Importance of stratifying acute kidney injury in cardiogenic shock resuscitated with mechanical circulatory support therapy

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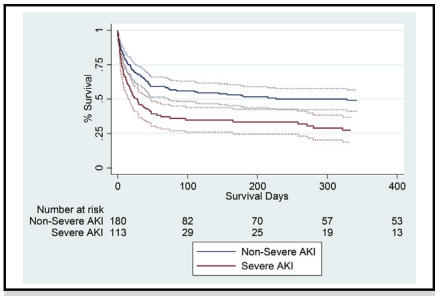
ABSTRACT

Objective: Although the outcomes of patients with cardiogenic shock remain poor, short-term mechanical circulatory support has become an increasingly popular modality for hemodynamic assistance and organ preservation. Because the kidney is exquisitely sensitive to poor perfusion, acute kidney injury is a common sequela of cardiogenic shock. This study examines the incidence and clinical impact of acute kidney injury in patients with short-term mechanical circulatory support for cardiogenic shock.

Methods: Retrospective review was performed of 293 consecutive patients with cardiogenic shock who were treated with short-term mechanical circulatory support. The well-validated 2014 Kidney Disease Improving Global Outcomes criteria were used to stage acute kidney injury. Outcomes of interest were long-term mortality and renal recovery.

Results: Acute kidney injury developed in 177 of 293 patients (60.4%), of whom 113 (38.6%) were classified with stage 3 (severe). Kaplan–Meier survival estimates indicated a 1-year survival of 49.2% in the nonsevere (stages 0-2) acute kidney injury cohort versus 27.3% in the severe acute kidney injury cohort ($P < .001$). Multivariable Cox regression demonstrated that severe acute kidney injury was a predictor of long-term mortality (hazard ratio, 1.54; confidence interval, 1.10-2.14; $P = .011$). Among hospital survivors, renal recovery occurred more frequently (82.4% vs 63.2%, $P = .069$) and more quickly (5.6 vs 24.5 days, $P < .0001$) in the nonsevere than in the severe acute kidney injury group.

Conclusions: Acute kidney injury is common and frequently severe in patients in cardiogenic shock treated with short-term mechanical circulatory support. Milder acute kidney injury resolves with survival comparable to patients without acute kidney injury. Severe acute kidney injury is an independent predictor of long-term mortality. Nonetheless, many surviving patients with acute kidney injury do experience gradual renal recovery. (J Thorac Cardiovasc Surg 2017;154:856-64)



Long-term mortality by severity of AKI.

Central Message

Although milder AKI resolves with survival comparable to patients without AKI, severe AKI is a predictor of long-term mortality. Still, many surviving patients experience gradual renal recovery.

Perspective

The impact of AKI in the extremely high-risk hemodynamically compromised population of patients with CS treated with ST-MCS remains poorly defined. This retrospective review of a robust clinical experience demonstrates the negative impact of AKI on long-term survival, yet also defines the likelihood and time course of renal recovery.

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Patients with cardiogenic shock (CS) continue to have a poor prognosis. The mortality of those with acute myocardial infarction (AMI) complicated by CS, the most common

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Abbreviations and Acronyms

AKI = acute kidney injury
AMI = acute myocardial infarction
CI = confidence interval
CS = cardiogenic shock
CVA = cerebrovascular accident
ECMO = extracorporeal membrane oxygenation
IQR = interquartile range
KDIGO = Kidney Disease Improving Global Outcomes
LVAD = left ventricular assist device
PCS = postcardiotomy shock
RRT = renal replacement therapy
ST-MCS = short-term mechanical circulatory support
VAD = ventricular assist device

cause of CS, remains up to 50% despite advances in early revascularization, hemodynamic device therapy, and pharmacotherapy.[1-4] Short-term mechanical circulatory support (ST-MCS) devices such as venoarterial extracorporeal membrane oxygenation (ECMO) and external ventricular assist devices (VADs) (surgical or percutaneous) are increasingly being used in this setting to improve systemic perfusion and protect vital organ function.[5,6]

