Contemporary treatment of acute myocardial infarction complicated by cardiogenic shock

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Kardiochirurgia i Torakochirurgia Polska 2007; 4 (3): 234–238

Despite major advances in the treatment of myocardial infarction (MI), the incidence of cardiogenic shock has remained unchanged, complicating 7% to 10% of acute myocardial infarctions (MI) [1] and constituting the leading cause of death in patients with acute MI [1]. During the last three decades, the hospital mortality rates from cardiogenic shock have declined from as high as 90% to 50%. These improvements are attributed to the many changes in clinical practice that occurred during this period, and in particular, early coronary revascularization and more aggressive use of circulatory support devices. The 50% mortality rate from cardiogenic shock is still substantial. The contemporary approach to cardiogenic shock complicating MI is reviewed in this article.

Early revascularization

Early mechanical reperfusion of occluded coronary arteries by percutaneous coronary intervention (PCI) or coronary artery bypass surgery (CABG) appears to be key for survival of patients with cardiogenic shock. The SHOCK trial (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock) was the first multicenter, prospective study that evaluated early revascularization (PCI or CABG) in patients with cardiogenic shock due to an ST-elevation/Q-wave or new left bundle branch block MI, which compared outcomes to either delayed revascularization or medical treatment [2]. The overall 30-day mortality did not differ significantly between the revascularization and the medical therapy groups, but the 6-month and 12-month mortality were significantly lower in the revascularization group (Fig. 1). One-year follow-up of the SHOCK trial [3] and the later study by Sleeper et al. [4] showed that early revascularization not only provided substantial survival benefit in these patients, but also resulted in much better long-term quality of life and fewer symptoms of heart failure.

Percutaneous coronary intervention (PCI) is the first line of therapy in acute cardiogenic shock (Tab. I) [5]. Rapid transfer of patients to the catheterization lab allows not only early opening of the occluded vessel, but also assessment of hemodynamics and temporary stabilization with an intraaortic counterpulsation balloon pump (IABP). Some patients considered CABG candidates may also undergo during this time a PCI of the diseased vessels as a measure of temporarily stabilization before surgery. The SHOCK trial

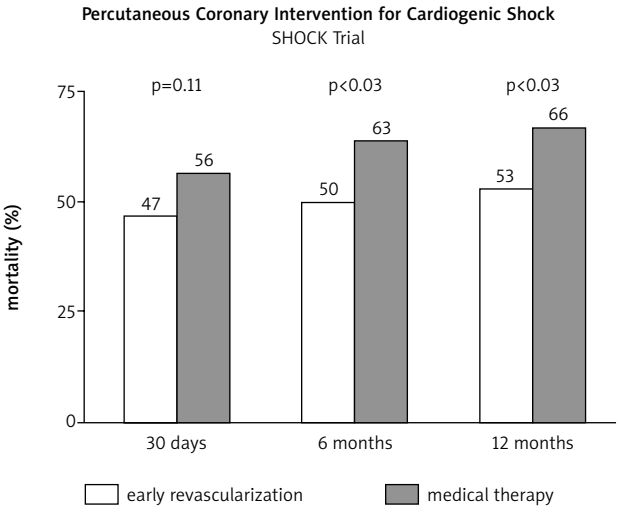

Fig. 1. The Shock Trial (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock) revealed no significant difference in 30-day mortality between the revascularization therapies and the medical therapy, but the 6-month and 12-month mortality were significantly lower in the revascularization group [2]

Tab. I. Trends in management and outcomes of patients with acute myocardial infarction complicated by cardiogenic shock [5]

	1995	2004
cardiac catheterization (%)	51.5	74.4
intra-aortic balloon pump use (%)	39.2	39.2
fibrinolytic therapy (%)	19.9	5.6
percutaneous coronary intervention		
primary (%)	27.4	54.4
total (%)	34.3	64.1
coronary artery bypass graft surgery (%)	11.5	8.8

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revealed that as many as one third (37%) of catheterized patients eventually underwent CABG [1]. The outcomes of PCI and CABG at 30 days and 1 year appeared similar, despite more severe CAD and higher prevalence of diabetes among those who underwent CABG [6]. Importantly, CABG provided substantial survival benefit in patients with heart failure. Among 136 patients with left ventricular dysfunction and cardiogenic shock who underwent emergent CABG, mortality was 27.9% compared to 45.5% in 268 patients undergoing PCI. These results led to ACC (American College of Cardiology) recommendations to proceed with CABG as a primary revascularization tool in patients who have significant left main disease or severe three-vessel disease without severe right ventricular infarction or major comorbidities [7].

