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專題報導

The Utilization of A New, Miniaturized Veno-arterial Bypass System for Cardiogenic Shock: A Review Article

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Abstract

Mortality for refractory cardiogenic shock (CS) remains high. However, while the technology of mechanical circulatory support device advances, the treatment options for CS patients are expanding. The percutaneous cardiopulmonary support system (PCPS) as an innovative tool is used to stabilize CS in our institute. The idea behind this system is that it is small, simple and can be easily, quickly and effectively operated by cardiologists like us. (J Intern Med Taiwan 2017; 28: 213-217)

Key Words: Cardiogenic shock; Veno-arterial bypass; Percutaneous cardiopulmonary support (PCPS)

Introduction

CS can be a consequence of left ventricular (LV), right ventricular (RV), or biventricular myocardial injury resulting in systolic and/or diastolic myocardial pump failure. This disorder is life-threatening and shared several common features including insufficient cardiac output, end-organ hypoperfusion, require temporary interventions to maintain circulation until spontaneous output is restored. LV failure secondary to myocardial infarction (MI) remains the most common cause of CS. The average survival to discharge after CS in the setting of acute MI is 28.3%[1]. Existing treatments for CS typically include high-dose inotropic support and use of an intra-aortic balloon pump (IABP).

Conservative therapy was known to produce disappointing results with a hospital mortality rate exceeding 80% in some clinical observational studies[2,3,4]. Transient mechanical circulatory support may be a therapeutic option for patients with cardiac failure unresponsive to pharmacologic therapy[5,6].Despite relatively few randomized trials validating these devices, some cardiovascular society guidelines recommend the use of mechanical circulatory support device in patients not responding to standard treatments for CS. (Class IIa, Level of Evidence C)[7].

The purpose of this article is to review a miniaturized percutaneous cardiopulmonary V-A bypass

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system (PCPS) as an interventional bridge to recovery in the setting of CS.

Mechanical Circulatory Support Devices

The use of cardiopulmonary bypass support to stabilize patients in severe cardiopulmonary failure was first proposed by Gibbon 1939[8,9]. However, the use of extracorporeal circulation systems did not gain widespread acceptance mainly due to its bulkiness, complexity of the technique in terms of priming or surgical vessel preparation, and the need for full-dose anticoagulation. We proposed that an ideal mechanical circulatory support device should have the following characteristics: light-weighted; the ability to be implanted rapidly and easily via a percutaneous approach; effective and reliable circulatory support (flow) to adequately unload the impaired ventricle(s), to maintain systemic perfusion pressure, and to reverse end-organ dysfunction; and low complication rates.

In recent years, the field of circulatory support has matured dramatically with the development of various percutaneous circulatory support devices (see Table 1 for a summary and comparison).

Intra-Aortic Balloon Pump Counterpulsation (IABP)

The most frequently used mechanical assist device for CS, IABP can improve coronary and peripheral perfusion via diastolic balloon inflation and augment LV performance via systolic balloon deflation.

Earlier data from the Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock(SHOCK) Trial Registry and in the Global Utilization of Streptokinase and TPA for Occluded Coronary Arteries(GUSTO-I) trial had demonstrated benefits in in-hospital mortality[10]; 30-day and 1-year all-cause mortality in patients with MI associated with CS [11].

Despite these initial results,a subsequent well-powered, prospective, randomized clinical trial (IABP-SHOCK II trial)[12], demonstrated that IABP did not reduce 30-day mortality or 12 month all-cause mortality in patients undergoing early revascularization for MI complicated by CS.

Percutaneous Cardiopulmonary Support System (PCPS)

Although ECMO technology was developed in the 1960s, there has been a recent renaissance of this technology owing to better cannulation techniques, smaller cannulas, improved oxygenator machines, and device miniaturization. Together, these improvements have resulted in light weight, portable, reliable, and rapidly implantable PCPS.

In a study conducted by Shinn and Lee[13], a

Table 1. Comparison of currently available percutaneous circulatory support devices

	Tandem Heart	Impella Recover LP5.0	Impella Recover LP 2.5	ImpellacVAD	PCPS
Cannula (French)	21 venous 12-19 arterial	21	12	9	17-21venous 16-18 arterial
Pump speed (rpm)	Maximum 7,500	Maximum 33,000	Maximum 51,000	Maximum 51,000	Maximum 3000
Flow (L/min)	Maximum 4.0	Maximum 5.0	Maximum 2.5	3.7-4.0	Maximum 4.0
Insertion/ Placement	Peripheral (femoral artery + LA)	Peripheral surgical (femoral artery)	Percutaneous (Femoral artery)	Percutaneous (Femoral artery)	Percutaneous (Femoral artery & Femoral vein)
Anticoagulation	+	+	+	+	+
FDA	+	+	+	-	+
Relative cost to IABP	++++	++++	+++	+++	++

considerably high percentage of patients were resuscitated by PCPS and survived to discharge: weaning from PCPS was achieved in 59 patients (64%) and survival to discharge in 39 patients (42%). It has been used as a bridge-to-recovery device in patients with fulminant myocarditis[14]; and it improves 30-day outcomes when used for hemodynamic support during primary PCI in patients presenting with STEMI and profound CS[15]. It can also be used successfully to support high-risk PCI in a patient with CS[16] and support pulmonary embolectomy in a patient with cardiovascular collapse secondary to a massive pulmonary embolism.

Set Up

The indications for PCPS in our institute are as follows: any causes of severe LV failure with peak systolic pressure less than 80 mmHg and cardiac index less than 1.8 L/min/m^2 for more than 30 min after the correction of hypovolemia, hypoxemia, and acidosis; RV heart failure due to RV MI or any other causes; a rapid decrease in cardiac output unresponsive to IABP; fatal ventricular tachyarrhythmia refractory to antiarrhythmic agents and witnessed cardiopulmonary arrest.

