Cardiac Arrest

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Cardiac arrest (CA) is a frequent cause of death and a major public health issue. To date, conventional cardiopulmonary resuscitation (CPR) is the only efficient method of resuscitation available that positively impacts prognosis. Extracorporeal membrane oxygenation (ECMO) is a complex and costly technique that requires technical expertise. It is not considered standard of care in all hospitals and should be applied only in high-volume facilities. ECMO combined with CPR is known as ECPR (extracorporeal cardiopulmonary resuscitation) and permits hemodynamic and respiratory stabilization of patients with CA refractory to conventional CPR. This technique allows the parallel treatment of the underlying etiology of CA while maintaining organ perfusion. However, current evidence does not support the routine use of ECPR in all patients with refractory CA. Therefore, an appropriate selection of patients who may benefit from this procedure is key. Reducing the duration of low blood flow by means of performing high-quality CPR and promoting access to ECPR, may improve the survival rate of the patients presenting with refractory CA. Indeed, patients who benefit from ECPR seem to carry better neurological outcomes.

extracorporeal membrane oxygenation | ECMO | cardiac arrest

1. Introduction

Cardiac arrest (CA) is a major public health issue. Its incidence in North American and Europe approximates 50 to 100 cases per 100,000 [1]. Cardiovascular etiologies account for half of the cases documented. The 30-day survival rate of out-of-hospital cardiac arrest (OHCA) patients who received cardiopulmonary resuscitation (CPR) is of 10.7% worldwide [2]. Indeed, this poor survival rate has brought interest in the development of a combined approach of conventional resuscitation techniques by means external cardiac compressions and defibrillation with extracorporeal life support by the use of Extracorporeal Membrane Oxygenation (ECMO). Thus, extracorporeal cardiopulmonary resuscitation has become a lifesaving approach for patients suffering a CA that is deemed refractory to conventional resuscitation.

ECPR helps maintain organ perfusion while investigations on the primary etiology of CA are being carried out, and etiologic treatment is being provided. Recently, it has been demonstrated that in-hospital cardiac arrests (IHCA) treated with ECPR show promising survival rates oscillating between 20 to 45% [3][4]. On the other hand, studies performed on non-hospitalized patients (out-of-hospital CA: OHCA) show worse outcomes [5]. Despite this, the most recent guidelines on OHCA's management elaborate the possibility of using ECPR, but not as routine standard of care.

The better survival rates post. IHCA are attributed to the earlier implementation of better quality resuscitation, along with quicker access to ECPR. In addition, when looking at studies where ECPR was employed, the length of conventional cardiopulmonary resuscitation (CPR) seems have a negative influence on survival [6]. The differences in survival between OHCA and IHCA handled with ECPR disappear when correcting for the duration of the low-flow period [7]. It would seem therefore plausible that through the promoting of access to ECPR, CPR time will be shortened and survival after CA will be improved [8]. A number of studies have shown the effectiveness of ECPR in cardiac catheterization rooms, emergency departments, and pre-hospital settings [9][10][11]. However, as published in two recent review articles, ECPR programs differ substantially across centers and are a cause of a lack of standardization [12][13].

2. Patients Management after ECPR

Management after ECPR is focused on preserving adequate organ perfusion restoring a pulsating rhythm with a native cardiac output. After establishing an adequate extracorporeal circulation, the chest compressions may be stopped. At this point, after an improvement in coronary perfusion pressure and a better supply of oxygen from the extracorporeal pump, defibrillation of shockable rhythms is generally more effective. Managing hyperoxia is challenging after the introduction of extracorporeal circulation. The oxygen supply has to be adequately calibrated in order to not negatively impact neurological and cardiovascular outcomes. The mean arterial blood pressure (MAP) should be maintained between 65 and 75 mmHg (expert recommendation) with a careful balance between flow and negative pressure inside the venous cannula. Most of the time, vasopressors (noradrenaline) are used to reach the target MAP. Invasive blood pressure monitoring is mandatory. It is advisable to catheterize the right radial artery in order to anticipate the occurrence of Harlequin syndrome in case of recovery of the left ventricular function and to allow the detection of hypoxemia of pulmonary origin. Sometimes aggressive volume resuscitation (ischemia-reperfusion syndrome) may be necessary to ensure an adequate preload to support ECPR.

