Systems of Care in Cardiogenic Shock

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ABSTRACT: Cardiogenic shock presents a significant challenge to the medical community, and there is much debate as to the best classification system and treatment mechanisms. As interventions and technologies improve, systems of care for patients with cardiogenic shock must evolve as well. This review describes the current treatment models for cardiogenic shock, including the "hub-and-spoke" model, and defines specific characteristics of the ideal system of care for this patient population.

INTRODUCTION

Despite advances in the treatment of several cardiovascular diseases, the incidence of cardiogenic shock (CS) continues to rise. In practical terms, CS is a state of low cardiac output resulting from impaired cardiac function; it eventually leads to inadequate tissue perfusion and is associated with a very high mortality rate.[1] Because the origin and milieu of CS is so complex, it requires an interdisciplinary team of experts who can recognize and treat it in the earliest stages before it progresses. The implementation of systems of care for myocardial infarction, stroke, and cardiac arrest has led to improved survival rates. In turn, the diagnosis and treatment of CS will only improve when a system of care recognizes and treat CS in early stages, enables appropriate and rapid escalation of therapy, and effectively directs patients to centers that can handle the complex decision making required for cases that require a more advanced, multidisciplinary approach.[1] This review highlights the current knowledge around CS and focuses on the strengths, challenges, and opportunities with various systems of care.

CURRENT LIMITATIONS AND BARRIERS

There are several limitations and barriers that complicate the implementation of an effective system of care for CS.[1,2] The foremost challenge is that there is no standardized and validated definition of CS. Because CS has different presentations and multiple causes, it can be difficult to diagnose; without a diagnosis, patients can quickly progress through increasingly severe phases. Next, the inability of many hospitals to recognize or manage patients with CS creates delays in the diagnosis and transfer to an appropriate center, thereby affecting short- and long-term outcomes. As a result, there is a strong need for clear and efficient diagnostic and transfer protocols. Finally, it takes multiple medical insitutions to provide an effective system of care. This would require mobile teams with shared hospital privileges, financial and administrative agreements between institutions, and resources for 24 hours a day/7 days a week (24/7) coverage in treatment facilities.

DEFINITIONS AND CLASSIFICATIONS OF CARDIOGENIC SHOCK

A patient in CS is in a low perfusion state that triggers a compensatory response in the body. This response can be increasingly deleterious and trigger a persistent cycle of worsening cardiac output, hypoperfusion, deteriorating target organ function, and eventually death.[3,4] Thus, the entire cardiovascular system is affected by an increase in neurohormones, endothelial dysfunction, and inflammatory markers that leads to profound vasodilation, worsening cardiac contractility, and injury.[3,5,6]

The most common definition of CS combines clinical and hemodynamic data as used in the SHOCK (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock) trial.[7] Specifically, CS is defined by a systolic blood pressure (SBP) of < 90 mm Hg for ≥ 30 min (or use of pharmacological and/or mechanical support to maintain or support SBP ≥ 90 mm Hg) and end-organ hypoperfusion with a cardiac index ≤ 2.2 L/min^{-1}/m^{-2} and pulmonary capillary wedge pressure (PCWP) ≥ 15 mm Hg.[7] These clinical thresholds represent a clear definition; however, the use of specific criteria for diagnosing CS has its own pitfalls. First, the different mechanisms of CS will lead to different presentations, even in advanced phases. Second, the hemodynamic thresholds are seen in the advanced stages of CS, so clinicians may underdiagnose shock if it presents in early phases, thereby delaying treatment. For example, a patient with chronic systolic heart failure can present with a SBP < 90 mm Hg, an elevated PCWP, and no evidence of organ dysfunction. However, a patient with prior normal heart function and a large acute myocardial infarction (AMI) may not be able to perfuse vital organs despite having an SBP > 90 mm Hg. Both of these are examples of CS and its disparate presentations. Lastly, the SHOCK trial definition does not consider comorbidities (eg,

cardiac arrest prior to presentation, right ventricular failure, or concomitant chronic end-organ dysfunction) that can affect outcomes and/or presentation in these patients.

