Management of myocardial infarction complicated by cardiogenic shock: Expert opinion of the Association of Intensive Cardiac Care and Association of Cardiovascular Interventions of the Polish Society of Cardiology

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DOI: 10.33963/v.kp.97817

Received:
September 8, 2023

Accepted:
October 10, 2023

Early publication date:
October 12, 2023

ABSTRACT

Despite significant advances in interventional cardiology and mechanical circulatory support (MCS) techniques, outcomes for patients with myocardial infarction (MI) complicated by cardiogenic shock (CS) remain suboptimal.

This expert consensus aims to provide information on the current management of patients with MI complicated by CS in Poland and to propose solutions, including systemic ones, for all stages of care. The document uses data from the Polish PL-ACS Registry of Acute Coronary Syndromes, which includes records of more than 820 000 hospital admissions.

We describe the role of medical rescue teams, highlighting the necessity to expand their range of competencies at the level of prehospital care. We emphasize the importance of treating the underlying cause of CS and direct patient transfer to centers capable of performing percutaneous coronary interventions. We present current recommendations of scientific societies on MCS use. We underline the role of the Cardiac Shock Team in the management of patients with MI complicated by CS. Such teams should comprise an interventional cardiologist, a cardiothoracic surgeon, and an intensive care physician. Patients should be transferred to highly specialized CS centers, following the example of so-called Cardiac Shock Care Centers described in some other countries. We propose criteria for the operation of such centers Other important aspects discussed in the document include the role of rehabilitation, multidisciplinary care, and long-term follow-up of treatment outcomes. The document was developed in cooperation with experts from different scientific societies in Poland, which illustrates the importance of interdisciplinary care in this patient population.

Key words: acute myocardial infarction, Cardiac Shock Care Center, Cardiac Shock Team, cardiogenic shock, intensive care, interventional treatment, mechanical circulatory support, prehospital care

INTRODUCTION

According to the definition of the European Society of Cardiology (ESC), cardiogenic shock (CS) is a life-threatening condition stemming from primary cardiac dysfunction, which results in low cardiac output leading to organ hypoperfusion and multiorgan failure [1]. Hemodynamically, CS is characterized by increased left ventricular end-diastolic pressure and wedge pressure, low systolic blood pressure despite adequate hydration, and low cardiac output. Based on clinical examination, CS patients are characterized as "wet and cold". The use of inotropes and vasopressors, mechanical circulatory support (MCS), and/or renal replacement therapy in CS patients may lead to an increase in systolic blood pressure to ≥90 mm Hg, but this does not necessarily result in the resolution of CS.

In more than 80% of cases, CS is caused by myocardial infarction (MI) with left and/or right ventricular failure. In an American study assessing approximately 4.3 million hospital admissions due to ST-segment elevation myocardial infarction (STEMI) in the years 2000–2017, CS was reported in 8.5% of patients [2]. Although CS is more often diagnosed in patients with STEMI, it also occurs in about 4% of individuals with non-STEMI (NSTEMI) [3] and in patients with out-of-hospital cardiac arrest.

The less common causes of CS include mechanical complications of MI: ventricular septal defect (4%), left ventricular free wall rupture (2%), or acute mitral regurgitation (7%) [4]. Apart from MI, CS may be also caused by acute decompensated heart failure, heart valve disease, myocarditis, acute pulmonary embolism, aortic dissection, postpartum cardiomyopathy, arrhythmia, or takotsubo syndrome [5].

Classification of cardiogenic shock

In clinical practice, CS is diagnosed on the basis of clinical criteria such as persistent hypotension unresponsive to fluid therapy with concomitant signs of organ hypoperfusion such as low urinary output and/or cognitive disturbances. An additional sign is increased blood lactate level. The reference range for serum lactate levels is <2.0 mmol/l. In the 9-point CardShock risk score proposed by Harjola et al. [6], a serum lactate level of 2.0–4.0 mmol/l scores 1 point, while a level of more than 4.0 mmol/l scores 2 points.

In the SHOCK study (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock), the hemodynamic criteria for CS diagnosis included the cardiac index of ≤2.2 l/min/m^2 and pulmonary capillary wedge pressure of ≥15 mm Hg [7].

In the most recent guidelines of the Society for Cardiovascular Angiography and Interventions, the authors distinguished 5 stages of CS [8]. The classification is presented in Table 1.

This expert consensus aimed to provide information on the management of patients with MI complicated by CS in current clinical practice in Poland and to suggest solutions, including systemic ones, for all stages of care. For this consensus, we used the database of the State Medical Rescue (Państwowe Ratownictwo Medyczne [PRM]) and the Polish PL-ACS Registry of Acute Coronary Syndromes (Ogólnopolski Rejestr Ostrych Zespołów Wieńcowych). The PL-ACS Registry contains data on almost 820 000 hospital admissions (as of the end of 2022). The prevalence rates of CS in patients with STEMI and NSTEMI were assessed on the basis of PL-ACS Registry data for the years 2004–2019 (Figure 1).

PREHOSPITAL CARE

A prompt diagnosis and emergency medical treatment are among the most important steps in CS management. In the prehospital setting, these are provided mainly by medical rescue teams (MRTs). In Poland, MRTs operate within the framework of PRM. To monitor and optimize Polish emergency medical services, a command support system was developed, known as SWD PRM (System Wspomagania Dowodzenia Państwowego Ratownictwa Medycznego). SWD PRM is a central information and communication technology system that collects data on the diagnostic, medical, and transport activities of all MRTs. This allows assessment of the number and quality of emergency medical service activities performed by MRT members [9]. In an analysis of SWD PRM data, Nadolny et al. [10] reported that

Table 1. Classification of CS based on the Society for Cardiovascular Angiography and Interventions guidelines [8]

