Cardiogenic shock in acute myocardial infarction: clinical outcome and predictors
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Jan J. Piek
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PART II

CHAPTER 5

Cardiogenic shock:
role of revascularization

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ABSTRACT

The most common cause of cardiogenic shock is myocardial ischemia developing early or late in the course of acute myocardial infarction. The incidence of cardiogenic shock (CS) is around 7% in ST-segment elevation myocardial infarction (STEMI) patients and has remained constant over the last 20 years. Therapy should be chain based by increased patient’s awareness. Early and prehospital diagnosis and treatment, with prompt transfer to a catheterization laboratory. Early revascularization is the cornerstone treatment of acute myocardial infarction complicated by cardiogenic shock. According to the guidelines, revascularization is effective up to 36 hours after the onset of CS and preformed within 18 hours after the diagnosis of CS. Primary percutaneous coronary intervention (PCI) is the most efficient and easily available therapy to restore coronary flow in the infarct related artery. Although recommended, there is little evidence that immediate multivessel PCI is beneficial for CS. The growing numbers of reports suggest staged PCI procedures or CABG is preferred in CS patients with significant LM disease or 3-vessel disease. The use of hemodynamic support with newly available percutaneous left ventricular unloading devices may herald a new era enabling preservation of adequate perfusion to other vital organs such as the brain, kidney and bowel. Despite all current efforts, in-hospital mortality for CS remains around 50%. However, long-term outcome and quality of life in hospital survivors is similar to patients with ST-segment elevation myocardial infarction patients presenting without CS.
CARDIOGENIC SHOCK

Cardiogenic shock is still the leading cause of in-hospital mortality for patients admitted with acute myocardial infarction, both ST-segment elevation myocardial infarctions (STEMI) as non-STEMI, with diffuse subendocardial ischemia. Due to improvement in therapy, mortality in STEMI patients without cardiogenic shock (CS) had declined over the years. In the early days mortality was around 30%, with bed rest as the only therapeutic modality. In the sixties mortality dropped to 13-15%, when coronary care units appeared with possibility of hemodynamic monitoring, defibrillation and B-blockers prescription. Nowadays mortality is around 6% in the era of early revascularization (ERV) (FIGURE 1). Despite improved strategies for acute STEMI, the incidence of cardiogenic shock in STEMI patients at presentation has remained constant over the last 20 years and is still around 7%. Only recently, some reports show a decline in the incidence of CS, mainly due to less delayed CS after hospital admission, parallel with an increase of pre-hospital triaging systems and primary PCI. Early revascularization (ERV) decreases cardiogenic shock late in the course of acute myocardial infarction. Once CS has been diagnosed in-hospital mortality remains still unacceptably high around 50%. Although in hospital mortality is still very high in these patients, long term survival after hospital discharge is comparable to STEMI patients without CS on admission with an annual mortality between 2-4%. Development of cardiogenic

FIGURE 1 Consequences of STEMI: early mortality risk over the last decades.
CCU= Coronary Care Unit, Adapted from Antman EM 2.0
shock may result from ischemic and non ischemic conditions leading to global or regional pump failure or ischemic or non ischemic mechanical complications (TABLE I).

The focus of this review is the role of revascularization in reversing CS due to ischemic heart disease.

PATHOPHYSIOLOGY OF CARDIogenic SHOCK

Cardiogenic shock is defined as systemic hypoperfusion induced by left ventricular (LV) failure in spite of adequate LV-filling pressure. The classic criteria for CS are shown in TABLE II.9 When over 40% of myocardium is ischemic or necrotic a mismatch between oxygen supply and demand leads to a downward spiral of low car-
Cardiac output reduced antegrade and collateral coronary perfusion. Decreased tissue perfusion results in anaerobic metabolism with formation of lactate in the affected hypoxic cells. Lactate acidosis consequently leads to myocardial cell membrane dysfunction, leakage of toxins into the circulation resulting in endothelial dysfunctions. Apoptosis of myocardial cells leads also to a systemic inflammatory response syndrome (FIGURE 2).

