

Determination of acute changes in new electrocardiography parameters during veno-venous extracorporeal membrane oxygenation support



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Abstract

Introduction: Veno-venous extracorporeal membrane oxygenation (ECMO) support has been used for respiratory insufficiency. Its role in blood oxygenation has been well documented. However, the effects on myocardial electrophysiology have not been studied in detail.

Aim: To reveal the acute effects of extracorporeal support on new electrocardiography (ECG) parameters in patients with preserved left ventricular functions.

Material and methods: This retrospective study was conducted in three separate clinics. Sixteen consecutive patients under veno-venous ECMO for respiratory insufficiency who soon could be successfully weaned were analyzed. Immediately before and 2 hours after initiation of ECMO, ECG was performed. P wave, QT, QTc and T wave peak to end were measured and calculated from obtained surface 12-lead ECG.

Results: There were statistically significant differences immediately before and 2 hours after initiation of ECMO treatment in the Tp-e interval and Tp-e/QTc ratio, the maximum QTc, minimum QTc, and QTc dispersion values, and P wave dispersion ($p < 0.0001$ for each). All ECG parameters were significantly decreased with ECMO support.

Conclusions: All atrial and ventricular repolarization parameters were decreased in patients with VV-ECMO support. Despite the limited role of ECMO in intractable arrhythmias, the findings of the study revealed that ECMO therapy for respiratory insufficiency may improve atrial ventricular depolarization and repolarization. Therefore, simple 12-lead surface ECG with new ECG parameters may be evaluated for better outcomes.

Key words: extracorporeal membrane oxygenation, electrocardiography, new ECG parameters.

Introduction

Extracorporeal membrane oxygenation (ECMO) is a developing approach for the management of acute cardiac and/or respiratory failure in critically ill patients who are not responsive to classical treatment [1, 2]. Two types of ECMO are used in routine daily practice: veno-arterial and veno-venous (VV) [3]. Veno-venous ECMO provides extra support to the pulmonary system by draining blood from the right atrium, oxygenating and returning back to the right atrium in patients with compatible circulation [3, 4]. The common indication for VV-ECMO is the reversible failure of the respiratory system including acute respiratory distress syndrome (ARDS) due to bacterial, viral atypical pneumonia, barotrauma, aspiration and interstitial pneumonitis [4, 5]. Namely, the strategy of ECMO support is advisable in case of persistent hypoxia and hypercarbia despite all the treatment options [5, 6].

ECMO management despite advances in circuit design still remains a complex issue and requires having a vast knowledge of the underlying physiology [7]. The primary goal for VV-ECMO support is the need to quickly improve systemic oxygen delivery [8, 9]. The oxygen content of the blood is dependent on hemoglobin concentration, hemoglobin oxygen saturation, dissolved oxygen and cardiac output [10]. These variables can affect cardiac electrophysiology and surface ECG and may cause cardiac lethal arrhythmias [11, 12].

The 12-lead electrocardiogram is a common, simple tool used for predicting atrial and ventricular arrhythmogenic risk in clinical practice [12, 13]. The QT interval and its correction by heart rate (QTc), and QT interval dispersion are known ECG parameters [13]. Recently published parameters such as the Tp-e interval and Tp-e/QTc ratio for predicting the development of malignant cardiac ventricular arrhythmias

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and P dispersion are recommended for predicting atrial arrhythmias [14, 15].

Aim

In this study, we aimed to determine and document the acute changes in newly documented ECG parameters with VV-ECMO treatment.

Material and methods

This retrospective study was conducted in Uşak Medical Park Hospital, Turkey, Afyon Park Hospital, Turkey and Bicard Clinic, Kyrgyzstan. Approval from each central Ethical Committee was obtained. Sixteen patients treated with VV ECMO between January 2018 and March 2020 were retrospectively studied. Patients with respiratory failure despite adequate pulmonary support with mechanical ventilation directed to VV-ECMO and weaned successfully were included. The patients had preserved left ventricular functions and normal echocardiographic parameters. Presence of known atherosclerotic heart disease, rhythm disorders, valvular heart disease and electrolyte imbalance were excluded.

