How to assess the severity of heart failure?

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Purpose of review
Mortality rates for acute decompensated heart failure and cardiogenic shock remain unacceptably high despite advances in medical therapy and mechanical circulatory support. Systems designed to quickly and accurately identify and risk stratify these patients are needed in order to improve survival.

Recent findings
The Society for Cardiovascular Angiography and Interventions developed an expert consensus statement aimed at early identification and assessment of patients with advanced heart failure and cardiogenic shock. Recent studies have validated this novel classification system within several large patient cohorts.

Summary
Assessing the severity of heart failure is a critical step in enabling the targeting of appropriate therapies to the appropriate patients. A novel classification system allows for accurate and reproducible identification and risk stratification.

Keywords
cardiogenic shock, heart failure, Society for Cardiovascular Angiography and Intervention classification

INTRODUCTION

Heart failure is a complex clinical syndrome that is a leading cause of morbidity and mortality worldwide, affecting an estimated 2% of all adults [1]. Although advances in medical and device therapy have decreased the mortality rate in patients with stable heart failure, those hospitalized with acute decompensated heart failure continue to have mortality rates as high as 25% in the first year [1]. More worrisome, cardiogenic shock, a feared outcome of progressive heart failure or a sequelae of acute cardiovascular dysfunction, carries a short-term mortality of nearly 50% [2]. Despite advances in reperfusion therapies and mechanical circulatory support (MCS), the mortality rate for patients who develop cardiogenic shock in the setting of acute myocardial infarction has remained unchanged over two decades [2].

It is widely believed that the early identification and risk stratification of patients at risk of worsening heart failure is essential, in order that treatment may be rapidly implemented, patients will be assessed and reassessed in real-time, and survival can be improved. Additionally, there is significant interest in developing comprehensive guidelines and treatment algorithms for patients with cardiogenic shock [3]. Currently, such guidelines rely on expert opinion rather than objective data because of the shortage of randomized trials [4]. This paucity of quality trials is partially attributable to the lack of a uniform classification system for cardiogenic shock.

Several risk scores and classification schemes have been proposed over the years to risk stratify patients with cardiovascular disease, grade their degree of heart failure, and take note of associated comorbidities. These algorithms rely on symptoms, physical examination, underlying structural cardiovascular disease, and hemodynamic and laboratory data. These classification systems have successfully prognosticated and provided treatment guidance in chronic heart failure. They have not, however, been as effective in risk-stratifying patients with acute decompensated heart failure [5]. Moreover, patients with all degrees of cardiogenic shock are often grouped together, despite the fact that this condition exists along a complex and heterogeneous spectrum of severity. In response, the Society for Cardiovascular Angiography and

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KEY POINTS

- Cardiogenic shock encompasses a spectrum of disease rather than a single entity.
- Previous heart failure classification schemes broadly grouped cardiogenic shock patients together.
- The SCAI classification algorithm provides an accurate and reproducible scheme to identify and treat advanced heart failure and cardiogenic shock.

Interventions (SCAI), in conjunction with a multidisciplinary and multisociety group of experts, developed a novel classification scheme that spans the entire spectrum of heart failure and cardiogenic shock, from those at high risk of developing heart failure to those with refractory cardiogenic shock [6▪▪]. In order to provide the appropriate context, and work from a common lexicon, we will first review several of the earlier classification systems.

KILLIP CLASSIFICATION

The Killip Classification was developed in 1967 on the basis of 250 patients with acute myocardial infarction (AMI) who were followed for approximately 2 years [7]. The classes were determined exclusively by physical examination findings at the time of presentation. Killip class I patients had no evidence of heart failure; Killip class II patients had signs of mild heart failure with bibasilar pulmonary crackles, a third heart sound, or elevated jugular venous pressure (JVP); Killip class III patients had frank pulmonary edema but maintained a SBP greater than 90 mmHg; and Killip class IV patients had pulmonary edema with hypotension and signs of peripheral vasoconstriction.

