Case study

Monitoring the treatment of myocardial stunning syndrome after acute carbon monoxide poisoning using arterial pulse wave analysis: a case report

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ABSTRACT

Myocardial injury due to acute carbon monoxide intoxication is often refractory to standard resuscitation methods. Levosimendan is a new inotropic agent that is used in the treatment of acute and chronic heart failure. We report a case of severe cardiopulmonary compromise after exposure to carbon monoxide in a 40-year-old woman who was monitored using transthoracic echocardiography and the arterial pulse contour analysis system (FloTrac) and successfully treated with levosimendan.

Keywords: carbon monoxide poisoning, Levosimendan, transthoracic echocardiography, arterial pulse contour analysis
INTRODUCTION
Carbon monoxide (CO) poisoning often presents significant clinical challenges due to the severe toxic effects of CO and the disastrous neurological and cardiovascular consequences. Myocardial injury results from tissue hypoxia as well as from damage at the cellular level. CO binds to hemoglobin with an affinity that is 240 times greater than oxygen. Carboxyhemoglobin (HbCO) decreases blood oxygen carrying capacity and shifts the oxyhemoglobin dissociation curve to the left decreasing the availability of oxygen to the organs and tissues. In addition, CO reacts with myoglobin to form carboxymyoglobin, which blocks myoglobin-facilitated diffusion of oxygen. Carboxymyoglobin also blocks myoglobin-mediated oxidative phosphorylation resulting in impaired cardiac contractility.

The cardiovascular manifestations of CO poisoning include myocardial ischemia and infarction, arrhythmia, pulmonary edema and stunned myocardium syndrome.1–6 Myocardial injury due to CO intoxication is often refractory to standard resuscitation methods.7,8 Recommended therapy of cardiac dysfunction usually includes the normalization of coronary blood flow and oxygen supply using vasopressors and inotropes.5 Levosimendan is a new inotropic agent that is used in the treatment of acute and chronic heart failure. It increases myocardial contractility by enhancing the sensitivity of the myocardial muscles to intracellular calcium without increasing intracellular calcium concentration. In addition, this drug decreases cardiac workload by opening ATP dependent potassium channels in vascular smooth muscles, resulting in systemic vasodilation and cardiac afterload reduction.9–12 These two mechanisms produce enhanced cardiac output without increasing myocardial oxygen demand, an effect that is not observed with other inotropic agents. Although the safety and efficacy of levosimendan has been demonstrated in different patient populations,11,12 there are few data about the use of levosimendan in patients with CO poisoning.

Myocardial injury in patients with CO intoxication usually manifests with elevated cardiac biomarkers and changes of global or regional wall motion in transthoracic echocardiography (TTE). In recent years new technologies based on arterial pressure waveform analysis have become available which are minimally invasive, allow beat-to-beat cardiac output monitoring and permit assessment of fluid responsiveness in critically ill patients.13 Currently, three devices (the FloTrac system, PiCCO monitor, and LiDCO system) are available to measure arterial waveform analysis-based cardiac output. In addition, dynamic preload parameters such as stroke volume variation (SVV) and pulse pressure variation (PPV) are determined, which may be useful to predict fluid responsiveness in mechanically ventilated patients. The validity of these devices has been verified in a variety of patients and circumstances.14,15 No data are available regarding the use of the arterial waveform analysis-based monitoring system in patients with myocardial injury after CO intoxication. To our knowledge, no study has examined the changes in hemodynamic variables during treatment of patients presenting CO poisoning using arterial waveform analysis.

We report a case of severe cardiopulmonary compromise after exposure to CO in a 40-year-old woman who was monitored using transthoracic echocardiography and the arterial pulse contour analysis system (FloTrac) and successfully treated with levosimendan. Since such cases are rare in the literature, the clinical presentation, monitoring and management are discussed below.