In circulatory failure, all compensatory mechanisms aim to preserve end organ perfusion. There is a clear hierarchy in preserving sufficient circulation to those organs that least withstand ischemia. This hierarchical order in preserving adequate circulation is brain, heart, kidney, bowel, before all other organs are supplied. Sympathetic activation to compensate low Cardiac Output (CO) and maintain blood pressure leads to peripheral vasoconstriction and progressive capillary dysfunction with peripheral pooling of blood. Inadequate flow especially to the brain and kidneys leads to irreversible damage and death. As brain function is the most
important function by which human life is determined, preservation of flow to the brain should intuitively be the most important target. However, until recently the only true option these patients had in deplorable conditions was by recovery of sufficient native heart function to maintain end organ perfusion. From this point of view, only early revascularization holds the premise of recovery.

**ACUTE MYOCARDIAL INFARCTION AND CARDIOGENIC SHOCK ALERT PLAN**

The cornerstone of preventing cardiogenic shock is early revascularization. Only a chain approach, with rapid evaluation and prompt initiation of supportive therapy with the purpose to shorten total ischemic time and consequently duration of cardiogenic shock, will lead to improved outcome. (FIGURE 3). The first step in this approach is timely recognition of signs and symptoms of acute myocardial infarction, for both patients and physicians or paramedics. The general public can be educated, by repeated public campaigns, when and how to search for medical help. Furthermore, easy access to medical care will enable early reporting and presentation of STEMI patients and thereby reducing the chance of developing CS. Pre-hospital or in ambulance diagnosis of STEMI and prompt treatment with antithrombotic agents is likely to further decline the incidence of CS at presentation. In patients with acute STEMI, rapid transportation to tertiary centers with 24/7 availability for immediate revascularization is mandatory, and if necessary prompt percutaneous mechanical support can be started.

Risk stratification for those at risk for developing shock, is likely to have an important impact on survival (as early diagnosis of acute myocardial infarction had had). Therefore, it is of major importance to study those at risk to develop cardiogenic shock. This may reduce the incidence of cardiogenic shock on admission as well as the development of CS even after reperfusion or early identify those at risk for further deterioration after initial therapy has been administered.

**RISK STRATIFICATION**

There are a number of risk factors associated with extended left ventricular dysfunction and development of cardiogenic shock.

Older patients tend to have longer delay before calling for assistance. Women are known to have a delay of around 30 minutes compared with men before seeking
medical care. The average age of women with their index myocardial infarction is higher. As a result, the Shock registry registered more women (43%) in cardiogenic shock compared to only 20-25% women reported in regular AMI patient cohorts. Also, their clinical presentation is different leading to both patient and doctors delay.

Some classical risk factors associated with higher mortality in STEMI patients are also risk factors for cardiogenic shock (CS). For example, patients with diabetes

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**FIGURE 3** Suggested cardiogenic shock alert plan

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Characteristic</th>
<th>Hemodynamics</th>
<th>ECG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest pain</td>
<td>Older age</td>
<td>Systolic pressure &lt; 100 mmHg</td>
<td>HR &gt; 100/min or &lt; 40/min</td>
</tr>
<tr>
<td>alteration in mental status</td>
<td>Female gender</td>
<td>Drop of mean arterial pressure &gt; 30 mmHg</td>
<td>Longer QRS-duration</td>
</tr>
<tr>
<td>Cool &amp; clammy extremities</td>
<td>Former myocardial infarction</td>
<td>Killip class &gt; I</td>
<td>New LBBB</td>
</tr>
<tr>
<td>sweating</td>
<td>known glucose intolerance/diabetes mellitus</td>
<td>Cyanosis</td>
<td>Pathological Q-waves</td>
</tr>
<tr>
<td></td>
<td>Former PCI + stent</td>
<td>Pulse &gt; 100/min or &lt; 40/min</td>
<td>LAD related infarction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Δ ≥ 1 mm extensive ST-segment ↑</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diffuse subendocardial ischemia</td>
</tr>
</tbody>
</table>