In this initial report, 30-day mortality ranged from 6% for patients in Killip class I to 81% for patients in Killip class IV [7]. Multiple subsequent analyses have validated these findings. Specifically, the presence of Killip class III or IV heart failure remains among the most powerful independent prognostic factors for both 30-day and long-term mortality following AMI [8]. The Killip classification highlights how physical exam findings on admission can provide valuable prognostic information. It is simple to remember, and does not require any calculations or laboratory data. However, the classification system is based on a single point in time, and therefore, does not take into account the dynamic nature of heart failure and cardiogenic shock. Additionally, the sole reliance on physical examination findings may result in significant inter-observer variation.

NEW YORK HEART ASSOCIATION CLASSIFICATION

The New York Heart Association (NYHA) functional classification system was initially proposed in 1928 but underwent multiple revisions until 1994 [9]. The classes are determined exclusively by symptom severity as judged by the patient and the physician. In all classes, the patients have known, underlying cardiac disease. Class I patients are asymptomatic (no angina pain, dyspnea, fatigue, or palpitations) with ordinary activity; class II patients are symptomatic with ordinary activity; class III patients are comfortable at rest but symptomatic with less than ordinary activity; and class IV patients are symptomatic at rest [9].

Similar to the Killip classification, this is a simple scheme that does not require calculations. Also, the inclusion of an asymptomatic class allows for earlier recognition and treatment of patients at risk. However, the NYHA class determination is entirely subjective, as no objective data points are included. Furthermore, the functional class can be influenced by noncardiac comorbidities, such as frailty, lung disease, and musculoskeletal abnormalities, which may lead to decreased specificity. Additionally, there is no standardized method or accepted list of questions by which the NYHA class is assessed. Thus, substantial inter-observer variation has been found, with a reported concordance of about 50% when NYHA class was assigned to the same patient by two independent cardiologists [9,10]. Furthermore, NYHA class correlated poorly with the objective and validated 6 min walking distance (6MWD) [11].

The NYHA classification system is the primary tool used to risk stratify patients in guidelines and in studies of chronic heart failure. Importantly, the NYHA classification places the patient experience at the forefront. Thus, NYHA classification is helpful when determining appropriate therapies for chronic heart failure. Nevertheless, it is not well suited for distinguishing among patients with acute decompensated heart failure or cardiogenic shock, as all of the patients in this very broad group would be classified as NYHA class IV.

AMERICAN COLLEGE OF CARDIOLOGY/ AMERICAN HEART ASSOCIATION STAGES

Unlike the NYHA functional classification, which focuses on symptoms, the ACC/AHA stages of heart

Table 1. American College of Cardiology/American Heart Association stages versus New York Heart Association functional classes

ACC/AHA Stages	NYHA Functional Classes
A: No structural disease but with comorbidities	I: Structural disease but asymptomatic
B: Structural disease but asymptomatic	II: Symptomatic with moderate exertion
C: Structural disease with current or past symptoms	III: Symptomatic with mild exertion
D: Refractory heart failure	IV: Symptomatic at rest

ACC/AHA stages [12]; NYHA Functional Classes [9]. ACC, American College of Cardiology; AHA, American Heart Association; NYHA, New York Heart Association.

failure emphasize the underlying development and progression of disease. There are four stages, with disease severity increasing at each subsequent stage (Table 1) [12]. Stage A patients are at high risk for heart failure but do not have structural heart disease; Stage B patients have structural heart disease but do not have symptoms; stage C patients have structural heart disease with current or past symptoms of heart failure; stage D patients have refractory heart failure and require specialized medical or mechanical interventions. In this classification scheme, once a patient is categorized as stage C, he or she cannot return to stage A or B.

As validated in multiple studies, the mortality rate worsens in each subsequent stage. Specifically, in a large community-based cohort, mortality increased two-fold at stage B and nearly eight-fold at stage C/D [13]. Guidelines for heart failure management refer to these stages when recommending therapies. The inclusion of stage A is particularly beneficial as the treatment of comorbidities is emphasized. The stages are easy to remember, without any required calculations or hemodynamic data.

Although the stages appear well defined, there is a level of ambiguity regarding the definition of structural heart disease. Mild valvular regurgitation, changes in diastolic function, or abnormalities in myocardial strain, for example, may or may not be considered structural disease. Likewise, atrial arrhythmias can predispose patients to heart failure without structural disease [14]. Additionally, stage D includes the entire spectrum of cardiogenic shock as a single entity, and the jump from stage C to stage D may be particularly large.