A	A hemodynamically stable patient without signs or symptoms of CS but at risk of its development (i.e., large myocardial infarction, decompensated heart failure). **At risk**
B	A patient with clinical evidence of hemodynamic instability (including hypotension, tachycardia, and hemodynamic abnormalities) without hypoperfusion. **Beginning CS**
C	A patient with clinical signs and symptoms of hypoperfusion who initially requires pharmacological or mechanical support. Hypotension is typically present. **Classic CS**
D	A patient with clinical evidence of shock but worsening or not improving despite escalation of therapy. **Deteriorating CS**
E	Circulatory collapse, cardiopulmonary resuscitation, and/or ECMO. A patient with refractory shock or actual/impending circulatory collapse. **Extremis CS**

Abbreviations: CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation

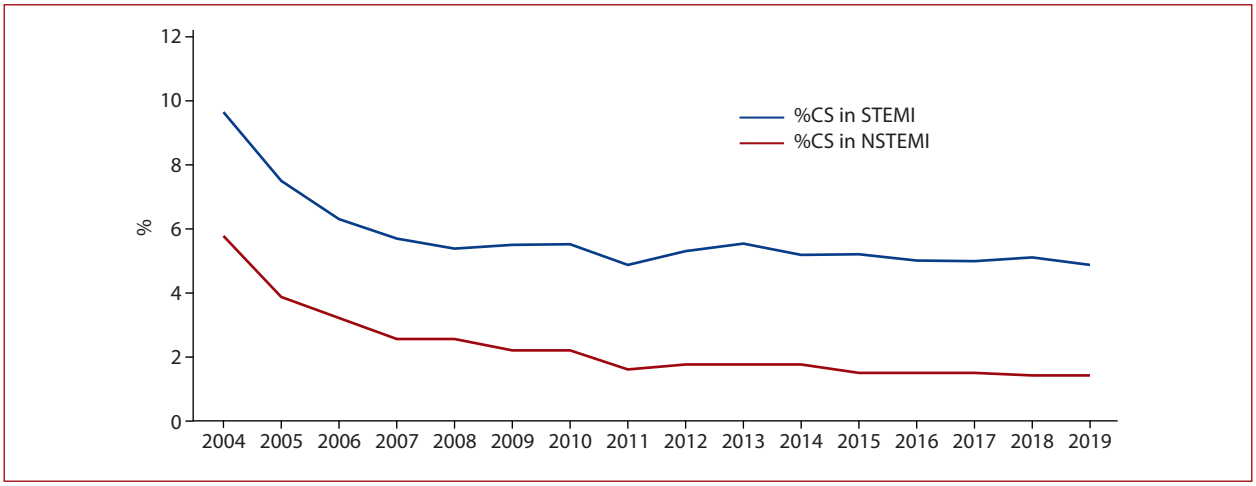

Figure 1. Rates of CS in patients with NSTEMI and STEMI; data from the PL-ACS registry for the years 2004–2019

systolic blood pressure lower than 90 mm Hg (ie, CS stage A-C) was recorded in 10.2% of almost 17 000 emergency ambulance calls to patients with STEMI.

The diagnosis should be established within 10 minutes after the first contact of the medical team with the patient. Delays in diagnosis are one of the quality-of-care indicators and a significant prognostic factor in patients with STEMI, including those with CS [11, 12]. The authors of the ESC guidelines on the management of patients with STEMI recommend that medical teams transfer these patients to a center capable of performing percutaneous coronary intervention (PCI) and that they bypass non-PCI centers (class of recommendation I, level of evidence C) [11]. This applies also to the Polish setting. The patient transfer should be preceded by a prehospital transmission of the electrocardiogram (ECG). In Poland, prehospital ECG transmission was performed in 37.5% of STEMI patients in 2018 based on SWD PRM data [10]. Although there are more than 160 catheterization laboratories that provide treatment for MI patients, not all of them are equipped with a system that can receive ECG transmissions. The key element of prehospital management is the ECG transmission and a rapid patient transfer to a reference center. A study based on the PL-ACS registry showed that transferring STEMI patients directly to a PCI-capable center was associated with a reduction in 12-month mortality rates [13].

So far, it has not been determined which cardiac centers should receive patients with CS. According to the scientific statement of the American Heart Association, CS patients may be transported directly to so-called "cardiac shock centers" providing the highest level of specialty care. Patients with confirmed STEMI can be also transferred to PCI-capable hospitals. If hemodynamic instability and CS persist, CS teams should be ready to receive such patients at their centers [5].

In our opinion, efforts should be made to ensure that all patients with MI complicated by CS are transferred directly to centers providing the highest level of specialty care such as the CS centers in the United States. The criteria for the operation of such centers in Poland are discussed below. Transfer to CS centers should be provided not only to the highest-risk CS patients (stages D and E). Patients with CS stages A-C also might derive the greatest benefits from such an approach because aggressive treatment strategies may prevent disease progression. Another argument for the direct transport of patients to CS centers is the limited availability of fully equipped ambulances that can secure the transfer of CS patients between hospitals. Until the network of CS centers is developed in Poland, patients should be transferred to PCI centers with on-site cardiothoracic surgery capabilities. If such a center is not within a reachable distance, transfer to the nearest interventional cardiology center should be considered. The decision on where to transfer the CS patient should be made after the MRT transmits the ECG recordings and consults the patient with a cardiologist from the center of the highest reference level.

Prehospital care involves the establishment of CS diagnosis and the initiation of treatment. Treatment provided by the MRT in Poland differs depending on whether it is a basic ambulance service (ambulance without an emergency physician on board) or a specialist ambulance service (with an emergency physician on board). Inotropes and vasopressors are the key players in the pharmacological treatment of CS. In the Polish setting, MRTs have access to the following medications: epinephrine, norepinephrine, dopamine, and dobutamine. In line with the ESC guidelines, norepinephrine can be considered in patients with hypotension [1]. According to Polish regulations, epinephrine is the only medication that can be administered by a paramedic, including a nurse paramedic, without the physician's order. The basic MRT ambulance is equipped with an infusion pump [14].