- **Chest pain**
- **Alteration in mental status**
- **Cool & clammy extremities**
- **Sweating**
- **Older age**
- **Female gender**
- **Former myocardial infarction**
- **Known glucose intolerance/diabetes mellitus**
- **Former PCI + stent**
- **Systolic pressure < 100 mmHg**
- **Drop of mean arterial pressure > 30 mmHg**
- **Killip class > I**
- **Cyanosis**
- **Pulse > 100/min or < 40/min**

**TABLE** Characteristics of patients with CS (prone) symptoms: calling for help
mellitus, usually older and more often female, have a higher incidence of CS when compared with patients without diabetes mellitus. Also patients with multivessel disease or previous myocardial infarction and kidney dysfunction, both conditions being associated with diabetes as well, are a subset of patients with higher risk for CS and death. Also, anemia has been associated with poor outcome in heart failure and in CS patients.\textsuperscript{12-14} Clinical characteristics represented by higher Killip class and higher heart rate contribute to worse prognosis. (TABLE 2, 3).\textsuperscript{15,16}

Recognizing all of these signs of (pre) shock can lead to an earlier diagnosis (diagnostic tests to confirm the clinical setting) and initiation of more intensive treatment. As previously mentioned, pre-hospital medical treatment leads to earlier reperfusion of the myocardium.

### TABLE 2 Classic criteria cardiogenic shock according to the SHOCK trial

<table>
<thead>
<tr>
<th>1 Systemic hypotension with adequate filling pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Systolic pressure &lt; 90 mmHg or vasopressors or IABP to maintain blood pressure ≥ 90 mmHg</td>
</tr>
<tr>
<td>■ LV end diastolic pressure &gt; 18 mmHg or RV end diastolic pressure &gt; 15 mmHg</td>
</tr>
<tr>
<td>■ Drop of mean arterial pressure &gt; 30 mmHg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2 Persistent hypotension &gt; 30 minutes</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>3 Poor Systolic Cardiac Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ CI &lt; 1.8 L/min/m(^2) or CI &lt; 2.2 L/min/m(^2) with support</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4 Tissue hypoperfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Brain: alteration in mental status</td>
</tr>
<tr>
<td>■ Kidney: oligurie &lt; 30 ml/hr</td>
</tr>
<tr>
<td>■ Skin: cool and clammy extremities, cyanosis, sweating</td>
</tr>
</tbody>
</table>

### TABLE 3 Killip classification & approximate mortality (%) in early revascularisation era

<table>
<thead>
<tr>
<th>Killip class I: no clinical signs of heart failure (3%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Killip class II: rales or crackles in lungs, an S3 gallop, elevated jugular venous pressure (9%)</td>
</tr>
<tr>
<td>Killip class III: acute pulmonary edema (20%)</td>
</tr>
<tr>
<td>Killip class IV: cardiogenic shock or hypotension (systolic blood pressure &lt; 90 mmHg) peripheral vasoconstriction (oliguria, cyanosis or sweating) (40%)</td>
</tr>
</tbody>
</table>

RISK ASSESSMENT IN CS WITH ECG
As the electrocardiogram is one of the first diagnostic tools for early risk assessment, it is of value to understand what features are associated with reduced clinical outcome or development of CS.