Multisystem organ dysfunction is a hallmark of recent or persistent systemic hypoperfusion and has been demonstrated to occur in 37% to 56% of patients with CS.[7-10] As a consequence of the kidney's exquisite sensitivity to poor perfusion, it is one of the first organs to suffer in CS, and its injury often persists even after restoration of perfusion with ST-MCS. Knowledge of the prognostic implication of renal injury is becoming more clinically relevant as more patients with CS and nonrecoverable myocardial injury are being sustained and evaluated for heart replacement therapy with durable left ventricular assist device (LVAD). Although acute kidney injury (AKI) is believed to develop frequently and be associated with significant morbidity after MCS resuscitation, available information on this entity is extremely limited. AKI often is reported only as part of a case series or meta-analysis without detailed analyses or stringent definitions, and the few studies that focus on AKI suffer from a small sample size and include only patients treated with ECMO.[11]

We evaluated the incidence of AKI in patients on ST-MCS and the effect of such injury on mortality. To better understand this clinically important entity, we investigated AKI both holistically and inclusively using granular variables, including detailed medical history, preoperative state, postoperative outcomes, and long-term follow-up.

MATERIALS AND METHODS

Management of Cardiogenic Shock

At the Columbia University Medical Center, both vasopressors and inotropes with or without an intra-aortic balloon pump are the first-line treatment for patients with signs of CS. A systolic blood pressure that was less than 90 mm Hg, a cardiac index of less than 2.0 L/min/m^2, and evidence of end-organ dysfunction despite pharmacologic and intra-aortic balloon pump augmentation defines refractory CS. At this juncture, patients were immediately evaluated for ST-MCS candidacy specifically considering the patient's and family's goals of care, desire to pursue further treatment, length of ongoing cardiopulmonary resuscitation, alternative causes of shock such as sepsis, and relevant comorbidities.[1] Once the decision has been made to use ST-MCS, ECMO or ST-VAD is placed. An external VAD with a magnetically levitated centrifugal pump (CentriMag, Abbott, Abbott Park, Ill) is used as a ST-VAD in our program.[12] ECMO is used primarily in patients in whom neurologic status is unclear, in patients who are too hemodynamically unstable for transport to an operating room, and in patients with severe coagulopathy.[1] Because of the complex nature of cardiorenal syndrome, there is no clear-cut decision tree or consensus detailing the initiation of renal replacement therapy (RRT). In our program, AKI, which often manifested with oliguria and further complicated by refractory acidosis, volume overload, or electrolyte anomaly, results in nephrology consultation. The decision to initiate continuous RRT is made on an individual case-by-case basis. Once ST-MCS is begun, patients are monitored and managed by a multidisciplinary heart team and are evaluated for heart transplantation or destination LVAD therapy. On clinical improvement of the general status of the patient on ST-MCS, myocardial function is evaluated by weaning device support under both echocardiographic and hemodynamic monitoring. With successful weaning, the device is explanted. Myocardial recovery is defined as survival to hospital discharge or more than 30 days after the device explant. Otherwise, if appropriate, the patient may undergo a device exchange to an implantable LVAD or total artificial heart, or undergo heart transplantation. If a patient neither achieves myocardial recovery nor meets the inclusion criteria of heart replacement therapy, comfort care is established.

Data Collection

This study was approved by the institutional review board of Columbia University Medical Center with waiver of consent. This was a retrospective single-center study focusing on 293 consecutive patients who received ST-MCS for refractory CS between 2007 and 2013, either with ST-VAD or ECMO. Excluded were those patients who had preexisting end-stage renal disease (n = 11), who had inadequate/incomplete data to stage AKI (n = 2), or for whom RRT was initiated more than 1 day before device insertion (n = 14). Laboratory values were collected from the patients' charts immediately before device insertion and periodically thereafter throughout the hospital stay. All patients were followed at least until hospital discharge. Outpatient charts were reviewed for postdischarge follow-up, and patients were censored from survival analysis at the time of last known follow-up.

Baseline renal status and degree of AKI were classified on the basis of the well-validated and widely accepted 2014 Kidney Disease Improving Global Outcomes (KDIGO) criteria.[13,14] A creatinine level just before device insertion was used as a baseline and compared with the highest creatinine level in the first 7 days of device support. The severity of kidney injury was staged according to this ratio (Table 1). Patients placed on RRT within the first 7 postoperative days were recorded as stage 3. Although KDIGO specifies criteria for urine output that accompany creatinine levels, these were not used because of variability in output recording, and therefore strictly speaking, the current criteria are modified KDIGO.

Renal recovery was assessed at discharge for patients who experienced AKI and was defined as freedom from RRT and, on the basis of KDIGO definitions, normalization of creatinine to within 150% of baseline. Date