In April 2019, the Society of Cardiovascular Angiography and Interventions (SCAI) proposed a new definition and classification system to enable rapid assessment, tracking of patient progression, and deployability across all clinical settings.[8] The resulting SCAI SHOCK Classification System clarifies several phases of shock and identifies patients at risk for CS by defining pre-shock states, with the goal being to help clinicians detect shock at the earliest possible stage (Table 1).[8] Although the SCAI classification is simple, it uses arbitrary criteria that can create confusion for providers because a patient's status can easily fluctuate between stages; therefore, it may not be useful in cases of mixed CS. Further, the SCAI system needs to be tested clinically to confirm its applicability.

Another way to classify CS is based on volume status and peripheral perfusion, such as the hemodynamic profiles developed by Steveneson's group that are widely used to assess heart failure.[9] Patients can be categorized by four hemodynamic presentations known as "warm and dry," "warm and wet," "cold and dry," or "cold and wet." Most patients with classic CS fall into the "cold and wet" category (patients with high filling pressures and low cardiac output) or the "cold and dry" category (normal filling pressures with low cardiac output). The most common example is patients with chronic heart failure presenting with volume overload ("cold and wet"); other patients present with AMI but no volume overload ("cold and dry"). In the less common "warm and dry" profile, patients have low filling pressures with normal or high cardiac output due to distributive or hypovolemic shock. Finally, the "warm and wet" profile includes patients with mixed shock (patients with volume overload but normal blood pressure or low/normal cardiac output).[8,9]

CARDIOGENIC SHOCK INCIDENCE AND OUTCOMES

The presentation and outcomes of patients with CS vary depending on the initial cause. Between 5% and 7% of patients who suffer an AMI will present with CS.[3] The CardShock study, a multicenter prospective observation study, found that 81% of all CS cases in Finland were secondary to AMI.[10] The Critical Care Cardiology Trials Network reviewed multicenter data from patients admitted to cardiac intensive care units and found that 30% of the CS cases were caused by AMI.[11] The median cardiac intensive care unit (ICU) stay, length of hospital stay, and mortality rates continue to be higher in patients with CS, especially those with mixed shock (39%) followed by AMI (36%) and non–AMI-related CS (31%).[11] In addition, inpatient mortality rates for CS increased from 27.6% between 2005 and 2006 to 30.6% between 2011 and 2013.[12]

SYSTEMS OF CARE IN CARDIOGENIC SHOCK

The evolving epidemiology and high mortality rate of CS underscore the need for an optimal system of care that can improve short- and long-term outcomes.[1] Research on care systems for patients with ST-elevation myocardial infarction (STEMI), stroke, trauma, and out-of-hospital cardiac arrest have shown promising results.[13-18] In Canadian stroke patients, for

STAGE		PATIENT DESCRIPTION
A	At risk	Large acute myocardial infarctions (MIs); prior MI or acute/chronic heart failure symptoms
B	Pre-shock/compensated shock	Clinical evidence of relative hypotension or tachycardia without hypoperfusion
C	Classic cardiogenic shock	• Clinical signs of hypoperfusion • Need for intervention (vasoactive medications or use of mechanical circulatory support) • Relative hypotension
D	Deteriorating	Patient's symptoms have escalated and fail to respond to initial interventions found in stage C
E	Extremis	Circulatory collapse requiring multiple interventions and support

MI: myocardial infarction

Table 1.
Society of Cardiovascular Angiography and Interventions classification of cardiogenic shock profiles.[8]

example, the implementation of integrated systems of care lowered the 30-day mortality rate from 15.8% to 12.7%.[14] Similarly, systems of care developed for trauma patients reduced mortality rates by 15%.[13] In patients with acute aortic dissection, inpatient mortality dropped by 43% after implementing a regional care model, and the follow-up rates after hospital discharge increased by 10%.[15] In patients with out-of-hospital cardiac arrest, regionalized systems of care improved survival-to-discharge rates by 46%.[17] Finally, several reports have shown improved survival in STEMI patients with regionalization of care.[16,18] For example, using a regionalized care system, the Mission Lifeline STEMI Systems Accelerator Demonstration Project showed a 5% increase ($P \leq .001$) in the number of patients who met the STEMI guideline of < 90 min from their first medical contact to device time.[19]