The current range of competencies should be changed to ensure that the members of basic MRTs can administer inotropes and vasopressors that are part of the ambulance

equipment (e.g. after they consult the case with the physician from the receiving hospital). Basic MRTs should be also authorized to perform a wider range of interventions (e.g., endotracheal intubation). According to current regulations, a paramedic can perform endotracheal intubation only in patients with sudden cardiac arrest [15].

In the prehospital setting, MI patients usually receive dual antiplatelet therapy with acetylsalicylic acid and $P2Y_{12}$ inhibitors. However, data on the efficacy and safety of $P2Y_{12}$ inhibitors in the prehospital treatment of STEMI patients are still limited. In cases where the diagnosis of STEMI is uncertain, a $P2Y_{12}$ inhibitor should not be used until the diagnosis is confirmed [11]. The use of ticagrelor and prasugrel is limited to selected patient populations. Therefore, the decision on the use of these medications and the choice of the other antiplatelet drug should always be discussed with the physician from the receiving cardiac center. This is another argument for increasing the number of real-time ECG transmissions.

Areas for improvement in prehospital care

- Real-time ECG transmission systems available in all invasive cardiology centers providing care for MI patients.
- An increase in the number of real-time ECG transmissions, consultations, and direct patient transfers to referral centers.
- Establishing rules for patient transfer. Patients with MI complicated by CS should be transferred directly to centers of the highest reference level, following the example of CS centers in the United States. Until such centers are created in Poland, patients should be transferred to PCI centers with on-site cardiothoracic surgery facilities. If such a center is not within a reachable distance, a transfer to the nearest interventional cardiology center should be considered.
- Authorizing basic MRTs to administer inotropes/vasopressors and to perform endotracheal intubation.

IN-HOSPITAL CARE

The in-hospital management of patients with MI complicated by CS is a multistep process that depends mainly on the patient's clinical condition. Early diagnosis and triage are the most important management steps in the emergency department. The key element of therapy in the MI setting is the treatment of the underlying cause, that is, percutaneous coronary revascularization. In CS patients, it is important to consider possible mechanical complications of MI, because they significantly worsen prognosis and usually require treatment at highly specialized centers with cardiothoracic surgery facilities. All patients with MI complicated by CS are treated in intensive care units (ICUs). Some patients do not respond to pharmacological treatment, which necessitates the use of MCS. This section discusses the key elements of in-hospital care.

Emergency room setting

At the emergency department that receives a CS patient, prompt diagnostic workup should be done to confirm the diagnosis and to triage the patient to an appropriate category in terms of the type of management and the level of urgency. Patients with MI should undergo 12-lead ECG and echocardiography, among other examinations. If MI is confirmed as the cause of CS, patients in stages A and B should be directly transferred to the catheterization laboratory for PCI [16, 17]. Patients with CS stages C or D should be stabilized first using vasopressors and mechanical ventilation. However, this should not significantly delay reperfusion. Patients in severe condition (CS stage E) should be assessed to identify potential benefits of an aggressive treatment strategy and to define therapeutic goals [17–20].

Revascularization

The introduction of urgent percutaneous revascularization and its increasing availability over the years have significantly reduced early mortality rates in patients with MI complicated by CS from 70%–80% to 40%–50% [21]. This trend was reflected in the ESC guidelines. The ESC guidelines on the management of STEMI recommend emergency PCI in CS patients unless the anatomy of the infarct-related artery (IRA) is unsuitable for the intervention [11]. In Poland, the network of catheterization laboratories available 24 hours 7 days a week makes it possible to quickly perform emergency PCI. According to the PL-ACS registry, in recent years, almost 90% of patients were treated by PCI, with low rates of cardiothoracic surgery procedures (Figures 2 and 3).

A delay in revascularization is one of the strongest predictors of unfavorable prognosis [19, 22, 23]. The FITT-STEMI trial (Feedback Intervention and Treatment Times in ST-Elevation Myocardial Infarction) showed that in patients with STEMI complicated by CS, every 10-minute delay in providing treatment within 60–180 minutes after the first contact with the emergency medical services resulted in an additional 3.3 deaths per 100 patients undergoing PCI [23].

While there is no doubt as to the importance of revascularization of the IRA in CS patients, the need for revascularization of other stenosed arteries has been debated for many years. It is estimated that even up to 70%–80% of CS patients have multivessel coronary artery disease defined as coronary stenoses or occlusions in a vessel other than the IRA [24]. The 2017 ESC guidelines on the management of STEMI recommend PCI of non-IRA lesions during the index procedure in CS patients (class of recommendation IIa, level of evidence C) [11].

However, in 2018, the ESC and the European Association of Cardiothoracic Surgery developed new guidelines on myocardial revascularization, in which routine treatment of non-culprit lesions is no longer recommended during the primary PCI (class of recommendation III, level of evidence B) [25]. The change of recommendations was

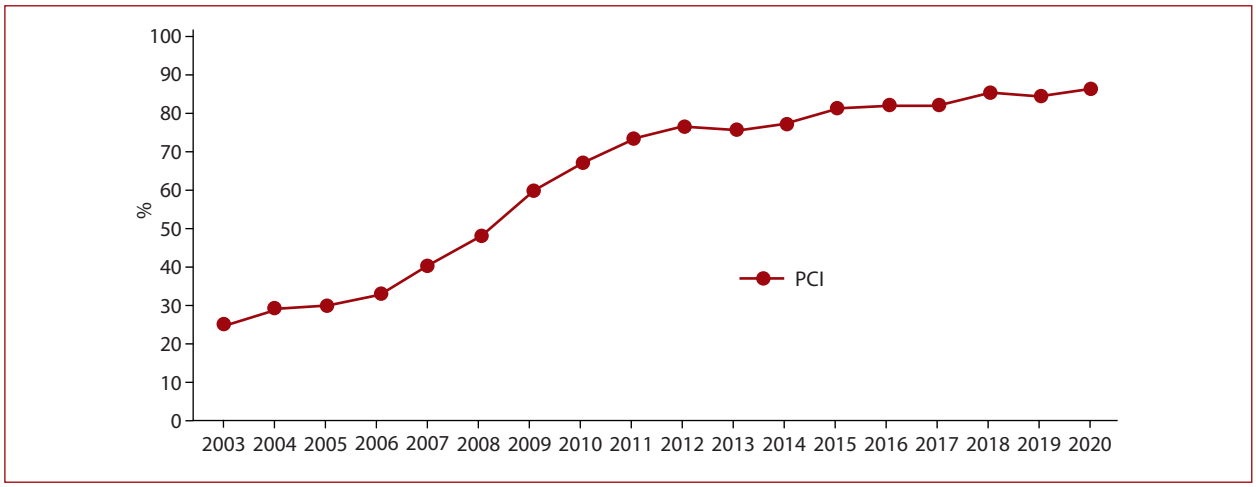

Figure 2. Rates of PCI in patients with MI complicated by CS data from the PL-ACS registry for the years 2003–2020