- Heart rate (<40/min or >100/min)
- ST segment elevation revealing transmural ischemia.
- Localization of myocardial infarction (inferior vs. anterior)
- Diffuse subendocardial ischemia (sum of ST-depression).
- Longer QRS duration
- New left bundle branch block
- Right bundle branch block with left axis deviation
- Signs of global ischemia such as ST segment elevation in AvR

RISK ASSESSMENT IN CS WITH ECHOCARDIOGRAPHY
When patients present with acute inferior wall infarction and CS, especially when the right coronary artery is involved, right ventricular failure may be part of the acute CS presentation. This condition usually responds quite well to adequate intravenous fluid administration and mild inotropic medication and resolves after adequate reperfusion. When more severe CS is present in inferior wall infarction, additional conditions need to be considered. Patients may have had prior (anterior) myocardial infarction or a concomitant mechanical complication should be suspected. One of the most important and easily available techniques is echocardiography. A transthoracic echocardiogram may sometimes not reveal subtle findings but will discriminate between severe left ventricular dysfunction or other reason for circulatory distress. When patient are on mechanical ventilation additional transoesophageal echocardiography is essential, as this may reveal more details and there is no real drawback in using a transoesophageal probe in already intubated patients. Clearly the need for intubation is usually a sign of worsening circulatory conditions requiring complete disclosure of myocardial function.

Besides revealing structural disease such as valvular disease it may give important information about filling pressures. A short mitral deceleration time (≤140 ms) is highly predictive of pulmonary capillary wedge pressure ≥ 20 mmHg in CS. Of note, the importance of echocardiography is much higher than the introduction of
a pulmonary artery catheter. There is no strong support for the latter to improve clinical outcome. The goal is to understand the origin of CS and potentially treat the underlying disease while a monitoring catheter will only monitor the patient.

**CURRENT THERAPEUTIC MODALITIES**

As mentioned before, the only approach of reversing ischemic induced CS is revascularization. Other supportive therapeutic modalities (pharmotherapeutic agents and mechanical support) are necessary to improve hemodynamic flow and perfusion. When pondering on the importance of brain and other end-organ perfusion, one might speculate if mechanical support might be even more important compared with early revascularization. Nevertheless, currently only recovery of sufficient native myocardial function is the real option for all patients. There is only one method: revascularization.

**ROLE OF REVASCULARIZATION**

The Should we emergently revascularize Occluded Coronaries for cardiogenic shock (SHOCK) was the first prospective multicenter trial comparing emergency revascularization (PCI or CABG) with initial medical stabilization. There was a significant benefit in survival in the ERV group on long term (> 6 months) survival. Although this trial has been seen as landmark trial in CS patients, few notes are in place. First of all, the trial was designed to show a survival benefit at 30 days after the initial event. After 30 days there was no significant difference. Additionally even after 6 months, although a significant difference in survival was observed, it was considerably smaller than the originally assumed mortality difference at 30 days. A total of 302 patients from 30 sites were randomized over the period of 5 years, resulting in an average of 2 pt/years (10/centre in 5 years). Nevertheless, this was the first trial showing that an available strategy resulted in higher survival compared with a conservative approach.

Consequently, the AHA guideline recommends ERV, PCI or CABG, for patients presenting with ST elevation or LBBB who develop shock within 36 hours of acute myocardial infarction and are suitable for revascularization that can be performed within 18 hours of shock. For all patients less than 75 years old and those over 75 years old with good functional status emergency revascularization is recommended.
IMMEDIATE CORONARY ANGIOGRAPHY BASED THERAPY IN CS

Coronary angiography gives detailed information concerning severity of coronary artery disease (CAD) for further risk stratification and therapy. (FIGURE 4) Angiographic findings in the SHOCK trial showed highest mortality in LM disease as culprit artery. In half of the patients the IRA was the left coronary descending artery (LAD). Multivessel disease (MVD) was identified in over 50% of cases and showed worse prognosis compared to single vessel disease. The initiation of cardiogenic shock in acute STEMI is due to an occlusion of a coronary artery. In electrocardiographic confirmed STEMI, a total 20-30% of patients have spontaneous reperfusion with already open coronary arteries on immediate angiography, when in ambulance anti thrombotic medication has been administered. In patients presenting with CS this is 10% at best. Coronary occlusions on the initial angiogram are associated with CS and reduced survival. Therefore, immediate transportation to tertiary centers with 24/7 availability of a catheterization laboratory and complementary cardiothoracic surgery is the optimal regimen.