Veno-venous ECMO indication in our patients was respiratory insufficiency due to ARDS. They were under mechanical ventilatory support for less than 7 days; PEEP > 12–16 cm H₂O, the tidal volume of 4–6 ml/kg (measured volume representing decreased tidal volume despite high peak inspiratory pressure), plateau pressure > 30 cm H₂O, FiO₂ > 80%, PaO₂/FiO₂ within 100–150 mm Hg, PaCO₂ > 60 mm Hg (for more than 6 hours) and EF > 50%. These signs were accepted for study in the light of current guidelines [16]. Veno-venous ECMO was initiated by a femoral and jugular veno-nous cannula. Immediately before and 2 hours after initiation of ECMO support, a 12-lead surface ECG (AT-102, Schiller AG, Baar, Switzerland) was recorded and analyzed for each patient in supine position. Recordings were acquired at a paper speed of 50 mm/s, with 1 mV/cm standardization for handmade measurements via calipers and magnifying lenses. The measurements and calculations were performed by one single experienced cardiologist. The onset of the P wave was defined as the first atrial deflection from the isoelectric line, and the offset was the return of the atrial signal to the baseline. The maximum and minimum P wave durations were measured and their difference was defined as the P dispersion. The QT interval was measured from the beginning of the QRS complex to the end of the T wave and corrected for the heart rate using the Bazett formula: $cQT = QT\sqrt{R-R \text{ interval}}$. The Tp-e interval was defined as the interval between the peak and end of the

T wave, measurements of the Tp-e interval were performed from precordial leads, and the Tp-e/QTc ratio was calculated from these measurements [15, 17].

Statistical analysis

Statistical analyses were performed using SPSS software for Windows version 17.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean values ± standard deviation (SD). Categorical variables were expressed as number and percentages. Characteristics were compared using the independent samples *t*-test for continuous variables. Statistical significance was set as $p < 0.05$.

Results

The mean age of the patients was 55.68 ± 6.32 years. There were 9 female and 7 male patients. The mean left ventricular EF and BMI were 58.62 ± 2.82% and 29.68 ± 4.78 kg/m² respectively. The demographic characteristics of patients are outlined in Table I.

The preECMO min QTc, max QTc, QT dispersion, Tp-e interval, Tp-e/QTc, Pmax, Pmin and Pdisp were 144.68 ± 1.70, 276.50 ± 1.36, 133.56 ± 2.42, 78 ± 2.03 ms, 0.28 ± 0.04, 253.81 ± 1.72, 193.75 ± 2.11 and 60.06 ± 2.95 ms respectively.

The ECMO at 2 hours min QTc, max QTc, QT dispersion, Tp-e interval, Tp-e/QTc, Pmax, Pmin and Pdisp were 121.37 ± 2.15, 236.37 ± 1.02, 115.31 ± 1.07, 66.75 ± 2.14 ms, 0.19 ± 0.04, 193.31 ± 2.24, 171.12 ± 2.12 and 22.18 ± 2.68 ms respectively.

When pre-ECMO and mid-ECMO ECG parameters were compared, there were statistically significant differences in each parameter. The Tp-e interval, Tp-e/QTc ratio, maximum QTc, minimum QTc, QTc dispersion values, P min, P max and P wave dispersion were significantly lower 2 hours after initiation of ECMO treatment ($p < 0.0001$ for each, Table II).

Discussion

Extracorporeal support for management of respiratory failure gained popularity during the last decade, especially in epidemics and pandemics. However, still proper utilization is not standard and the effects of ECMO, not only on blood oxygenation, but other well-being parameters, have not been fully examined. Recently, new ECG parameters were defined and revealed to estimate arrhythmia risk by means of myocardial repolarization and depolarization [15, 17]. With the rationale that treatment of intractable arrhythmias was possible with VV-ECMO support [18, 19], we hypothesized that those above-mentioned ECG parameters may be affected by short-term VV-ECMO therapy.