Other studies have demonstrated that team-based approaches also improve survival. The Detroit Cardiogenic Shock Initiative found that use of early mechanical circulatory support (MCS) in patients with AMI complicated with CS improved the survival-to-explant rate compared to historical controls (85% vs 51%, $P < .001$).[20] More recently, Tehrani et al. showed that a standardized team-based approach to care, with specific criteria to guide clinical decision making, increased 30-day survival from 47% to 76.6% in patients with CS.[21]

Hub-and-Spoke Care Model

Studies have shown the feasibility of using regional systems of care for patients admitted with CS. One of the earliest attempts to use an integrated system of care was at a "hub-and-spoke" hospital network in New York. In this model, a "hub" hospital is usually a high-volume tertiary cardiovascular center that ideally has a multidisciplinary shock team, and the "spoke" hospitals are referral or community hospitals with less on-site capabilities and expertise.[1] In the New York study, patients with postcardiotomy shock were transferred to a hub hospital where implantable left ventricular assist devices were used as bridge to transplantation or recovery therapy. This model demonstrated a 74% survival-to-hospital-discharge rate, which was signicantly higher than the 25% survival in historical controls.[22] Other hub-and-spoke systems soon formed based on these positive results. Over a 4-year period, the Mayo Clinic in Arizona demonstrated a 56% survival-to-discharge rate after integrating 18 community hospitals and transferring all patients with cardiopulmonary shock[2]; this was a dramatic improvement over the 25% survival rates found in the INTERMACS database.[23] Despite the promising results, these single insitutional experiences lack the validity of randomized large-scale studies.

The National Cardiogenic Shock Initiative has provided a new algorithm that enables the rapid recognition and triage of patients with AMI and CS or cardiac arrest. It uses three levels of care: Level I for the shock- and MCS-capable center, Level II for the STEMI-receiver and PCI-capable centers, and Level III for non–PCI-capable hospitals. Thus, the Level I center serves as the hub while Level II and III centers are the spokes (Figure 1).[24]

DEVELOPING SYSTEMS OF CARE FOR CARDIOGENIC SHOCK

Hub Center Characteristics (Level I Center)

The use of multidisciplinary shock teams improves survival-to-discharge odds for patients in CS,[20,21] and hospital volume also affects outcomes. A study by Shaefi et al. found that hospitals with > 100 cases of CS per year had a lower mortality rate than centers with < 30 cases per year (37% vs 42%).[25] Similarly, 30-day mortality for AMI, heart failure, mechanical ventilation, and pneumonia is lower in higher-volume hospitals.[26,27] Thus, it is important that the hub is a

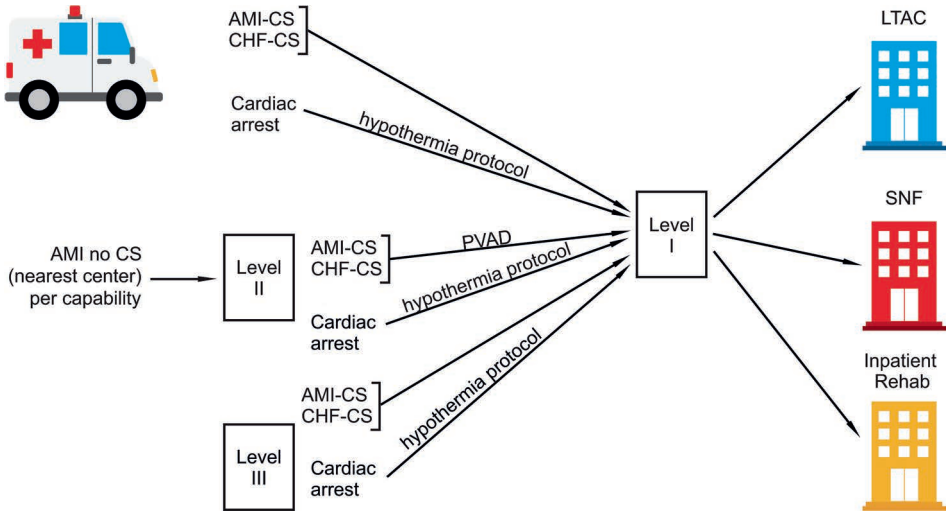

Figure 1.
The National Cardiogenic Shock Initiative algorithm for rapid recognition and triage of patients with AMI and cardiogenic shock or cardiac arrest.[23] AMI: acute myocardial infarction; CHF-CS: congestive heart failure with cardiogenic shock; LTAC: long-term acute care; SNF: skilled nursing facility; PVAD: percutaneous ventricular assist device.

high-volume center with multidisciplinary teams available at all times for consultation and temporary MCS/extracorporeal membrane oxygenation insertion, cardiac catheterization, and angioplasty.