**FIGURE 4** Revascularization strategy. Adapted from the ACC/AHA/ESC guidelines.20, 29
PCI AND CABG THERAPY RESULTS

Primary percutaneous coronary intervention (PCI) is the most efficient and easily available therapy to restore coronary flow in the infarct related artery (IRA). It is superior to thrombolysis, which only leads to successful reperfusion in 40-50% of all cases with CS and has not shown to lead to improved survival compared to conventional therapy for CS STEMI patients.22 Clearly, PCI is the cornerstone therapy for all STEMI patients including those in CS.

As single vessel disease is currently treated with primary PCI, the issue for acute surgical revascularization, only arise in the case of multivessel disease on the initial angiogram. Multivessel disease (MVD) was seen over 50% of cases in the SHOCK trial as well as in other reports. Patients with MVD had worse clinical outcome compared to single vessel disease.21 MVD is correlated to worse LV function at baseline. As restoration of coronary blood flow to the ischemic myocardium has been the rationale for treatment, many MVD patients underwent additional PCI or CABG. However, there is no evidence that additional revascularization in MVD patients results in superior clinical outcome.23 Recently, our group has identified that the impact of MVD on mortality is mainly determined by the presence of a chronic total occlusion (CTO) in a non-IRA. A CTO was found to be an independent predictor of both short- and long-term mortality. It is associated not only with poor LV function immediately after the index event, but also with a higher rate of a further deterioration of LV function. Even in a STEMI CS cohort of 292, only the presence of a CTO is an independent predictor for mortality and MVD without a CTO was no longer an independent predictor.25

Multivessel PCI in MVD is only recommended by the AHA/ACC/ESC guidelines in case of persistent CS after primary PCI. Early multivessel PCI is associated with higher rate of complications probably due to adverse thrombotic events in a pro-thrombotic environment.28,29 Furthermore, implanting stents while in cardiogenic shock holds the risk of under deployment of stents with higher risk for stent thrombosis. Staged PCI procedures or CABG is preferred in patients with significant LM disease or 3-vessel disease. Of note, in the SHOCK trial patients were treated with an aim to complete revascularization. Therefore, 37% of these very poor patients underwent immediate surgical revascularization. Surprisingly, patients treated with CABG has comparable outcomes with PCI patients, while those treated with surger-
ry were in worse condition. One of the reasons for this relatively good outcome of CABG patients may have had to do with the fact that the severity and presence of a CTO were importantly stratified for either strategy, with a larger amount of complete revascularization in the group selected for CABG. Furthermore, the presence of a CTO is associated with a further decrease of LV function during hospitalization as well as follow up. In case of a concomitant CTO our data might support a strategy to recanalize a CTO in the non-IRA within the first week or early thereafter after the index myocardial infarction. This strategy is currently being tested in the global Explore trial.

The ACC/AHA practice guidelines recommend immediate CABG for LM or 3 VD. However, daily clinical practice is different. Even in the SHOCK trial administered therapy was somewhat different as pre-specified and recommended per protocol. As there seems to be a discrepancy between the guidelines and daily clinical practice, one may wonder about potential explanations. Either the guidelines should be reinforced more strongly or the daily clinical practice does not support this strategy. Additionally, as mentioned, multivessel PCI or CABG has not shown to lead to better clinical outcome with similar, very high mortality rates. Also, it is important to keep in mind the fact that the SHOCK trial was in fact a per protocol negative trial, with (although a statistically significant) only a mild difference in mortality and only after 1 year (53.3 vs 66.4 %, P<0.03).33

WHERE SHOULD WE GO TO IN PATIENTS WITH MULTIVESSEL DISEASE IN DAILY CLINICAL PRACTICE? CABG OR PCI?