CASE
A 40-year-old woman was transferred to the emergency department (ED) of a local hospital due to confusion, dyspnea, tachypnea, sinus tachycardia and hypotension. There was a high suspicion of CO poisoning as there was a history of exposure to a heating source. She had no history of hypertension, angina or congestive heart failure. Upon arrival at the emergency department, elevated carboxyhemoglobin (28.5% reference range < 2%) was detected. On physical examination, the heart rate (HR) was 110 beats min⁻¹, blood pressure (BP) was 85/50 mm Hg, respiratory rate was 30 bpm and SpO₂ was 90% on 8 litre min⁻¹ oxygen. Auscultation revealed an S3 gallop without murmurs, and bilateral basal crepitations, and the chest radiograph showed pulmonary oedema and mild cardiomegaly. 12-lead ECG demonstrated diminished R waves in V1-V6, and laboratory investigations revealed increased serum troponin I (10.9 ng ml⁻¹; normal range 0 - 0.05 mg litre⁻¹). There were no electrolyte disturbances and the patient’s arterial blood gas showed pH 7.219, PaO₂ 96.9 mm Hg, PCO₂ = 52 mm Hg and [HCO₃⁻] = HCO₃⁻ 20 mmol/L. The patient was immediately treated with infusion of isotonic crystalloids, however, her blood pressure declined to 70/32 mmHg, and the patient became soporous. She was intubated and transferred to the intensive care unit where a central venous catheter and a femoral arterial line were inserted. Norepinephrine infusion was started at a rate of...
The norepinephrine requirement decreased to 1 mg kg\(^{-2}\) and CI increased to 2.5 litre min\(^{-1}\). Transthoracic echocardiography demonstrated mild dilation of both ventricles and severe global hypokinesia with an ejection fraction of 20-25%. Cardiac function indices were monitored continuously using arterial waveform analysis (FloTrac/Vigileo monitoring system, Edwards Lifesciences). The monitor showed: cardiac index (CI) of 1.4 litre min\(^{-1}\) m\(^{-2}\), stroke volume variation of 18% and stroke volume index of 21 ml/m\(^2\). As intravenous fluid replacement and norepinephrine of 3 mcg kg\(^{-1}\) min\(^{-1}\) failed to maintain resuscitation goals, dobutamine of 5 mg kg\(^{-1}\) min\(^{-1}\) was administered to keep mean arterial pressure more than 65 mm Hg. The dobutamine dose was increased to 7 mg kg\(^{-1}\) min\(^{-1}\), but the patient’s HR progressively increased to >125 beats min\(^{-1}\) despite a central venous pressure (CVP) of 13 mm Hg. This precluded further increase in dobutamine dosage. The patient’s serum lactate was 9.6 mmol litre\(^{-1}\). Since carboxyhemoglobin levels were already normalized (<2%) and the primary standard vasopressor and inotropic therapy failed, levosimendan infusion was initiated and dobutamine was stopped. Levosimendan is an inodilator with an alternative mode of action to more traditionally used agents. Cardiac output is augmented and diastolic relaxation is improved without an increase in myocardial oxygen demand. Given that the toxic effects of CO poisoning are associated with decreased O\(_2\) availability, this agent was chosen to reverse the functional sequelae without exacerbating the cellular oxygen deficit. Levosimendan 6 mg kg\(^{-1}\) was administered as a bolus infusion over 10 minutes, followed by a continuous infusion of 0.2 mg kg\(^{-1}\) min\(^{-1}\). The patient’s CI increased to 2.2 litre min\(^{-1}\) m\(^{-2}\) within 18 hrs of starting the levosimendan infusion, and the serum lactate level decreased to 2.0 mmol litre\(^{-1}\) after 20 h of therapy. The norepinephrine requirement decreased to 1 mg kg\(^{-1}\) min\(^{-1}\) within 16 h of starting the levosimendan infusion, and norepinephrine was discontinued at 20 h. The levosimendan infusion was continued for 24 hours. Serum troponin levels measured at 24 and 48 h after presentation were 3 ng/ml\(^{-1}\) and 1.57 ng ml\(^{-1}\), respectively. On day three, echocardiography showed full recovery of the LV (EF $\geq$ 55%) and normal size of cardiac cavities, SVV and SVI were at normal levels (10% and 31 ml/m\(^2\) respectively), and CI increased to 2.5 litre min\(^{-1}\) m\(^{-2}\). Weaning from mechanical ventilation was begun 48 h after commencing levosimendan infusion and the trachea was extubated on day three. The patient was discharged to the medical ward on day four, and she left the hospital seven days after admission.