In the era of direct PCI and CABG, fibrinolysis has fallen out of favor as the primary therapy for cardiogenic shock. This approach, however, may still be appropriate for ST-elevation MI patients, who are unsuitable for invasive care or are far from the angiography lab and timely revascularization may be an issue, providing they have no contraindications to this treatment. In large clinical trials, such patients had in-hospital survival rates ranging from 20% to 50% when treated with intravenous fibrinolytic therapy.

Early hemodynamic support

When it comes to cardiogenic shock, early mechanical circulatory support with left-ventricular unloading is as important measure of early stabilization as early coronary revascularization. Over half of deaths in the SHOCK trial occurred within the first 48 hours after MI from profound circulatory failure, underscoring the importance of early hemodynamic stabilization. Placement of AIBP is the most common intervention, and is favored over the use of vasopressors and inotropes alone, which may increase metabolic demand and most often are unable to prevent the downward spiral of hemodynamic failure. Placement of IABP is particularly helpful as a bridge to PCI or CABG in acute mitral regurgitation, ventricular septal defect, intractable ventricular arrhythmias and refractory angina. However, IABP support may not always be sufficient to maintain end-organ perfusion and treatment may escalate to other mechanical circulatory support devices.

There are a variety of new generation assist devices available, which may be used in various clinical scenarios of cardiogenic shock. Short-term percutaneous support pumps, such as the TandemHeart device (Fig. 2), have been studied in a small randomized trial of 42 patients [8]. The device improved patients' hemodynamics, although the 55% survival was not any different from that seen in patients supported with AIBP. The transvalvular assist device Impella is another type of percutaneous miniaturized pump that can be placed through a transfemoral approach [9] (Fig. 3), and has been shown to be useful in the reported short series of patients with cardiogenic shock. More aggressive methods, such as the implantation of a short-term bridge-to-bridge device, such as the CentriMag Levitronix [10] (Fig. 4), may be useful in patients with uncertain neurologic

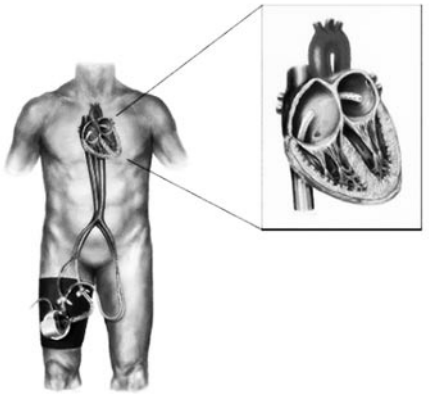

Fig. 2. The TandemHeart™ pVAD (CardiacAssist, Inc) is a short-term percutaneous pump deployed with dual perfusion cannulae. With the device in place oxygenated blood is withdrawn from the left atrium of the heart through a tube placed in the large vein in the leg and returned through the large artery. It is also possible to percutaneously deliver the TandemHeart into the pulmonary artery to stabilize right ventricular bypass

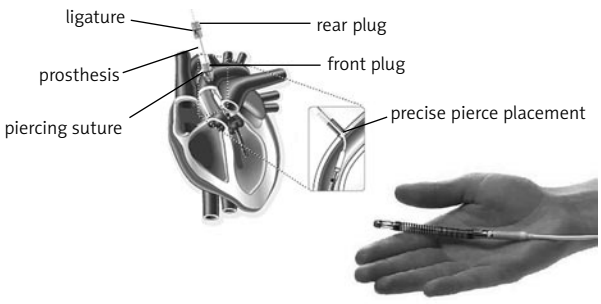

Fig. 3. The Impella Recover LD/LP 5.0 Support System is a miniaturized impeller pump located within a catheter. The device can provide support for the left side of the heart using either approach via direct placement into the left ventricle or percutaneous placement through the femoral artery and positioning in the left ventricle