According to the SHOCK trial, complete revascularization has beneficial effect on long term survival. In the SHOCK trial both emergency CABG and PCI showed comparable results in survival and quality of life on the long term. Another series of emergency CABG in CS patients showed a better in hospital survival when a beating heart procedure was used. Also a 6-fold higher usage of a left internal mammary artery graft was seen which might explain the better survival on the long term. Staged PCI procedures might be considered as a good alternative in 3 VD and LM disease. Nevertheless, one needs to keep in mind that it is all about the culprit artery in acute myocardial infarction. Our AMC revascularization strategy is therefore more focused on treating the culprit artery and not only seldom treat CS patients.
with immediate or delayed CABG (FIGURE 5). Our strategy may in fact be more in line with current daily practice in the majority of tertiary hospitals. In addition, during the decision making process one may keep in mind that a high Syntax score will direct to a more complicated PCI with possibility of not achieving full revascularization (FIGURE 6).

Primary PCI has evolved, including the introduction of stents and platelet glycoprotein IIb/IIIa receptor inhibitors (GPI). Although intracoronary stenting has not showed to impact on survival, it reduces recurrent myocardial infarction and target vessel revascularization. Contrariwise, it may hold a higher risk for stent thromboses, associated with a worse clinical outcome.
The administration of GPI results in a higher rate of TIMI 3 flow after PCI which has been shown to be one of the most important prognostic factors for survival, especially in CS. Not only does pre-treatment with GPI lead to higher rates of TIMI 3 flow, also administration before arrival on the cath-lab or in the ambulance results in a higher rate of TIMI 3 flow on the initial angiogram before PCI.\textsuperscript{37} Restoration of coronary flow, in cardiogenic shock due to ischemia, is apparently not sufficient in these critically ill patients. Besides ERV probably a combination with intensive medical - and left ventricular (LV) mechanical support might be necessary in improving survival on the long term.

**MECHANICAL SUPPORT**

The guidelines recommend Intra Aortic Balloon Pump (IABP) therapy when CS persists and is not quickly reversed with pharmacological therapy. The IABP reduces afterload, leading to reduced LV wall stress, higher CO and less oxygen demand. Furthermore, diastolic augmentation with elevated diastolic coronary inflow leads to better oxygen supply. Both the GUSTO and SHOCK trial showed a trend towards improved survival. However, a recent meta analysis did not show any bene-
fit and in fact, patients treated with an IABP had more often severe complications. The most used percutaneous LV unloading devices that may serve as bridge-to-recovery (or to decision) are the TandemHeart (Cardiac Assist, Inc, Pittsburgh, Pa) and the Impella 2.5 (Abiomed, Inc, Danvers, Mass). The TandemHeart pVAD is an extra corporeally continuous-flow assist device. The pump is capable of delivering blood flow up to 5.0 liters per minute. TandemHeart pVAD provides short-term support from a few hours up to 14 days. Another easily insertable LVAD is the Impella 2.5 in the left ventricle, generating flows up to 2.5 L/min. It directly unloads the left ventricle, reduces myocardial workload and oxygen consumption. It increases cardiac output and coronary and end-organ perfusion. Both LVADs at least partly support circulation by draining blood from the left side of the heart and returning oxygenated blood to the systemic arteries. LVAD therapy results in a higher cardiac power index compared with IABP. Cardiac power is the product of cardiac index and mean arterial pressure. Cardiac power output and index were the most important independent predictors of in-hospital mortality in the SHOCK trial.

Although promising techniques, there are no studies yet showing a better clinical outcome when treated with any of these devices. Another support system is extracorporeal membrane oxygenation (ECMO). An ECMO machine is similar to a heart-lung machine. The ECMO machine continuously pumps blood from the patient through a “membrane oxygenator” that imitates the gas exchange process of the lungs. In a small series of 5 patients, it immediately stabilized circulation and organ perfusion before a LVAD was implanted. After continuation for 3 days as support for RV failure it could be stopped safely with preserved organ function. The bleeding complications and the LV overloading effects seem to limit its widespread usage.