**DISCUSSION**

There is little literature about the cardiovascular consequences of CO poisoning. An incidence rate of myocardial injury ranging from 37% to 59% in adult patients with moderate to severe CO poisoning is reported by Satran et al.\(^5\) and Kao et al.\(^{16}\), respectively. Patients with coronary artery disease and HbCO concentrations between 10-30% are at particular risk for cardiovascular compromise, although cardiac ischemia/infarction may also occur in young and otherwise healthy patients leading to stunned myocardium.\(^5\) Postischemic dysfunction, or myocardial stunning is the mechanical dysfunction that persists after reperfusion despite the absence of irreversible damage and despite restoration of normal or near-normal coronary flow.\(^{17}\) In our patient we observed a global left ventricular dysfunction diagnosed by TTE which was consistent with stunned myocardium. The left ventricular dysfunction remained severely impaired despite the low carboxyhemoglobin levels and high inspired oxygen concentration. Treatment of myocardial ischemia in patients with CO intoxication is challenging. Clinical trials addressing the use and efficacy of intravenous levosimendan in acute heart failure in patients with systolic dysfunction or cardiogenic shock due to myocardial stunning are scarce. Our patient was resuscitated with conventional treatment including norepinephrine and dobutamine infusion. However, her clinical status, hemodynamic variables, and ECG alterations did not improve until initiation of levosimendan. Levosimendan has been shown to improve left ventricular performance and to decrease left ventricular filling pressures without an increase in myocardial oxygen consumption. Indeed, stabilisation of hemodynamic parameters was achieved within 16 hours of continued combined therapy with norepinephrine and levosimendan. Norepinephrine was used as a vasopressor to counteract the vasodilation caused by the levosimendan’s agonistic properties on peripheral vascular K(+) (ATP) channels. This positive experience with levosimendan in the patient with stunned myocardium suggests that the use of this agent in patients with myocardial injury complicating CO intoxication should be further evaluated. Rocco et al., mention the use of levosimendan in patients with CO poisoning\(^{18}\) and reported cardiac magnetic resonance imaging to assess the effectiveness of treatment. It is worth noting that the use of this non-invasive monitoring method may present some drawbacks due to difficulties in patient transportation outside of the ICU, time constraints, its non-continuous monitoring process and high cost.
Arterial waveform analysis provides a continuous, easy to use, minimally invasive bedside monitoring system for critically ill patients. To our knowledge, no study has looked at the time course of hemodynamic parameters obtained by a pulse contour analysis in patients with CO poisoning and low cardiac output condition. Taking into consideration the subnormal levels of hemodynamic indices, such as SVI, CI, and high level of SVV and lactate in our patient, we concluded that faster fluid infusion would be most effective during the first hours after poisoning. The decrease in SVV in our patient was associated with an increase in cardiac index, indicating the improvement of cardiac performance due to volume loading and levosimendan administration.

CONCLUSION
Levosimendan might be considered as an additional treatment option in patients with CO intoxication and cardiovascular shock refractory to standard management. Continuous measurement of stroke volume variation, cardiac index and stroke volume index by arterial pulse contour analysis in combination with transthoracic echocardiography seems to be valuable in patients with myocardial dysfunction after CO poisoning.

REFERENCES