The PCPS system at our institution comprised of a centrifugal pump, polypropylene hollow fiber membrane oxygenator, and a heparin-coated circuit (Capiox EBS circuit; Terumo Inc, Tokyo, Japan) (Figure 1 and 2). The most important benefit of this system is its autopriming, which takes only 5 min to prime the circuit before use. Cannulation could be done percutaneously in the femoral artery and vein using the Seldinger technique by Cardiologists.

PCPS flow was initially maintained in the range 3.0 to 3.5 L/min/m^2 and catecholamine dosage was reduced to maintain a mean arterial pressure between 60 and 70 mmHg. With a heparin-coated

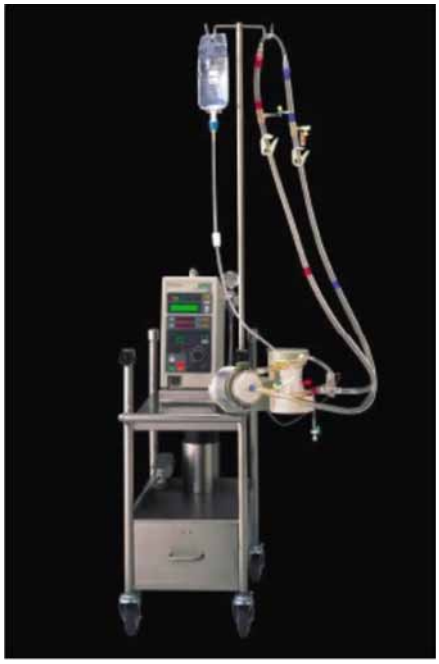

Figure 1. The Terumo Percutaneous Cardiopulmonary Support System (PCPS) Pump-Driving Console.
Kindly provided by Terumo Taiwan Medical Co., Ltd Speakers Deck.

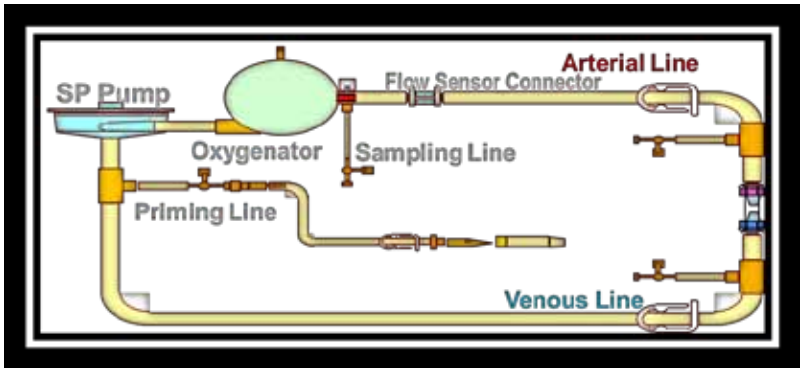

Figure 2. The Terumo Percutaneous Cardiopulmonary Support System (PCPS) closed circuit comprising of lock connector that enables quick set up of circuit.
Kindly provided by Terumo Taiwan Medical Co.,Ltd Speakers Deck.

circuit, full dose anticoagulation is not required as long as activated clotting time is controlled at 150–200 seconds. All patients are sedated by a continuous infusion of fentanyl and midazolam. When the patient's cardiac output and oxygen delivery were restored, the ventilation mode is modified to provide lung protective ventilation.

Complications

Cannulation related leg ischemia and vessel injuries, major bleeding, thromboembolic complications, failure of the extracorporal systems, and multiple system organ failure are the most common reasons for the substantial morbidity and mortality[17]. Despite low-dose systemic heparin therapy (due to the use of heparin-coated extracorporeal systems), substantial bleeding demanding blood transfusions and sometimes surgical exploration remained a major problem in many previous reports[17,18]. V-A cardiopulmonary bypass can also lead to inadequate LV unloading, LV distension, and subsequently myocardial injury[19]. Insufficient unloading cause pulmonary congestion and lung edema, blood retaining in the LV with an increased risk of systemic emboli, and can impede LV recovery[18,20].

Goals of Support and Weaning

In the absence of definitive guidelines, weaning can be initiated in patients having stabilized hemodynamics (including minimal/no pressor requirement) and improving end-organ/cardiac performances. It is accomplished by gradually decreasing the pump speed/flow to maintain mean arterial pressure >65 mm Hg, a mixed venous oxygen saturation of >70%, central venous pressure <15 mmHg and pulse pressure was more than 30 mmHg. PCPS was discontinued when the above hemodynamic parameters was attained with PCPS flow between 1.5 and 2.0 L/min.

Conclusion

CS and cardiac arrest are common, lethal, debilitating and costly. PCPS as a second generation miniaturized, veno-arterial cardiopulmonary bypass systems has been widely accepted for restoring blood flow and oxygen delivery in severe cardiac or cardiopulmonary failure resistant to critical care treatment. Ease of implementation remains the nemesis of current PCPS systems. However, high-quality, adequately controlled trials are required to verify its effectiveness.

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利用一種新型的輕小經皮心肺體外循環維生系統輔助心因性休克治療：綜述文章

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摘 要

雖然多年來心因性休克之死亡率持續偏高，但隨著醫療維生系統的進步，心因性休克的治療方式就更為多元化。此篇文章，主要是要介紹本院近年來，用來穩定心因性休克的一種創新維生輔助系統。稱之為：經皮心肺功能維生系統(PCPS)，此系統之好處在於儀器之設計，體積輕巧、操作快速，可由心臟內科醫師，快速完成導管之放置與儀器設定，儘速建立患者之血液動力學。以提高存活率。