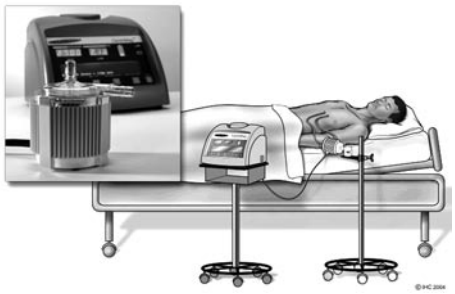

Fig. 4. The Levitronix CentriMag is a short-term support pump, which consists of a centrifugal pump that is unique in that it can operate without mechanical bearings as the motor impeller, which magnetically levitates, is able to achieve rotation with no friction or wear. The pump can be used for left-, right- and bi-ventricular support

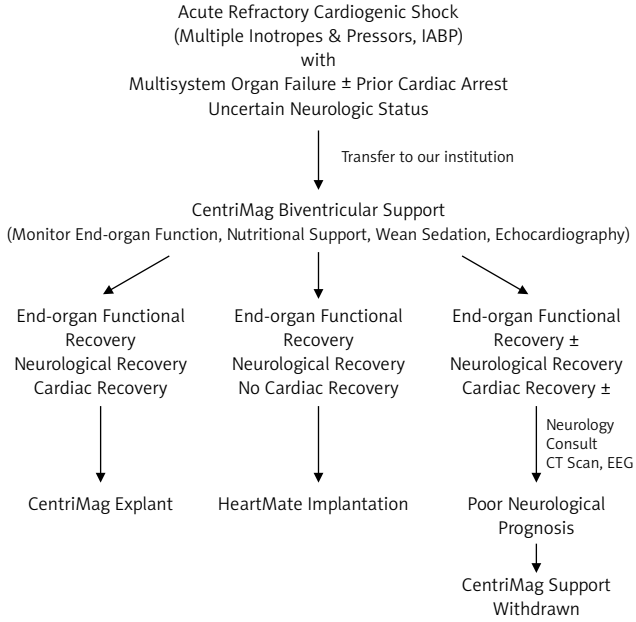

Fig. 5. Algorithm for implantation of the Levitronix CentriMag short-term support pump depicting the management of patients transferred from outside institutions with refractory acute cardiogenic shock with multiorgan failure. IABP – intraaortic balloon pump; CT – computed tomography; EEG – electroencephalogram [10]

status and multiorgan failure who are potential candidates for permanent left ventricular assist device (LVAD) implantation (Fig. 5). We have previously published a series of 10 Levitronix recipients who underwent bridge-to-bridge implantation with 65% survival rate to implantation of LVAD [10]. And lastly, emergent LVAD implantation as bridge-to-transplantation is another option of addressing cardiogenic shock in transplant candidates, such as the HeartMate XVE pusher-plate pump (Fig. 6), or the newer generation, axial flow HeartMate II (Fig. 7).

Controversies and challenges in cardiogenic shock

There are many areas of controversy when considering treatment of cardiogenic shock. One of them is early revascularization of older patients. The SHOCK trial showed that only patients younger than 75 years appeared to derive a clear survival benefit from early revascularization, but not patients older than 75 years. We believe that in elderly patients, rapid revascularization (PCI or CABG) may still be suitable, providing that patients are in good overall medical condition and functional status and are agreeable to more aggressive therapy. Advanced patient age is also an important issue in terms of use of mechanical circulatory support, as older patients are not transplant candidates, and outcomes of permanent LVAD implantation as destination therapy, or alternative to transplantation, may be very poor in hemodynamically decompensated patients.

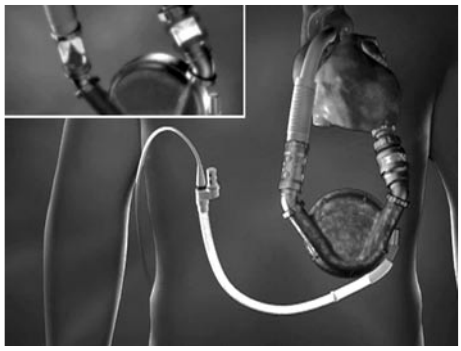

Fig. 6. The HeartMate XVE Left Ventricular Assist Device. The HeartMate XVE LVAD consists of an implantable titanium blood pump, whereby the inflow valve conduit of the LVAD is attached to the apex of the left ventricle and the outflow graft is attached to the ascending aorta. This device is equipped with porcine tissue inflow and outflow valves providing unidirectional, pulsatile blood flow based on preload and filling pressures. A percutaneous drive line carries the electrical cable and air vent to the battery packs and electronic controls, which are worn on a shoulder holster and belt. (Adopted from HeartMate XVE Left Ventricular Assist System, Professional Education Program, Thoratec Corporation, 2004)