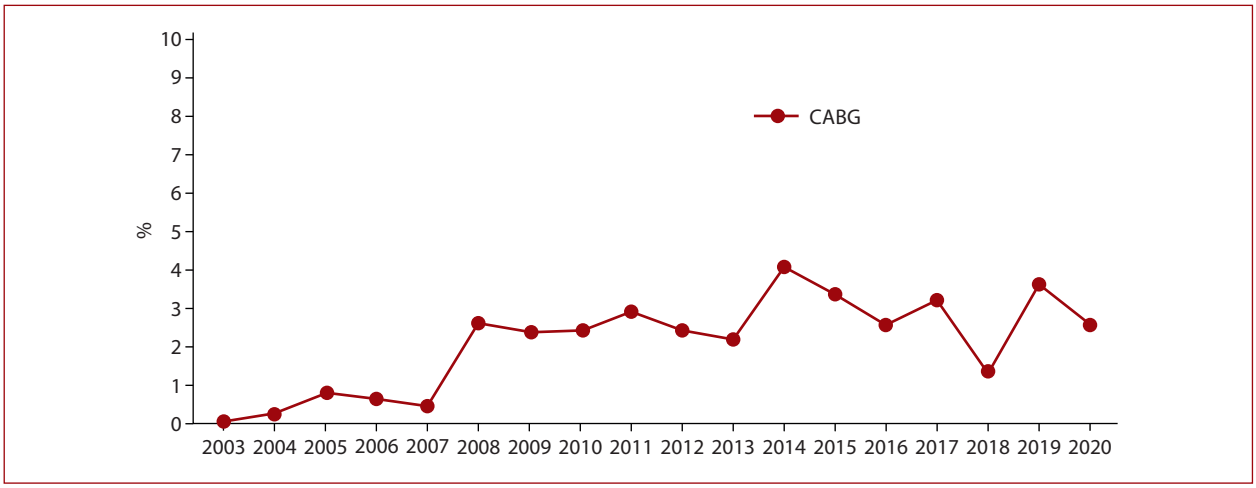

Figure 3. Rates of CABG in patients with MI complicated by CS ; data from the PL-ACS registry for the years 2003–2020

guided by the results of the randomized multicenter CULPRIT-SHOCK trial (Culprit Lesion Only PCI vs. Multivessel PCI in Cardiogenic Shock). The study showed a significantly lower incidence of the composite endpoint (death from any cause and/or renal replacement therapy at 30 days) in patients who underwent PCI of the culprit lesion only (45.9% vs. 55.4%; relative risk [RR], 0.83; 95% confidence interval [CI], 0.71–0.96; $P = 0.01$). This was caused mainly by a reduction in the rate of all-cause death (43.3% vs. 51.5%; $P = 0.03$) [26]. At 1-year follow-up, there were no differences in mortality rates, and the risk of rehospitalization and repeat revascularization was higher in the culprit-lesion-only PCI group. The highest mortality rates in CS patients are reported in the first 30 days. In the CULPRIT-SHOCK study, a relative reduction in the rate of death from any cause was 16% (RR, 0.84; 95% CI, 0.72–0.98) in the culprit-lesion PCI group. Between the 30 day and 1-year follow-up periods, the mortality rate was 6.6% and did not differ between the groups (RR, 1.08; 95% CI, 0.60–1.93) [26]. Therefore, long-term outcomes do not affect the recommendation to perform PCI of the IRA in CS patients.

The guidelines of cardiac societies usually recommend percutaneous revascularization [11, 25]. Coronary artery bypass grafting (CABG) is recommended mainly in patients in whom PCI failed or was not feasible because of unsuitable coronary anatomy. The rates of CABG in CS patients in randomized trials are usually below 5% [21, 27], which is in line with the rates of surgical revascularization reported in the PL-ACS registry (Figure 3).

Fibrinolysis

Thanks to the network of catheterization laboratories in Poland, fibrinolysis is used extremely rarely. The ESC guidelines recommend that CS patients undergo immediate PCI (class of recommendation I, level of evidence B), and fibrinolysis should be considered if primary PCI cannot be performed within 120 minutes from STEMI diagnosis and mechanical complications have been excluded (class of recommendation IIa, level of evidence C). Rescue PCI is indicated immediately in the case of failed fibrinolysis or if patients present with hemodynamic or electrical instability or worsening ischemia (class of recommendation I, level

of evidence A) [11]. In CS patients, the greatest benefits of fibrinolysis are observed within the first 2 hours from the onset of MI. After 3 hours from MI, these benefits are significantly reduced [28].

Mechanical complications of MI

In some patients, CS is caused by mechanical complications of MI that often require cardiac surgery. The reported rates of papillary muscle rupture, ventricular septal defect, and free wall rupture in STEMI patients are 0.05%–0.26%, 0.17%–0.21%, and 0.01%–0.52%, respectively [29, 30]. Conservative treatment of these complications is associated with poor prognosis. The guidelines of the American College of Cardiology Foundation/American Heart Association, and the ESC recommend early cardiac surgery in patients with hemodynamic instability. Mortality rates in these patients range from 20% to 87% and depend on the type of the complication [1, 31]. Owing to a limited number of studies on percutaneous interventions for ventricular septal defect and papillary muscle rupture, a decision on the treatment strategy should be made by the Heart Team or the CS team [32–34] and should be guided primarily by the center's experience.