INTERAGENCY REGISTRY FOR MECHANICALLY ASSISTED CIRCULATORY SUPPORT PROFILES

In 2006, a multicenter committee created the INTERMACS profiles as part of a comprehensive registry to identify advanced heart failure patients who would benefit from MCS [15]. The development of this system was based on a recognition that the jumps from stage C to stage D in the ACC/AHA classification, from Killip class III to IV, or from NYHA class 3 to 4, can be quite large and encompass both severe heart failure and cardiogenic shock. A classification scheme to subclassify those patients was needed, which could also assist in the identification of patients in need of heart transplantation.

The INTERMACS registry has revolutionized the utilization of MCS, and is currently the national registry for Food and Drug Administration (FDA)-approved circulatory support devices [16]. There are seven profiles, ranging from the most critically ill (profile 1: Critical Cardiogenic Shock), to the most stable (profile 7: Advanced NYHA III). Each profile also has a memorable 'tag' for easy memorization (Table 2). Additionally, there are three risk modifiers that provide enhanced risk assessment: temporary circulatory support (TCS), arrhythmia (A) and frequent flyer.

The new profiles provided an improved mechanism to categorize advanced heart failure patients who were previously classified more broadly. Several studies have shown a correlation between the sicker

Table 2. Interagency Registry for Mechanically Assisted Circulatory Support profiles

Profile	Tag name	Description of clinical status
1	Crash and burn	Life-threatening hypotension with critical end organ hypoperfusion
2	Sliding on Inotropes	Acceptable blood pressure but declining function on inotropes
3	Dependent Stability	Stable on inotropes but unable to wean because of symptoms or hypotension
4	Frequent Flyer	Stable oral meds but daily congestive symptoms at rest despite diuresis
5	Housebound	Comfortable at rest but unable to tolerate even mild activity
6	Walking Wounded	Can tolerate limited activity but fatigue very easily
7	Place Holder	NYHA III type symptoms

Data from [16]. NYHA, New York Heart Association.

INTERMACS profiles and increased perioperative mortality [17,18]. Because of these data, there has been a significant shift away from implanting left ventricular assist devices (LVADs) in the sickest patients because of poor postoperative outcomes [16]. Instead, there is a focus on early identification of patients who will benefit most in both the short-term and long-term.

Although these profiles have aided in the selection process for MCS, they have limited utility in the acute management of advanced heart failure or cardiogenic shock. Similar to the other schemes, the determination of INTERMACS profile relies solely on subjective assessment. There is no guidance on treatment strategy and no differentiation between the different types of cardiovascular support. Thus, patients on an intra-aortic balloon pump (IABP) are classified in the same manner as those on extracorporeal membrane oxygenation (ECMO). The profiles specifically represent a single snapshot of the risk for perioperative mortality and morbidity rather than their place on the cardiogenic shock spectrum.

SOCIETY FOR CARDIOVASCULAR ANGIOGRAPHY AND INTERVENTIONS STAGES

In 2019, SCAI released a multidisciplinary expert consensus statement to better categorize advanced heart failure and cardiogenic shock. The goal was to create a simple scheme that was both intuitive and reproducible without the need for complicated calculations [6▪▪]. Additionally, the stages should cover the entire spectrum of heart failure and cardiogenic shock. Keeping these principles in mind, five stages of shock were proposed (Table 3).

Stage A stands for 'At Risk' and describes patients who are currently asymptomatic but at risk for development of cardiogenic shock. These patients do have underlying cardiac disease but are normotensive with normal renal function and lactate levels. On exam, they have clear lungs, normal JVP, and normal mentation.

Stage B stands for 'Beginning' cardiogenic shock, or compensated shock, and includes patients with relative hypotension or tachycardia but without overt hypoperfusion. Patients in stage B have a SBP less than 90 mmHg [or mean arterial pressure (MAP) less than 60 mmHg] but have a normal lactate and minimally impaired renal function. On exam, rales and an elevated JVP are present, but mentation is normal. The cardiac index is normal and inotropes, vasopressors, or mechanical support are not in use. Historically, stage A and B patients have been excluded from cardiogenic shock trials.