Ideally, the hub center has a designated cardiac ICU to receive patients in CS. This ICU needs 24/7 coverage by an attending physician, a 1:1 nurse-to-patient ratio and mechanical ventilation, continuous renal replacement therapy, invasive hemodynamic monitoring, transvenous pacemakers, and temporary/durable MCS capability. Specialists in cardiothoracic surgery, cardiology, intensive care, neurology, nephrology, and palliative care are necessary at Level I centers. Ideally, the allied health professional team includes pharmacists, social workers, respiratory therapists, physical and occupational therapists, and nutritionists or dieticians.[1]

Given the different presentations for CS, it is important that each center enact standardized protocols to reduce variation in treatment and improve outcomes. Level I centers must have a centralized number dedicated to activation calls; the operator receives vital information from the transferring center and contacts the "on-call team," which includes an advanced heart failure cardiologist, interventional cardiologist, cardiothoracic surgeon, and critical care physician. Based upon the information from the transferring center, the team is able to prepare and make decisions regarding further care of the patient based on established protocols. In particular, Level I centers must have an established protocol for therapeutic hypothermia to treat out-of-hospital patients in cardiac arrest.[21,24,28] Of equal importance is the implementation of a strong continuing education program to train staff on the latest guideline updates. The need for consistent and accurate data collection is required to ensure that Level I centers are able to maintain quality improvement reviews.[1,29] Finally, Level I centers should maintain resources and protocols to provide necessary family support and counseling to patients admitted for CS. This is discussed further in the "Additional Resources" section below.

Spoke Center Characteristics (Level II and III Centers)

While there may be variablilty at each of the spoke centers, prior hub-and-spoke care models have underscored the importance of a few key components.[29,30] First, the spoke centers should be within a reasonable distance from the hub center. Research estimates that 210 miles is the maximum distance for a regional system of care.[2,22,30] Second, the protocols at spoke centers should be based on their institutional capabilities and acuity of their patients; however, it is imperative that each spoke hospital have a protocol that enables early identification of CS and quick transfer to a hub center.[1] Cardiogenic shock should be suspected if abnormal left ventricular function is identified by bedside echocardiogram or if invasive hemodynamics suggest cardiac dysfunction. Upon first review of a case, CS may be indicated if the patient: (1) needs two or more vasopressors, (2) needs one high-dose vasopressor and has worsening lactate despite support, or (3) does not improve within 1 to 2 hours of initial management. Third, a physician should be empowered to activate a transfer with a single phone call. And fourth, similar to Level I centers, a strong continuing education program and in-depth training for all personal are pivotal to ensure compliance and early identification of CS.

Level II centers should have cardiac catheterization and angioplasty capabilities. If they are capable of initiating percuataneous ventricular assist device support, this should be considered for patients in CS prior to transfer. The use of percutaneous devices is preferable to escalating doses of inotropes and vasoactive medications, which are associated with increased mortality.[24,31]

Emergency Departments and Emergency Medical Services

In all cases of CS, early recognition is the most important step in optimizing treatment. To this end, a clear definition of CS is essential to help emergency departments and emergency medical services make rapid decisions and ensure that patients go from first medical contact to treatment time in ≤ 90 min, as has been done with STEMI patients.[24] Once CS is identified, the patient should immediately be transferred to the nearest Level I center. Emergency physicians at Level II and III centers must be able to activate the transfer with one call to avoid unnecessary administrative burdens. The principal goal is to shorten the door-to-LV unload time as much as possible. Based on limited data from single-center studies, we suggest a time of ≤ 90 minutes[20-24]; this means that emergency medical system transport protocols should bypass spoke centers and proceed straight to hubs when necessary. In addition, emergency departments should have a dedicated area with proper equipment for rapid evaluation of ventricular function, valvular disease, and complications such as pericardial effusion with cardiac tamponade or mechanical complications of AMI.[24] They should also have a standardized hypothermia protocol that can be activated in patients in cardiac arrest.