Intensive care

The key factors that determine successful outcomes are adequate volume expansion, appropriate ventilation strategy, and prevention of bleeding complications and multiorgan failure. CS patients require hemodynamic monitoring at the ICU. Invasive hemodynamic monitoring with a Swan-Ganz catheter is helpful in CS patients and is indispensable in those with concomitant pulmonary edema [35]. Despite advances in technology, the use of noninvasive hemodynamic monitoring is still insufficient. In ICU patients, hourly diuresis should be assessed and ultrafiltration can be considered to reduce volume overload. In some centers, ultrafiltration seems to be underused or is started too late during treatment.

Pharmacological treatment in CS patients aims to improve perfusion of the key organs by increasing the cardiac output and arterial blood pressure. It is estimated that almost 90% of CS patients are administered inotropes and vasopressors [27]. These agents increase oxygen demand and cause vasoconstriction, which may impair microcirculation and increase cardiac afterload. Therefore, they should be used at the lowest possible doses and for the shortest possible time. Inotropes are used to increase cardiac output and blood pressure, improve peripheral perfusion, and help maintain the function of individual organs [36]. They can be considered in patients with systolic blood pressure lower than 90 mm Hg, with signs of hypoperfusion, who do not respond to standard treatment including fluid therapy (class of recommendation IIb, level of evidence C). Typically, dobutamine is used. In patients on chronic beta-blocker treatment, levosimendan can be considered because its inotropic action is independent of beta-adrenergic stimulation. In STEMI patients, phosphodiesterase III inhibitors are not recommended. In patients with acute left ventricular failure and hypoperfusion, norepinephrine is favored over dopamine (class of recommendation IIb, level of evidence B) [11].

In a randomized trial, De Backer et al. [37] compared dopamine with norepinephrine in a relatively small group of CS patients. Patients in the dopamine group showed higher rates of arrhythmia and no significant reduction in mortality [37]. Comparative studies with catecholamine in patients with MI complicated by CS are lacking [36, 38]. In a recent randomized study in patients with MI complicated by CS, no significant difference was noted between epinephrine and norepinephrine in terms of the effect on arterial pressure and cardiac index. However, patients receiving epinephrine showed a higher incidence of refractory CS (37% vs. 7%; $P = 0.008$), which led to premature termination of the study [36]. Mortality rates increase exponentially with an increase in catecholamines [39]. Instead of escalating inotrope doses, MCS should be considered.

Mechanical circulatory support

Over the past decade, early revascularization has become increasingly available, stent technology has vastly improved, and antiplatelet drugs have become even more effective. Despite this, no reduction in mortality in patients with MI and CS has been reported in Poland (Figure 4). According to the PL-ACS registry data for the past 15 years, patients are becoming increasingly older and more often have a history of MI, PCI, stroke, diabetes, peripheral vascular disease, and out-of-hospital cardiac arrest (Figure 5).

To improve prognosis, there have been increasing efforts to determine the role of MCS in this population of patients [40]. MCS is recommended in patients who cannot be stabilized with pharmacological treatment. Most often, it is used to unload the ventricle and improve organ perfusion. Data from randomized clinical trials on the efficacy and safety of different types of MCS are lacking. Moreover, there is generally no consensus as to when to refer the patient for MCS. According to the guidelines, the treatment starts with the use of catecholamines. In our opinion, it is necessary to apply a standard protocol for determining MCS eligibility. The Swan-Ganz catheter should be considered in all patients receiving MCS. The fulfillment of the criteria should be an indication for MCS, irrespective of the time since starting the pharmacological treatment. It is important that the same protocol is used across all centers. Previous experience shows that novel treatment methods are initiated too late, especially if there is limited access to these methods and there is only a small group of clinicians with sufficient training and expertise.

Intra-aortic balloon counterpulsation

Intra-aortic balloon pump (IABP) is the most well-established method of MCS. Over the years, cardiac societies

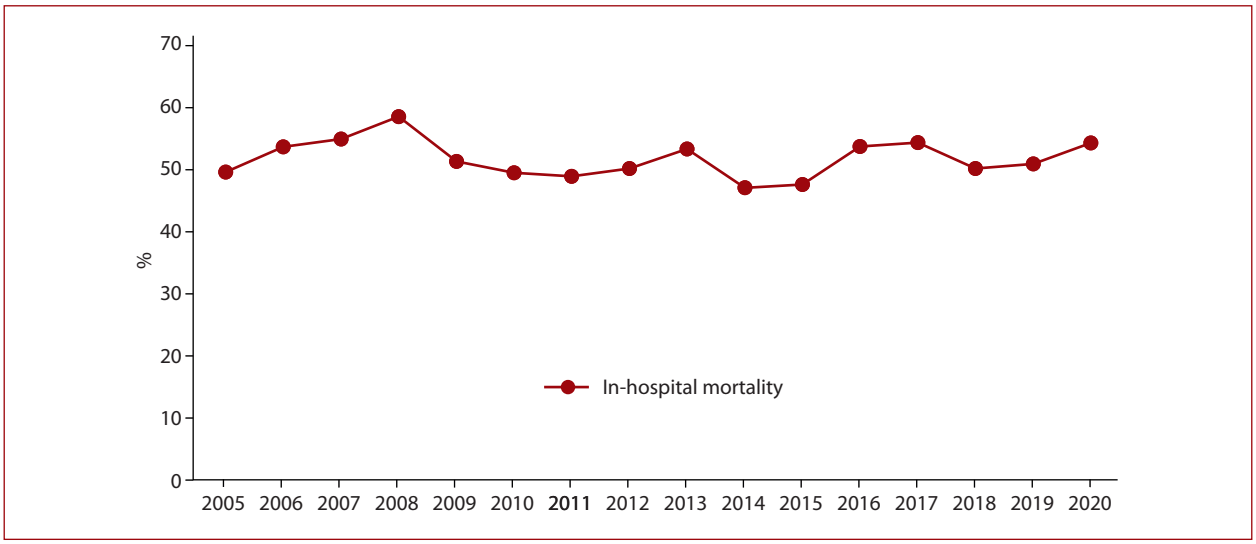

Figure 4. In-hospital mortality in patients patients with MI complicated by CS; data from the PL-ACS registry for the years 2003–2020