Stage C stands for 'Classic' cardiogenic shock and includes patients with hypoperfusion, characterized by a SBP less than 90 mmHg, elevated lactate, worsening renal function, elevated liver enzymes, and/or elevated brain natriuretic peptide. Patients are volume overloaded, and have signs of hypoperfusion manifested by alterations in mentation, low urine output, cold extremities, and extensive rales. Additionally, hemodynamic evaluation demonstrates a low cardiac index and cardiac power output with an elevated pulmonary capillary wedge pressure. These patients require emergent interventions, which may include inotropes, vasopressors, or MCS. The key differentiator between stages B and C is the development of clinical, biochemical, or hemodynamic manifestations of hypoperfusion.

Stage D stands for 'Deteriorating' cardiogenic shock and includes patients previously in stage C but who have failed to stabilize despite the initial interventions for at least 30 min. Their physical exam findings, laboratory tests, and hemodynamic numbers are worsening despite initial efforts. These patients require further escalation in mechanical support, inotropes, or vasopressors.

Stage E stands for 'Extremis' and includes patients who have circulatory collapse and are often in cardiac arrest undergoing cardiopulmonary resuscitation. These patients are critically ill and require the collaboration of a multidisciplinary team.

An arrest modifier (A) is also included in the statement to describe patients with an episode of cardiac arrest. The modifier can be applied to any stage for further risk stratification.

Each stage is defined by physical exam findings, laboratory values, and hemodynamic evaluations. The inclusion of all three components allows for a combination of subjective and objective data in order to best categorize a patient. This facilitates better communication between colleagues and provides a platform for reproducible research [19]. There is also less ambiguity among the stages. The reassessment of laboratory studies and hemodynamic data is at the discretion of the treating physician, although the authors developed this document with the intention that patients would be re-evaluated frequently and their stage updated often. As the clinical status worsens, the statement provides guidance for escalation of care. Additionally, the inclusion of stages A and B stresses the importance of identifying and treating patients before end organ damage, as well as allowing the potential to reclassify patients to lower stages as they improve. As intended, the SCAI stages encompass the entire spectrum of advanced heart failure while defining subsets within cardiogenic shock (Table 4). Finally, the SCAI stages have facilitated the

Table 3. Society for Cardiovascular Angiography and Interventions stages: physical exam, biochemical markers, and hemodynamics

Stage	Description	Physical examination/ bedside findings	Biochemical markers	Hemodynamics
A At risk	A patient who is not currently experiencing signs or symptoms of CS, but is at risk for its development. These patients may include those with large acute myocardial infarction or prior infarction acute and/or acute on chronic heart failure symptoms.	Normal JVP Lung sounds clear Warm and well perfused Strong distal pulses Normal mentation	Normal labs Normal renal function Normal lactic acid	Normotensive (SBP≥100 or >normal for pt.) If hemodynamics done cardiac index ≥2.5 CVP <10 PA sat ≥65%
B Beginning CS	A patient who has clinical evidence of relative hypotension or tachycardia without hypoperfusion.	Elevated JVP Rales in lung fields Warm and well perfused Strong distal pulses Normal mentation	Normal lactate Minimal renal function impairment Elevated BNP	SBP <90 OR MAP <60 OR >30 mmHg drop from baseline Pulse ≥100 If hemodynamics done Cardiac index ≥2.2 PA sat ≥65%
C Classic CS	A patient that manifests with hypoperfusion that requires intervention (inotrope, pressor or mechanical support, including ECMO) beyond volume resuscitation to restore perfusion. These patients typically present with relative hypotension.	May include any of: Looks unwell Panicked Ashen, mottled, dusky Volume overload Extensive rales Killip class 3 or 4 BiPap or mechanical ventilation Cold, clammy Acute alteration in mental status Urine output <30 mL/h	May include any of: Lactate ≥2 Creatinine doubling OR >50% drop in GFR Increased LFTs Elevated BNP	May include any of: SBP <90 OR MAP <60 OR >30 mmHg drop from baseline AND drugs/device used to maintain BP above these targets Hemodynamics cardiac index <2.2 PCWP >15 RAP/PCWP ≥0.8 PAPI <1.85 Cardiac power output ≤0.6
D Deteriorating/ doom	A patient that is similar to category C but are getting worse. They have failure to respond to initial interventions.	Any of stage C	Any of stage C AND: Deteriorating	Any of stage C AND: Requiring multiple pressors OR addition of mechanical circulatory support devices to maintain perfusion
E Extremis	A patient that is experiencing cardiac arrest with ongoing CPR and/or ECMO, being supported by multiple interventions.	Near pulselessness Cardiac collapse Mechanical ventilation Defibrillator used	'Trying to die' CPR (A-modifier) pH ≤7.2 Lactate ≥5	' SBP without resuscitation' PEA or refractory VT/VF Hypotension despite maximal support

