (< 45 years old) are considered ideal as they are often in better condition. However, there is no strict age limit; older donor hearts can be used if they are free of significant pathology. The donor must be evaluated for conditions that may adversely affect the heart's suitability, such as obstructive coronary artery disease, significant valvular disease, recent endocarditis, substantial myocardial scar, HIV, hepatitis B and C, diabetes, or hypertension.

Cardiac Size and Function

The donor heart needs to be of a similar size to the recipient's chest cavity to ensure a proper fit and function. The heart should have normal function without significant myocardial scar or valvular disease. These are typically assessed through echocardiography, CT, or MRI.

Blood Type and Immunologic Compatibility

The donor and recipient should have compatible blood types and Rh factor to reduce the risk of rejection. Testing for human leukocyte antigens and panel reactive antibodies also reduces the risk of rejection.

Time From Retrieval

The donor heart is preserved using cold storage techniques to maintain viability during transport. The use of specialized preservation solutions helps to minimize ischemic damage. The heart must be transplanted within a certain time frame after retrieval, usually 4–6 hours, to ensure viability.

Conclusion

In summary, CHF is a major public health burden that is commonly encountered across numerous health care settings. Familiarity with the stages of heart failure and the imaging modalities that show their typical imaging findings are of utmost importance in patient management. In patients who are being considered for heart transplant, radiologists play a critical role in transplant planning by providing essential imaging data to guide both clinical decision-making and the surgical approach. By utilizing and optimizing various imaging techniques, integrating findings into a multidisciplinary approach, and staying abreast of technologic advancements, radiologists can contribute substantially to the success of heart transplant and improved patient outcomes.

REFERENCES

1. Bozkurt B, Ahmad T, Alexander KM, et al. Heart failure epidemiology and outcomes statistics: a report of the Heart Failure Society of America. *J Card Fail* 2023; 29:1412–1451
2. Benjamin EJ, Muntner P, Alonso A, et al. Heart disease and stroke statistics: 2019 update—a report from the American Heart Association. *Circulation* 2019; 139:e56–e528
3. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA guideline for the management of heart failure. *J Am Coll Cardiol* 2013; 62:e147–e239
4. Ho KK, Pinsky JL, Kannel WB, Levy D. The epidemiology of heart failure: the Framingham study. *J Am Coll Cardiol* 1993; 22(4 suppl A):6A–13A
5. McMurray JJV, Pfeffer MA. Heart failure. *Lancet* 2005; 365:1877–1889
6. Hunt SA, Abraham WT, Chin MH, et al. 2009 focused update incorporated into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults. *J Am Coll Cardiol* 2009; 53:e1–e90
7. Caraballo C, Desai NR, Mulder H, et al. Clinical implications of the New York Heart Association classification. *J Am Heart Assoc* 2019; 8:e014240
8. Heidenreich P, Bozkurt B, Aguilar D, et al. 2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation* 2022; 145:e895–e1032
9. Gluecker T, Patrizio C, Pierre S, et al. Clinical and radiologic features of pulmonary edema. *RadioGraphics* 1999; 19:1507–1531
10. Storto ML, Kee ST, Golden JA, et al. Hydrostatic pulmonary edema: high-resolution CT findings. *AJR* 1995; 165:817–820
11. Mehra MR, Canter CE, Hannan MM, et al. The 2016 International Society for Heart Lung Transplantation listing criteria for heart transplantation: a 10-year update. *J Heart Lung Transplant* 2016; 35:1–23
12. Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure: the task force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) developed with the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur J Heart Fail* 2016; 18:891–975
13. Khush KK, Cherikh WS, Chambers DC, et al.; International Society for Heart and Lung Transplantation. The International Thoracic Organ Transplant Registry of the International Society for Heart and Lung Transplantation: thirty-sixth adult heart transplantation report—2019. Focus theme: donor and recipient size match. *J Heart Lung Transplant* 2019; 38:1056–1066
14. Chambers DC, Cherikh WS, Harhay MO, et al.; International Society for Heart and Lung Transplantation. The International Thoracic Organ Transplant Registry of the International Society for Heart and Lung Transplantation: thirty-sixth adult lung and heart-lung transplantation Report—2019. Focus theme: donor and recipient size match. *J Heart Lung Transplant* 2019; 38:1042–1055
15. Meshulami N, Shah P, Kaushik S, Murt R. Cardiac transplantation in adult congenital heart disease: a narrative review. *J Thorac Dis* 2023; 15:5074–5087
16. Attenhofer Jost CH, Schmidt D, Huebler M, et al. Heart transplantation in congenital heart disease: in whom to consider and when? *J Transplant* 2013; 2013:376027
17. ElAmm CA, Al-Kindi SG, Oliveira GH. Characteristics and outcomes of patients with myocarditis listed for heart transplantation. *Circ Heart Fail* 2016; 9:e003259
18. Siwik D, Apanasiewicz W, Żukowska M, et al. Diagnosing lung abnormalities related to heart failure in chest radiogram, lung ultrasound and thoracic computed tomography. *Adv Respir Med* 2023; 91:103–122
19. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr* 2015; 28:1–39
20. West AM, Kramer CM. Cardiovascular magnetic resonance imaging of myocardial infarction, viability, and cardiomyopathies. *Curr Probl Cardiol* 2010; 35:176–220
21. Kitchin SS, Manubolu VS, Roy SK, Budoff MJ. The role of cardiac computed tomography in heart failure. *Curr Heart Fail Rep* 2022; 19:213–222
22. Angelidis G, Giamouzis G, Karagiannis G, et al. SPECT and PET in ischemic heart failure. *Heart Fail Rev* 2017; 22:243–261
23. Di Cesare E, Carerj S, Palmisano A, et al. Multimodality imaging in chronic heart failure. *Radiol Med (Torino)* 2021; 126:231–242
24. Beaty CA, Arnaoutakis GJ, Grega MA, et al. The role of head computed tomography imaging in the evaluation of postoperative neurologic deficits in cardiac surgery patients. *Ann Thorac Surg* 2013; 95:548–554
25. Masarone D, Kittleson MM, Falco L, et al. The ABC of heart transplantation. Part 1. Indication, eligibility, donor selection, and surgical technique. *J Clin Med* 2023; 12:5217
26. Copeland H, Knezevic I, Baran DA, et al. Donor heart selection: evidence-based guidelines for providers. *J Heart Lung Transplant* 2023; 42:7–29