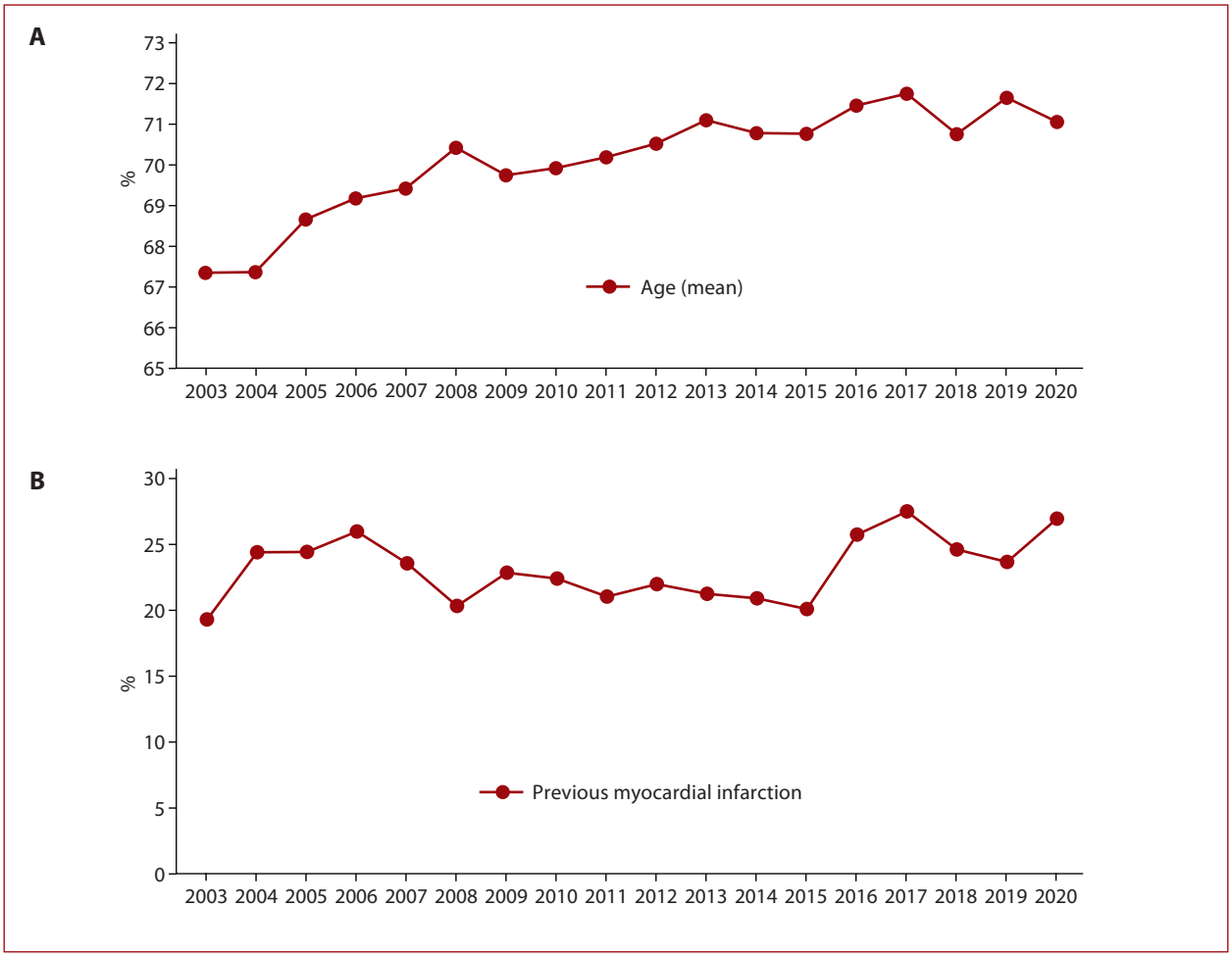

Figure 5. Characteristics of patients with MI complicated by CS; data from the PL-ACS registry for the years 2003-2020 **A**. Mean age. **B**. Rates of previous MI. **C**. Rates of previous PCI. **D**. Rates of previous stroke. **E**. Rates of diabetes. **F**. Rates of IABP use

Table 2. Recommendations on the use of the intra-aortic balloon pump in patients with cardiogenic shock based on the ESC guidelines on the management of heart failure, ST-segment elevation myocardial infarction, and revascularization

ESC guidelines	Recommendations	Class of recommendations	Level of evidence
Heart failure 2021 [1]	Routine use of IABP is not recommended in CS patients	III	B
STEMI 2017 [11]	Routine use of IABP is not recommended.	III	B
Myocardial revascularization 2018 [25]	Routine use of IABP is not recommended in patients with ACS complicated by CS	III	B

Abbreviations: ACS, acute coronary syndrome; IABP, intra-aortic balloon pump; STEMI, ST-segment elevation myocardial infarction; other — see Table 1

have changed their recommendations on IABP use, which affected the popularity of the device in clinical practice. IABP is the most accessible and frequently used MCS device in patients with MI complicated by CS (Figure 5F). In 2012, the results of the IABP-SHOCK II study (Intra-Aortic Balloon Pump in Cardiogenic SHOCK II) were published, reporting no significant differences in 30-day all-cause mortality between patients assigned to IABP vs. no IABP (41.3% vs. 39.7%; $P = 0.69$) [27]. The 6-year follow-up of the IABP-SHOCK II study showed that IABP had no effect on long-term outcomes in patients with MI complicated by CS No differences in mortality, recurrent MI, repeat revascularization or rehospitalization rates were shown between the IABP group and controls [41]. This led to an update of the 2017 ESC recommendations on the use of IABP in STEMI patients complicated by CS. According to the guidelines, IABP should be considered in patients with mechanical complications of MI: severe mitral regurgitation and ventricular septal rupture (class of recommendation IIa, level of evidence C) [11]. Recommendations on IABP use based on the most recent ESC guidelines on the management of heart failure, STEMI, and myocardial revascularization are presented in Table 2. Considering limited access to advanced MCS techniques, it seems justified to identify CS patients other than those with mechanical complications who also might benefit from IABP.