BNP, B-type natriuretic peptide; CPR, cardiopulmonary resuscitation; CS, cardiogenic shock; CVP, central venous pressure; ECMO, Extracorporeal Membrane Oxygenation; GFR, glomerular filtration rate; JVP. jugular venous pressure; LFT, liver function test; MAP, mean arterial pressure; PAPI, Pulmonary Artery Pulsatility Index; PCWP, pulmonary capillary wedge pressure; PEA, pulseless electrical activity; RAP, right atrial pressure; VF, ventricular fibrillation; VT, ventricular tachycardia.

Table 4. Comparison of Killip, New York Heart Association, American College of Cardiology/ American Heart Association, I Interagency Registry for Mechanically Assisted Circulatory Support, and Society for Cardiovascular Angiography and Interventions Classification Systems

Patient description	Comorbidities but no structural disease	Structural disease but asymptomatic	Symptomatic HF but no hypoperfusion	Cardiogenic shock but stable on initial intervention	Cardiogenic shock and worsening on initial intervention	Refractory cardiogenic shock or arrest
Killip		I	II III	IV	IV	IV
NYHA		I	II III	IV	IV	IV
ACC/AHA	A	B	C	D	D	D
INTERMACS			IV–VII	III	II	I
SCAI		A	B	C	D	E

ACC, American College of Cardiology; AHA, American Heart Association; INTERMACS, Interagency Registry for Mechanically Assisted Circulatory Support; NYHA, New York Heart Association; SCAI, Society for Cardiovascular Angiography and Interventions.

development of SHOCK teams at hospitals, where communication in real-time between multiple specialists can help coalesce treatment decisions and keep everyone abreast of the patient clinical status.

To validate the SCAI algorithm, three recent studies retrospectively applied the scheme to large cohorts of patients. Schrage *et al.* applied the SCAI classification to 1007 consecutive cardiogenic shock patients at a single center and found that a sicker classification was significantly associated with a lower 30-day survival rate. Specifically, the survival rate in stage A was 96.4%, whereas it was only 22.6% in stage E [20▪]. Similarly, Jentzer *et al.* [21▪▪] applied the scheme to 10 004 consecutive ICU patients and found comparable results, as the hospital mortality ranged from 3.0% in stage A to 67.0% in stage E. Finally, Jentzer *et al.* also analyzed 9096 ICU patients who survived the initial hospitalization, to evaluate if the SCAI classification was predictive of postdischarge mortality. In this unique cohort, the 5-year survival rate was highest in stage A at 88.2% and lowest at stages D/E at 71.7% [22▪]. Importantly, in all trials, mortality rates increased significantly from stages C through E, all of which meet classic cardiogenic shock criteria. In previous classification schemes, these patients were grouped together.

CONCLUSION

The assessment of the severity of heart failure has undergone many transformations since the description of the initial Killip classification. The NYHA classes, ACC/AHA stages, and the INTERMACS registry have all provided unique frameworks, but each suffers from significant subjectivity and inadequate granularity, especially in cardiogenic shock. The SCAI stages have addressed these concerns by including clear objective evaluations and providing recommendations for managing the different stages throughout the spectrum of cardiogenic shock. Although validated retrospectively, prospective trials utilizing the SCAI classification system are needed to evaluate the impact of its use on patient management and, most importantly, on patient outcomes.

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Conflicts of interest

There are no conflicts of interest.

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Papers of particular interest, published within the annual period of review, have been highlighted as:

- ▪ of special interest
- ▪▪ of outstanding interest

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