Abstract

Introduction: A 60 yo male was under ECMO and Intra Aortic Balloon Pump (IABP) support due to cardiogenic shock. When IABP was suspended for few seconds, myocardial contractility decreased with an \(\text{EtCO}_2\) around 14 mmHg and an arterial blood flat line. Despite the IABP suspension, an ABP tracing was observed and \(\text{EtCO}_2\) increased to 25 mmHg.

ECMO is a lifesaving treatment in some specific cases of cardiac arrest [8] and \(\text{EtCO}_2\) represents a non-invasive measurement of the quality in cardiopulmonary resuscitation, which also gives a good probability of ROSC with levels above 10-15 mmHg [20].

Materials and methods: A case report and literature review were applied to study a correlation between \(\text{EtCO}_2\) and cardiac output during ECMO support and identify the \(\text{EtCO}_2\) measurement like a non-invasive parameter about recovery of cardiac contractility during ECMO and IABP support.

Results: Different studies confirm \(\text{EtCO}_2\), cardiac arrest and ROSC correlation: in a meta-analysis and systematic review emerged that \(\text{EtCO}_2\) values are lower in ROSC obtained by a superficial CPR with differences between 10 to 20 mmHg. [13] Another survey deals an \(\text{EtCO}_2\) higher in people with ROSC than others without a pulse restored (34.5 ± 4.5 vs 23.1 ± 12.9 mmHg, \(p < .001\)) [23]. However, there are less references about ECMO and \(\text{EtCO}_2\).

Discussion: A literature review and case report, about \(\text{EtCO}_2\) and cardiac output during ECMO – IABP support, revealed that \(\text{EtCO}_2\) can be a non-invasive indicator of heart contractility in patients with low ejection fraction and non-pulmonary circulation, and it shows a contractility increasing with a consequent recovery of pulmonary circulation, without suspending the IABP activity, during ECMO VA support.

Keywords: ECMO: extracorporeal membrane oxygenation; VA ECMO: veno-arterial membrane oxygenation; CPA: cardiopulmonary arrest; \(\text{EtCO}_2\): endtidal CO\(_2\); ROSC: return of spontaneous circulation; CO: cardiac output

Introduction

From European Guidelines of Resuscitation (2015), the out-of-hospital cardiac arrest (OHCA) has an incidence of 38 per 100,000 people: cardiac etiology is around 40% in a population under 75 years old, whereas traumatic or non-cardiac etiologies concerned, principally, patient under 35 years old [10]. According to ELSO and AHA Guidelines, ECMO should be considered the lifesaving treatment in some specific cases of patient who had an excellent CPR [8] or in adults with cardiogenic shock and low cardiac output, in persisting shock despite volume, drugs administration and intraaortic balloon pump (IABP), in septic shock, or in many cardiac diagnosys (i.e. acute myocardial infarction, myocarditis, post cardiotomy shock) [9].

For an efficient resuscitation it’s fundamental an adequate blood flow and an optimal perfusion, relied to capnography parameter [22,11]. Related to \(\text{EtCO}_2\) concept, \(\text{CO}_2\) is a result of relation between volume ventilation and pulmonary perfusion (V/Q), directly linked to blood flow [15]. It depends on many
Factors like issues about ventilation system, placement of endotracheal tube, body temperature, hyperventilation or hyperventilation, blood perfusion and so forth [27].

EtCO₂ swings are rapid indicators of systemic changes about CO₂ like in cardiac arrest [4], where the EtCO₂ trace crashes to zero [20]; during a cardiopulmonary arrest (CPA), it can recognize a ROSC, managing the resuscitation efforts. Therefore, an EtCO₂ increasing is an index of myocardial contractility restoring and a successful reanimation [20].

Considering a pattern of intubated-patient in Intensive Care Unit with same conditions of ventilation system [18] and catecholamine administration [22], capnography is associated to cardiac output [1,5] and pulmonary flow [20].

In literature, there are many references about the EtCO₂ role to manage the resuscitation effort, especially in ROSC. EtCO₂ levels above 10-15 mmHg give a high probability of ROSC, but at the same time low levels are indicator of negative prognosis [20].

EtCO₂ has a key role in the chain of survival to advanced circulatory support, especially in extracorporal life support (ECLS); the French Society of Intensive Care Medicine published a decision algorithm with ECLS inclusion criteria, like the "no-flow" time <5 min and EtCO₂ > 10 mmHg [12]. While the early cardiopulmonary resuscitation (CPR) by bystanders has been demonstrated to be fundamental to improve survival and neurological outcome in CPA victims [6], the EtCO₂ plays an important role in ECLS application, because several studies demonstrate that EtCO₂ < 10 mmHg (before ECMO implantation) is related to 100% of mortality rate [2]. Heart activity can be functional or not during ECMO support and this is recognizable by arterial blood pressure waveform. In fact, a numeric value of systolic and diastolic pressure is indicator of heart contractility and cardiac output; however, an absence of this value remarks cardiac inactivity and systemic pressure (represented by mean arterial pressure) is totally supported by VA ECMO.

Sometimes, in addition to ECMO, an implant of IABP support can prevent pulmonary edema due to inadequate heart venting: in this case the suspension of IABP activity for few seconds allows to evaluate the presence of flatline [16].