Impella, Impella RP

Following the results of the IABP-SHOCK II study and the changes in recommendations, the frequency of using IABP support has dropped significantly, both in Europe and in the United States [42]. At the same time, the popularity of other MCS devices has increased. This includes the Impella device (Abiomed, Danvers, MA, US), which is a microaxial flow pump that pulls blood from the left ventricle to the aorta.

The following Impella devices are currently available: Impella CP, Impella 5.0, and WK Impella 5.5. The last of these pumps is equipped with intelligent technology and can be also used in CS patients. Impella CP has been designed for use via the percutaneous femoral artery approach, while Impella 5.0 and 5.5 require a surgical approach. Impella CP, which was designed specifically for CS patients, comes with the SmartAssist heart pump, which allows for sustained peak flows of up to 4.3 l/min, repositioning without imaging, and hemodynamic monitoring.

The large diameter of Impella devices and the need for intensive anticoagulation regimens compromise the benefits conferred by the high level of circulatory support. Mechanical support with Impella pumps is associated with increased risk of vascular complications and major bleeding, which constitutes the main limitation of MCS [43]. Moreover, the IABP-SHOCK II subanalysis showed that some CS patients survive without the need for support (50%–60%) [41].

The remaining CS patients (40%–50%) constitute the most challenging population. These are both patients with severe CS, who cannot be rescued irrespective of the type of MCS, and patients in whom MCS can improve chances of survival. The identification of eligible patients who can gain the most benefit from MCS at minimal risk of complications remains challenging.

In addition to patient identification, it is important to develop management algorithms that would cover the whole spectrum of care. Currently, there are no data that could serve as the basis for developing precise recommendations on MCS use in patients with CS. According to the 2018 ESC guidelines on myocardial revascularization, MCS may be considered in selected patients with CS caused by acute coronary syndromes, depending on patient age, comorbidities, neurological function, and prospects for long-term prognosis and quality of life (class of recommendation IIb, level of evidence C) [25].

In line with the 2021 expert consensus of the European Association of Percutaneous Coronary Interventions/Association of Acute Cardiovascular Care (EAPCI/ACVC), microaxial flow pumps (including Impella) may be considered short-term therapy in CS stages C or D, in patients with a potentially reversible cause of CS, or in candidates for long-term left ventricular assist device support or heart transplant [44].

In clinical practice, microaxial flow pumps, such as Impella, may be considered in patients with CS caused mainly by acute left ventricular failure, who do not present with hypoxia and acute right ventricular failure. Caution is advised in patients with inferior wall and right ventricular MI complicated by CS.

Recently, the Impella RP device has been introduced to clinical practice. Impella RP is inserted via the femoral artery approach. It pumps blood directly from the inferior vena cava to the pulmonary artery. In line with current knowledge, Impella RP can be used in patients with right heart failure complicated by CS.

In selected patients with biventricular heart failure who do not require extracorporeal membrane oxygenation (ECMO), the use of simultaneous biventricular MCS support (Bipella) can be considered. However, data from clinical research are lacking [44]. In the Polish setting, the use of Impella devices is limited by high cost. The procedure is usually available only in selected university medical centers. There are no uniform recommendations that guide the selection of patients who should be treated with Impella pumps.

Veno-arterial extracorporeal membrane oxygenation

ECMO is a form of life support in which blood is pumped and oxygenated outside the body. It offers the highest level of mechanical support, accommodating a blood flow of up to 7 l/min. Moreover, by providing blood oxygenation, ECMO can be used in patients with cardiac and respiratory failure. Following the guideline update that led to the reduced IABP use, there was an increase in the use of ECMO in the CS setting. However, evidence from randomized clinical trials on the use of ECMO in CS patients is limited [45]. A meta-analysis of prospective and retrospective studies by Ouweneel et al. [46] demonstrated a 13% increase in 30-day survival in patients assigned to the veno-arterial ECMO (VA- ECMO) group. In the propensity-matched analysis, VA-ECMO showed a 33% higher survival rate compared with IABP (219 patients in each group) [46]. On the other hand, registry studies showed no significant improvement in survival despite the higher frequency of use [44].

In the ESC guidelines, recommendations for ECMO are similar to those for microaxial flow pumps (class of recommendation IIb, level of evidence C). There are no specific recommendations for the use of VA-ECMO. In clinical practice, VA-ECMO can be considered in patients after successful resuscitation, particularly in the presence of respiratory failure and/or right heart failure.

According to the EAPCI/ACVC consensus, VA-ECMO can be considered in patients with severe hemodynamic abnormalities, especially if they present with left heart failure and/or respiratory failure in the course of CS (stages C, D, or E). This applies particularly to patients with a reversible underlying cause of CS or to candidates for long-term left ventricular assist device support or heart transplant [44]. Thus, ECMO is not a therapeutic option that can be used in all patients with CS. In the Polish setting, the use of ECMO is additionally limited by the insufficient availability and lack of uniform recommendations for the identification of eligible CS patients.

The ECLS-SHOCK study in 217 patients with MI and CS, which was presented at the 2023 ESC Congress, failed to show that VA-ECMO improves 30-day outcomes. At 30 days, death from any cause occurred in 47.8% of patients in the VA-ECMO group and 49.0% of patients in the control group (RR, 0.98; 95% CI, 0.80–1.19; $P = 0.81$) [47]. Therefore, it cannot be ruled out that the reported outcomes will influence future recommendations on the use of VA-ECMO support.