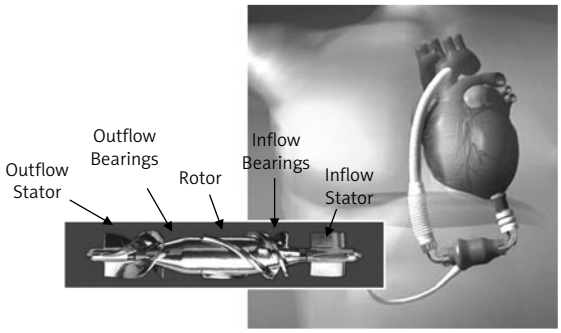

Fig. 7. The axial flow pumps are much smaller than the conventional pusher-plate pumps. The HeartMate II is one of the axial flow pumps, which can produce high flows using an electromagnetically actuated impeller housed within a very small titanium pump

Cardiogenic shock due to isolated right ventricular infarct is often a great challenge. Medical therapy with nitric oxide has shown some promise in this area, although the early experience is still very limited. In terms of temporary mechanical circulatory support, it is now possible to percutaneously deliver the TandemHeart device into the pulmonary artery and stabilize the right ventricle. This, however, again is a temporary measure and experience is still limited.

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Treatment of acute myocardial infarction complicated by cardiogenic shock

Answers to editorial questions

Marian Zembala (MZ): I*s an anesthesiologist or critical care specialist involved in the care of patients in cardiogenic shock?*

Katherine Lietz (KL): Patients in cardiogenic shock are admitted to specialized cardiac intensive care units under the care of the attending cardiologist. These units allow continuous hemodynamic monitoring and have highly specialized nursing staff to work with cardiac patients. The cardiologist is the primary physician taking care of these patients. Occasionally, when patients present with complicated lung disease, we may consult a pulmonary/critical care specialist. Anesthesiologists do not participate in patient care outside the operating room.

MZ: *What happens to patients in cardiogenic shock who are admitted to centers that cannot provide mechanical circulatory support?*

KL: If the patient develops persistent cardiogenic shock despite IABP, and the hospital has no means of mechanical circulatory support/transplant, then the hospital refers this patient to the closest LVAD/transplant center. Our LVAD team members will go on site and evaluate the patient's candidacy for mechanical support. If the patient is acutely decompensating, for instance, then that patient will be immediately transferred for emergent surgery without an on-site visit, and evaluated upon arrival at our centers.

MZ: *Who decides on the timing and type of mechanical support at the LVAD center?*

KL: Patients with cardiogenic shock in LVAD/transplant centers are followed by either a critical care unit cardiologist, who consults a specialist in advanced heart failure, or by an advanced heart failure specialist alone. It is the specialist in advanced heart failure who identifies patients that may require cardiac replacement. An LVAD surgeon is then consulted and together a consensus is reached regarding timing of mechanical support and the type of device, such as short- vs. long-term, left- vs. bi--ventricular, bridge-to-bridge, -transplant or destination therapy, etc. Often the first call is made to the surgeon, who then advises evaluation by the cardiologist.

MZ: *Does LVAD implantation require additional subspecialty training?*

KL: In the current era of mechanical circulatory support it is strongly recommended that both cardiologists and surgeons undergo additional training. An advanced heart failure specialist is a cardiologist with additional training in transplantation and mechanical circulatory support. This requires an extra one year of training and/or experience with these patients following general cardiology training. The LVAD surgeon is also required to do one additional year of training following cardiothoracic surgery training.

MZ: *Who follows patients after LVAD surgery?*

KL: Usually, cardiac surgeons and advanced heart failure cardiologists follow patients together after device implantation. The work is somewhat divided between the two specialists; the heart failure cardiologist follows medical therapy and hemodynamics, whereas the cardiac surgeon follows on surgical complications, such as pleural effusions, bleeding, tamponade, etc. These roles, however, often overlap. Each patient receives input from both teams of cardiologists and surgeons.