**INOTROPIC AGENTS**

In reaction to extensive myocardial depression due to ischemia or necrosis, compensatory mechanisms are activated in order to prevent further damage to the heart and end organs. Insight into these acute phase reactions might lead to new treatment modalities. A variety of mechanisms and factors play an important role not only in the genesis of shock but also in outcome after shock. The neurohumoral reaction to hypo perfusion is release of catecholamine, angioten-
sine II (ACE II), vasopressin and retention of salt and water. Catecholamines increase contractility and elevate periferal vasoconstriction. ACE II and vasopressin improve peripheral and coronary blood flow but a negative side effect is the increase in afterload leading to a higher myocardial oxygen demand with a toxic effect. This is probably why higher dose of inotropic agents are associated with poorer outcome.42

The cytokine system also plays an important role. Activation of this systemic inflammatory stress syndrome (SIRS) with symptoms as fever, elevated white blood count and CRP can lead to lower inappropriate systemic vascular resistance, similar to sepsis, with persistent cardiogenic shock. Thusfar iNOS inhibition has failed to show any improvement in clinical outcome.43 The TRIUMPH trial not only showed that targeting this pathway did not result in improved clinical outcome, it also showed that increase of cardiac output by whatever agent is not necessarily associated with improved clinical outcome.

FUTURE DIRECTIONS

Improving early pre-hospital identification, presentation and therapy will be the cornerstone by which we can reduce the occurrence of and fatality rate in CS. Immediate transport to a catheterization laboratory and appropriate and state-of-the-art revascularization is mandatory. When CS develops prompt additional testing to elucidate the underlying diagnosis of cardiogenic shock is mandatory. Echocardiography has a cornerstone role. In addition, known or new (bio)markers may identify patients at risk for developing CS.44

It is likely that with the arrival of newer, more potent and safe percutaneous circulatory support devices we need to re-engineer the strategy in these CS patients. Early and adequate circulatory support and LV unloading may enable not only to open up the infarct related artery but perhaps also full revascularization even in case of a CTO. Furthermore prolonged LVAD support might lead to less activation of SIRS. Therefore in STEMI patients with CS, the paradigm may shift from “time-to-balloon” to “time-to-circulatory support”.

Although CS is usually a disease of the left ventricle and left coronary artery, a total of 38% in STEMI patients admitted with CS, have RV-failure.45 The only adequate therapy now available is inototropic infusion when adequate filling pressure of 15
mmHg has been achieved by fluid infusion. Higher pressures in combination with fluid infusion will lead to shifting of the interventricular septum, limited filling of the LV and lower CO. Currently there are no specific percutaneous cardiac assist devices for right ventricular failure. The first in man study of the newly designed RV Impella for right ventricular support is therefore eagerly awaited. Nevertheless, the above mentioned visions may prove to be only futuristic. Currently, prompt restoration of the infarct related artery is the single most important therapy and additional revascularization in MVD patients should be only carefully considered.

CONCLUSIONS
Cardiogenic shock is a syndrome of the failing heart. The most common cause of cardiogenic shock is ischemia developing early or late in the course of acute myocardial infarction. Early revascularization has been proven to be effective in the treatment of acute myocardial infarction. Since the rise of primary PCI, the development of cardiogenic shock late in the course of MI has declined. Therapy should be chain based, starting with educating the patient, early diagnosis and treatment before arrival at an emergency catheterization laboratory with all facilities. Immediate transportation to a tertiary center with availability to perform primary PCI is mandatory. The so called rise of the percutaneous LVAD machines potentially herald a new era. Although in hospital mortality remains high we have to bear in mind that long term outcome is comparable to STEMI patients without CS with good quality of life.
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