Cardiac Shock Team and Cardiac Shock Care Centers

Considering high mortality rates, CS patients should be managed at centers providing the highest level of specialty care [5, 48–51]. It is increasingly suggested that CS patients should be treated by a multidisciplinary team referred to in the literature as the "cardiac shock team". The CS team should comprise an invasive cardiologist, an intensive care physician, a cardiac surgeon, and an advanced heart failure expert [47, 52–54]. A few studies reported that the management of CS patients by the CS team was associated with a reduction in 30-day mortality [52, 55].

Recent literature describes the benefits of creating CS centers, that is, referral centers dedicated to CS patients. A classification of centers providing CS treatment into Level I, II, and III centers has been proposed. Level III centers are local hospitals without a catheterization laboratory. These are hospitals to which patients are usually transported in the first place. In most cases, the CS patient should be promptly transferred from a non-PCI center to a center with a higher level of specialty care. Level II centers are PCI centers without advanced MCS capabilities. Finally, level I centers are CS centers with a catheterization laboratory and advanced MCS available 24 hours 7 days a week, and with on-site cardiothoracic surgery facilities. They can receive patients with cardiac arrest. The catheterization laboratory and CS teams are immediately alerted if a patient with CS has been admitted to the hospital or if their admission is planned. A prompt multidisciplinary consultation aims to facilitate decision-making on treatment, including MCS [46, 48, 49].

Currently, in Poland, most patients with MI complicated by CS are admitted to the nearest center with a catheterization laboratory available 24 hours 7 days a week. These are often centers with a limited availability of specialist personnel, especially during night duty. Moreover, these centers usually provide only IABP support. In our opinion, all patients with MI complicated by CS should be transported to the most highly specialized centers (CS centers) directly from the field, provided that the duration of transport does not result in a significant delay in the treatment of the underlying cause of CS. Until the network of CS centers is developed in Poland, patients should be treated at PCI-capable centers with on-site cardiothoracic surgery facilities. Such an approach to management increases the possibility of providing MCS and surgical treatment of the mechanical complications of MI. If such a center is not within a reachable distance and the transfer might delay treatment, transporting the patient to the nearest PCI-capable center should be considered.

Efforts should be made to set up CS centers capable of performing the whole range of interventional cardiology

and cardiac surgery procedures and with sufficient capacity to accommodate a large number of patients each year. Except for a catheterization laboratory and a highly specialized cardiology unit, these centers should also have cardiothoracic surgery and intensive care units as well as imaging facilities, including a computed tomography laboratory. This is particularly important for CS patients after out-of-hospital cardiac arrest. It is important that CS centers have access to MCS techniques described in this consensus and that patients are managed by CS teams comprising a cardiologist, an interventional cardiologist, an intensive care physician, a cardiothoracic surgeon, and a nurse with specialization in anesthesiology and intensive care. To ensure a quick patient transfer, helicopter landing areas should be constructed on the property of the hospital or within a short distance from the hospital. In Poland, helipads are available only in a few multispecialty hospitals and university centers. It seems that in the Polish setting, a single CS center should serve a population of 1–1.5 million inhabitants, after considering geographic and demographic factors. The development of a national treatment program for patients with MI complicated by CS and a network of CS centers should become a priority for the cardiac community in Poland.

The proposed algorithm for the management of patients with MI complicated by CS including prehospital and hospital care, is presented in Figure 6 (central illustration).

Figure 6. Algorithm for the management of patients with MI complicated by CS (central illustration)

Areas for improvement in the hospital setting

- A system for the in-hospital management of CS patients should be developed. The first step is to determine how many such centers are needed and to define the criteria for their operation. This applies to centers of all referral levels.
- All patients with MI complicated by CS should be managed by a multidisciplinary CS team.
- Patients should be treated at CS centers, that is, centers providing the highest level of specialty care and a full range of diagnostic and treatment procedures. Until CS centers are developed, patients should be preferably transferred to PCI-capable centers with on-site cardiothoracic surgery facilities.
- Considering limited access to advanced MCS, it is important to identify CS patients who might benefit from this type of support. At the same time, efforts should

be made to consistently increase the availability of MCS and to extend indications for their use in line with the recommendations of scientific societies. Education on the use of MCS is also important.
- Research on the benefits of various MCS techniques in CS patients should be conducted at centers of the highest reference level.

CARE AFTER HOSPITAL DISCHARGE

For a long time, the role of care after hospital discharge for improving outcomes in patients with MI complicated by CS has been underestimated. This refers particularly to cardiac rehabilitation. Data on the number of CS patients participating in a cardiac rehabilitation program after hospital discharge are lacking. A few years ago, a program for comprehensive care after MI (Kompleksowa Opieki nad Chorym po Zawale Serca [KOS Zawał]), was introduced in Poland. It not only provided access to rehabilitation but also to regular cardiac monitoring. However, it was estimated that fewer than 20% of patients with MI participate in the program, and there are no data on CS rates in this population. A rehabilitation program and multispecialty care should be provided to all patients after MI.

There are also no data on the long-term outcomes of patients with MI complicated by CS. To improve the effectiveness and quality of treatment, it is necessary to monitor the incidence of cardiovascular adverse events in long-term follow-up.

Areas for improvement in patient care after hospital discharge

- Patients with MI complicated by CS should be included in a rehabilitation program and multispecialty care.
- Long-term outcomes should be assessed, for example, by monitoring the rates of cardiovascular adverse events.

CONCLUSION

Despite significant advances in intensive care and an increase in the number of catheterization laboratories, MI complicated by CS is still associated with high mortality rates. Although novel MCS devices offer considerable promise, randomized clinical trials are needed to confirm their efficacy. The limited availability of highly specialized centers with access to advanced MCS techniques as well as the high cost of the MCS technology constitute additional barriers to the widespread use of MCS.

This consensus presents a number of organizational solutions for all stages of CS management. Several suggestions, such as establishing CS centers, require implementation of systemic solutions. To achieve these goals, an expert panel comprising specialists in CS treatment and policymakers should be convened.

Article information

Conflict of interest: None declared.

Funding: None.

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