Case report

A 60 yo male was admitted from another hospital for cardiogenic shock due to anterior STEMI. After percutaneous coronary intervention and intraaortic balloon pump (IABP) placement, the cardiogenic shock status remained with increasing of serum lactate, anuria, and VA ECMO was inserted. The cardiac output was highly depressed, and the blood flow was totally ensured by ECMO with the mean arterial pressure generated by ECMO output, when the IABP was suspended. During ECMO and IABP supports, EtCO₂ had different values corresponding to changes of arterial blood pressure waveform.

Cause of the clinical case report, we can pose the following question: Can EtCO₂ monitor functional cardiac recovery in patient supported by ECMO and IABP, without suspension of aortic counterpulsation?

Materials and Methods

We performed a literature review and a retrospective study on clinical case report.

The principal medical databases consulted were PubMed, Cinahl and Cochrane Library with a search strategy composed by two principal steps: firstly, correlation between EtCO₂, CPA and ROSC was searched and, secondly, relation between EtCO₂ in VA ECMO was applied.

The inclusion criteria were VA ECMO in adult’s population, whereas pediatric ECLS and VV ECMO were excluded. Relevant articles between 2008 and 2018 were considered for the first search strategy.

The principal keywords used in literature review were "EtCO₂" OR “end-tidal carbon dioxide” OR "capnography" AND "cardiac arrest" OR "heart arrest" OR "cardiopulmonary arrest" AND "rosc" OR "return of spontaneous circulation" AND "post-arrest" AND "cpr" OR "cardiopulmonary resuscitation" OR "cardiorespiratory resuscitation" OR "chest compressions" OR "cardiac arrest".

A retrospective study was applied on the telemetry, as a continuous multiparameter registration. We focused on temporary stopping of IABP activity and hemodynamic signs, especially the correlation between EtCO₂ and arterial blood pressure.

Results

Case report

Observing hemodynamic sign registrations, during IAPB stopping, we have extracted the time we checked the pulsatility presence. In these time-lapse, we notice a correlation with EtCO₂ and arterial blood pressure (ABP). When pulse is present, checking the arterial waveform with a systolic pressure around 90 mmHg and diastolic around 40 mmHg, the EtCO₂ increases to 24-26 mmHg, as represented in figure 2; when there is pulseless activity, EtCO₂ values are around 13-15 mmHg, as represented in figure 1. During the recovery in ICU, many decreasing-increasing episodes about EtCO₂ were identified, respectively, in depression and in recovery of cardiac output; this was confirmed by arterial pressure waveform during interruption of IABP activity.

Literature review

In the first search strategy many articles were consulted, while in the second one five relevant articles were identified. The literature review was extended to the Extracorporeal Life Support Organization (ELSO), American Heart Association (AHA) and European Resuscitation Council Guidelines (ERC) and to principal books, especially about EtCO₂ and ECMO correlation: in these references the keywords “EtCO₂”, “CO₂” and “capnography” were searched.

Different studies confirm a juction between EtCO₂ and ROSC: from different reviews, like Paiva E. and Aminiahidashti H. studies in 2018, it’s emerged that EtCO₂ is statistically higher in patients survived after CPR. In a meta-analysis and systematic review,
participants in ROS with EtCO$_2$ level about 25 mm Hg have higher values than people in ROSC with a superficial CPR with differences between 10 to 20 mmHg [13]. Another survey deals EtCO$_2$ higher in people with ROSC than others without a pulse restored (34.5 ± 4.5 vs 23.1 ± 12.9 mmHg, p < .001) [23].

**Discussion**

According to European Resuscitation Council most recent 2018 guidelines, EtCO$_2$ is an early parameter of cardiac output variation; in fact, an increase of this waveform between 2.5 and 2.0 kPa [11] is an indicator of optimal CPR [5] and it can be used like a clinical tool during advanced cardiac life support [23,10].

The literature search revealed a lack of correlation studies between EtCO$_2$ and ECMO. By the retrospective analysis of the clinical case, through the telemetries, it has been analyzed the relation between EtCO$_2$ and ABP and identified an increase in CO$_2$ at the resumption of myocardial contractility during ECMO support. This is physiologically permitted by cardiac contractility resumption, which allows a recovery of pulmonary circulation and alveolar-capillary exchange between oxygen and carbon dioxide. When contractility is depressed, the values of EtCO$_2$ decrease, because of pulmonary circulation arrest, as reported by figure 1 and figure 2. The use of the EtCO$_2$ could also reduce the IAPB suspension, considering that these interruptions still haven’t been declared capable of damage or not by literature.

Therefore, the respiratory CO$_2$ can be a non-invasive, rapid and early parameter to find the re-establishment of the pulmonary circle and then the activity increasing of the left ventricle and right ventricle.

However, our hypothesis is based on clinical observation of the hemodynamic parameter recordings, determining the limit of the study between the respiratory and circulatory correlation during ECMO to a single case.

The intent of the authors is to continue, retrospectively and prospectively, to a correlation analysis between EtCO$_2$ and cardiac output.

![Figure 1: Correlation between EtCO$_2$ – ABP in no cardiac output](image)
**Figure 2**: Correlation between EtCO$_2$ – ABP in return of cardiac output

**References**