ADDITIONAL RESOURCES

Palliative Care

While it is imperative to be able to quickly diagnose and treat patients with CS, it is equally important to plan for additional support to help patients and their families. Although there are no studies showing the appropriate timing for consultation, we recommend palliative care consultation (PCC) as soon

as possible after admission for CS. As an integral part of an effective interdisciplinary approach, palliative care specialists improve the quality of life for patients and their families because they facilitate difficult conversations about care goals and decision making.[32] Campbell and Guzman demonstrated that proactive early intervention by a pallative care specialist for patients with global cerebral ischemia or multiple organ system failure decreased ICU length of stay by 5 and 12 days, respectively.[33] Proactive PCC also significantly shortened the time between identifying the poor prognosis and establishing comfort care goals, which decreased the use of unnecessary resources.[33] Despite this evidence, PCC continues to be underused in patients with CS, with nearly half of patients receiving consultation only during the end-of life process.[34] In patients with AMI complicated by CS, just 4.5% received PCC. These patients had higher mortality and less in-hospital resource utilization, and fewer were discharged to home, indicating that PCC happened too late in the process.[35]

Social Services

Many patients with CS will not be candidates for advanved therapies. Therefore, it is important that all centers (hubs and spokes) have a clear policy that addresses what should occur if a patient is ineligible for or refuses advanced therapies. Prompt, straightforward communication with social workers and administrators can ensure that health insurance and other needed approvals are obtained in a timely manner.

The extensive resources needed for patients with CS have a large impact on health care costs. Therefore, financial considerations must be discussed with the patient and/or family to facilitate the most appropriate and desired level of care. For example, financial clearance must be obtained, and the availability of a hospital bed must be confirmed, before a patient can be transferred to a hub; otherwise, a lack of communication could delay care. In addition, reimbursements rarely provide adequate compensation to the treating hospital, which places financial burdens on the patient and hub hospital. Ideally, centers within the system should form financial agreements to share the costs of managing these patients.

Post-Shock Care

Finally, it is important to understand that caring for patients with CS goes beyond managing the acute pathology. Similar to other ICU patients, those with CS are at risk of developing chronic pain, cognitive impairment, ICU-acquired weakness, and psychological consequences.[36,37] Thus, one of the principal goals when treating these patients should include managing and preventing post–intensive-care syndrome and following up after discharge. To this end, systems of care need to incorporate inpatient rehabilitation services, skilled nursing facilities, and long-term acute care centers as part of the network.

CONCLUSION

The treatment of cardiogenic shock will be most effective when regionalized systems of care are coordinated, staffed, and properly trained to serve this vulnerable patient population. Only then will the advancements made in cardiovascular care and technology reach their full potential. Multidisciplinary teams are mandatory to treat cardiogenic shock due to is complex pathophysiology, and research shows that implementation of a "hub-and-spoke" model of regional care will improve both outcomes and the efficient use of resources. Finally, the administrative burden of care must be coordinated so that social services and post-shock care resources are available and implemented to improve the patient's long-term outcomes.

KEY POINTS

- Cardiogenic shock is a complicated clinical entity with complex pathophysiology that leads to impaired end-organ function and life-threatening multisystem organ failure. It has an elevated morbidity and mortality despite the use of advance medical therapies.
- Cardiogenic shock systems of care that include multidisciplinary teams have shown improvement of short- and long-term outcomes, including quality of life and survival.
- A regionalized system of care that includes hub-and-spoke institutions should have standardized protocols for early recognition and appropriate management of patients with cardiogenic shock and an efficient transfer plan between institutions.
- Lack of specific social and post-shock services can prevent the adequate implementation of a regionalized system of care and should be addressed by the institutions to optimize patient care and improve short- and long-term outcomes.

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The authors have completed and submitted the *Methodist DeBakey Cardiovascular Journal* Conflict of Interest Statement and none were reported.

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