The circulatory support by peripheral veno-arterial ECMO (VA-ECMO) is based on organ perfusion via retrograde arterial flow [14]. An important limitation of this strategy is the increase in the left ventricular afterload [15]. In the context of cardiogenic shock, a condition that often presents after refractory CA, an increase in the left ventricular afterload can lead to an increase in myocardial ischemia, an increased incidence of ventricular arrhythmias, pulmonary edema, and thrombotic events [16][17][18][19]. Severe aortic regurgitation should be a contraindication to VA-ECMO because the risk of left ventricular overload is too high. Moreover, for mild to moderate aortic regurgitation, the risk of ventricular distension is not negligible [20]. Several interventions can be used in conjunction with ECMO to unload the left ventricle (LV) and thereby avoid some of these complications related to an increase in LV afterload [14][18]. However, the optimal approach to decrease left ventricular afterload during VA-ECMO remains unknown. Inotropic drugs, like dobutamine, can be given in small doses to ensure the opening of the aortic valve and minimal output of the left ventricle [21]. The later optimizes left ventricular contractility with the opening of the aortic valve and prevents the occurrence of acute congestive pulmonary edema A minimal pulsed pressure of at least 10 mmHg is recommended. In some centers, the placement of an intra-aortic balloon pump is considered standard of care, while in others the assessment of LV unloading dictates its use [22].

Finally, certain research groups have shown that the unloading of the LV via a continuous axial flow pump such as the Impella® type improves the survival of patients with VA-ECMO [23]. In a recent meta-analysis of almost 4000 patients, 42% of whom received a concomitant left ventricular unloading device with VA-ECMO (intra-aortic balloon 91.7%, percutaneous ventricular assist device 5.5%, pulmonary venous cannulation or left atrial trans-septal 2.8%), the mortality was lower in the patients having benefited from a ventricular unloaded device compared to the patients not having benefited from it. (54% vs. 65%, relative risk: 0.79; 95% confidence interval: 0.72 to 0.87; $p < 0.001$). However, rates of hemolysis were higher in patients with a left ventricular unloading device [24].

Once the patient is assisted and stabilized on VA-ECMO, treatment of the suspected cause of the CA should be initiated. If an acute coronary syndrome is suspected, the patient has to be referred to for immediate coronary angiography with PCI. In this specific group of patients, studies have demonstrated that coronary lesions are frequently multiple and proximal [25][26]. Moreover, it has been shown that the delay between CA and PCI is associated with survival [27]. If a pulmonary embolism is the origin of the CA, an injected pulmonary CT-scan should be considered to confirm the diagnosis [28]. Echocardiography can also provide useful diagnostic clues [29]. Some teams also recommend ECMO support to perform in situ thrombolysis or surgical thrombectomy [30][31]. Others believe that ECMO's effect is solely attributable to the patient's intrinsic fibrinolysis and that therefore, patients should be managed with heparin therapy only [32][33][34]. Lastly, intracranial hemorrhage (ICH) is a common complication in adults treated with ECMO and associated with increased mortality. Treating an ICH during ECMO represents a balance between pro- and anticoagulatory demands. Neurosurgical treatment is associated with severe morbidity, but has been successful in selected cases [35]. If an ICH is suspected, a cerebral CT-scan must be the first priority over any subsequent interventions or ECMO insertion.

3. Conclusions

CA remains a frequent cause of death and a major public health issue. Conventional CPR is to date the sole efficient resuscitation procedure available to improve the prognosis of these patients. ECMO is a complex and relatively high-priced technique that necessitates expertise. Therefore, it cannot be used in all hospitals and has to be performed in high-volume centers that routinely perform these procedures. ECPR allows for hemodynamic and respiratory stabilization of patients with CA refractory to conventional CPR and permits, by means of preserving organ perfusion, the initiation of treatment of the underlying cause of CA. However, the current evidence does not support a recommendation for routine use of ECPR in all patients with refractory CA. Therefore, it seems crucial to appropriately select the patients among those who could potentially benefit from its use. This may include patients presenting with a risk of imminent death with specifically designed scores that can predict a survival benefit associated with the use of ECPR. The desirable benefit of its use will be adequate resuscitation which promotes medium to long term survival acceptable neurological outcomes. Finally protocols to best manage patients with refractory CA by means of extra hospital ECPR remain an active area of research.

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