During ECMO therapy, supervision is a very important task keeping in mind that the ECMO is a dynamic process. Operator and supervisor should be able to give immediate and radical decisions to prevent morbidity and mortality. More than machinery functioning and hemodynamic and metabolic status of the patient are necessary for successful outcomes. Despite the few published guidelines, not many informative tools exist. Those guidelines do not include ECG parameters at least for now [16, 20]. In contrast, it is well established that the patients are vulnerable to lethal

Table I. Baseline demographic characteristics of patients ($n = 16$)

Parameter	Value
Age [years]	55.68 ± 6.32
Gender, male : female	7 : 9
LVEF (%)	58.62 ± 2.82
BMI [kg/m ²]	29.68 ± 4.78

LVEF – left ventricular ejection fraction, BMI – body mass index.

and non-lethal arrhythmias due to respiratory insufficiency prior to initiation of ECMO. This is why some kind of refractory arrhythmias [18] and intractable primary arrhythmias and heart blocks [19] could be treated by extracorporeal support. We could document a proper improvement in atrial and ventricular depolarization and repolarization parameters. This may be possibly due to immediate improvement in oxygenation status of the patient leading to improvement in myocardial electrophysiology [20].

ARDS is associated with high airway pressure, hypoxia and hypercapnia. VV-ECMO improves oxygenation, reduces hypercapnia and lowers airway pressures. Consequently ECMO support decreases pulmonary hypertension and right ventricular afterload [21]. It was shown that initiation of V-V ECMO in ARDS is associated with right ventricular unloading by an immediate decrease in mean pulmonary artery pressure, increased mixed venous oxygenation and decreased PaCO₂. Increase in venous return, cardiac contractility and decrease in pulmonary and systemic vascular resistance were also postulated [22]. Moreover, cannulation can also affect intravascular and intracardiac blood flow dynamics. The draining position in the venous system, ECMO pump flow, return flow position and the cardiac output all have an impact on recirculation. All mentioned parameters may have mechanical and electrophysiological effects on myocardium [21, 22].

Changes in ECG parameters were revealed to occur following a short period of ventilation disturbance which probably caused alterations in pH [22]. T-wave changes were documented to occur due to ventilation in a high CO₂ atmosphere where hypocapnia and alkalosis did not occur. Decreasing PCO₂ also decreases the amplitude of T-waves [23]. Based on these facts, we believe that the changes in ECG parameters of VV-ECMO stem from improved oxygenation, reduced CO₂ and immediate changes in myocardial mechanical and electrophysiological properties.

The study comprises only 16 patients, which may indicate that the power of the study is low. Moreover, electronic ECG measurements could not be done. The study included only VV-ECMO patients with preserved LV functions for standardization issues. Other modes of ECMO and patients with disturbed left ventricular functions were outside the scope of this study. Those patients need to be included and studied in larger scale studies.

Conclusions

ECMO support immediately improves patient's condition via metabolic-hemodynamic changes. This improvement is only monitored via circulatory hemodynamic and metabolic parameters in addition to assessment of clinical well-being. Although clinical significance is unclear, ECG parameters improved after ECMO support. Moreover, 12-lead surface ECG can easily be applied during clinical assessment. One should take into consideration the new ECG parameters as well.

Disclosure

The authors report no conflict of interest.

Table II. Comparison of electrocardiographic parameters obtained immediately before and 2 hours after initiation of extracorporeal membrane oxygenation support

Parameter	Pre-ECMO (n = 16)	ECMO (n = 16)	P-value*
Max QTc interval [ms]	276.50 ±1.36	236.37 ±1.02	< 0.0001
Min QTc interval [ms]	144.68 ±1.70	121.37 ±2.15	< 0.0001
QTc dispersion [ms]	133.56 ±2.42	115.31 ±1.07	< 0.0001
Tp-e interval [ms]	78 ±2.03	66.75 ±2.14	< 0.0001
Tp-e/QTc	0.28 ±0.04	0.19 ±0.04	< 0.0001
Pmax [ms]	253.81 ±1.72	193.31 ±2.24	< 0.0001
Pmin [ms]	193.75 ±2.11	171.12 ±2.12	< 0.0001
Pd [ms]	60.06 ±2.95	22.18 ±2.68	< 0.0001

*Independent samples t-test.

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