

EDITORIAL

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High time to omit oxygen therapy in ST elevation myocardial infarction

Ardavan Khoshnood^{1,2}

Abstract

Supplemental oxygen (O₂) therapy in patients with chest pain has been a cornerstone in the treatment of suspected myocardial infarction (MI). Recent randomized controlled trials have, however, shown that supplemental O₂ therapy has no positive nor negative effects on cardiovascular functions, mortality, morbidity or pain in normoxic patients with suspected MI and foremost patients with ST Elevation Myocardial Infarction (STEMI). O₂ therapy in normoxic STEMI patients should therefore be omitted. More studies are needed in discussing hemodynamically unstable STEMI patients, as well as patients with non-STEMI, unstable angina and other emergency conditions.

Keywords: Oxygen, Oxygen therapy, ST elevation myocardial infarction, STEMI, Physiology, Pathology, Emergency medicine

Main text

ST Elevation Myocardial Infarction (STEMI) is the most serious manifestation of Acute Coronary Syndrome (ACS) and is by the Fourth Universal Definition of Myocardial Infarction deemed to be a Type I myocardial infarction, caused by an acute atherothrombotic coronary artery disease (CAD) [1]. The consequence of CAD is a partial or complete occlusion of a coronary artery thus contributing to the termination of oxygen (O₂) supply to the myocardium, giving rise to ischemia [1, 2].

Because of its seriousness, prompt and rapid diagnosis and treatment is of high importance to reduce both mortality and morbidity [3]. The most important treatment in STEMI is Percutaneous Coronary Intervention (PCI), which should be performed as soon as possible after that the condition is diagnosed [4–6].

International guidelines also emphasize on treatment with dual antiplatelets in the emergency phase before the start of the PCI [4–6]. Previous guidelines also recommended the immediate administration of O₂ to patients with diagnosed or suspected ACS, without any respect to the blood O₂ saturation [7–10]. In discussing current guidelines, only the 2017 ESC Guidelines for the management of patients with STEMI [5] states that O₂ should not routinely be administered to patients with

STEMI, and that only those with a blood O₂ saturation < 90% or PaO₂ < 60 mmHg should receive O₂ therapy.

With an overwhelming scientific evidence that O₂ therapy has no positive (nor negative) effects in patients with STEMI, all international, regional and local guidelines should be updated and omit O₂ therapy in normoxic (≥ 90%) STEMI patients.

Oxygen therapy

The history of O₂ as a medicine dates back to 1775 when the British chemist Joseph Priestly discovered O₂ and stated that it could be used as a medicine [11]. It was, however, in 1900 that the first publication on the role of O₂ therapy in patients with chest pain was published. It was a short letter by Dr. Charles Steele, in which he deemed that O₂ therapy had relieved chest pains in one single patient he believed to have angina [12]. Ever since this letter by Dr. Steele, several studies have tried to answer how supplemental O₂ therapy in both healthy and ill patients affect their cardiovascular system.

The rationale behind O₂ therapy has been that by adding O₂ to the patient's blood, the myocardium can be oxygenated, which in turn will contribute to a diminished ischemic area and infarct size, thereby minimizing the risk for lethal arrhythmias [13, 14]. Studies on canines [14–16] have given some support to this theory, showing that O₂ therapy decreases infarct size and ischemia in these animals. A recent study on swine, however, showed that hyperoxemia can aggravate and worsen myocardial ischemia [17].

Correspondence: ardavan.khoshnood@med.lu.se

¹Department of Clinical Sciences, Faculty of Medicine, Lund University, Lund, Sweden

²Department of Emergency and Internal Medicine, Skåne University Hospital Lund, Lund, Sweden



In healthy individuals, experimental studies have shown that hyperoxemia because of supplemental O₂ therapy, may contribute to negative cardiovascular effects like a decrease in coronary blood flow, arterial vasoconstriction, diminished cardiac output, an increase in the systemic vascular resistance as well as impaired blood flow to organs and tissues [18–26].

In patients with suspected as well as confirmed myocardial infarction, the role of O₂ were for a long time highly inconclusive. Our knowledge gap in this matter was not because of lack of studies, but rather because of the poor methodologies used in these studies. Ever since 1900, several studies have been published on the role of O₂ in patients with chest pain, coronary artery disease, cardiac failure as well as suspected and confirmed myocardial infarction. All of them have unfortunately had serious limitations and have therefore not been able to correctly answer the question of how O₂ therapy affects the cardiovascular system in both healthy patients and patients with myocardial infarction and cardiac failure. The studies have either been case studies or small reports including only a few patients, thus not being generalizable, or small studies [18–20, 27–43]. Furthermore, the vast majority of the studies was conducted in the pre-PCI era and even before Troponin was used as an important part in the diagnosis of myocardial infarction.

Because of the above limitations, a Cochrane report from 2013 [44] called for randomized controlled trials to once for all answer the question about which role supplemental O₂ therapy should have in patients with chest pain and suspected myocardial infarction. The authors of the report stated that “A definitive randomised controlled trial is urgently required [...]”

Randomized controlled trials

Before the Cochrane reports call for a definitive randomized controlled trial (RCT) in 2013, there were already four RCTs on the role of supplemental O₂ in patients with myocardial infarction; Rawles et al. from 1976 [45], Wilson et al. from 1997 [42], Ukholkina et al. from 2005 [46] and Ranchord et al. from 2012 [47].

The two first studies were conducted in the pre-PCI era. While Wilson et al. [42] found no significant differences between the patients with myocardial infarction randomized to supplemental O₂ or air, Rawles et al. [45] showed that patients with myocardial infarction receiving supplemental O₂, had a larger infarct size as measured with serum aspartate aminotransferase.

The study by Ukholkina et al. [46] is the only randomized study showing a positive effect of supplemental O₂ therapy in patients with myocardial infarction. The study is thus highly biased because of a limited methodology [44].

Ranchord et al. [47] have a sound methodology, and should be considered the first modern RCT on the role

of supplemental O₂ in patients with STEMI. The authors found no significant differences between the two arms (supplemental O₂ vs titrated O₂) with regard to infarct size as measured by cardiac Troponin T, as well as cardiac MRI (CMRI) close to one month after inclusion.

After the Cochrane report from, three more RCTs have been published discussing the role of supplemental O₂ therapy in myocardial infarction; the AVOID study [48, 49], the SOCCER study [50–53] and the DETO2X study [54–57].

The main publication of the AVOID study was conducted by Stub et al. [48] in which 441 STEMI patients were randomized to supplemental O₂ therapy or air. Even though the study found no significant difference in infarct size as measured by cardiac Troponin, a subset of the patients undergoing CMRI after six months, showed that those randomized to supplemental O₂ therapy, had a larger infarct size as measured in absolute mass but not in percent of the left ventricle. A sub study [49] of the AVOID trial showed later that patients randomized to the O₂ arm, had significantly higher cardiac Troponin rates than those randomized to the air arm.

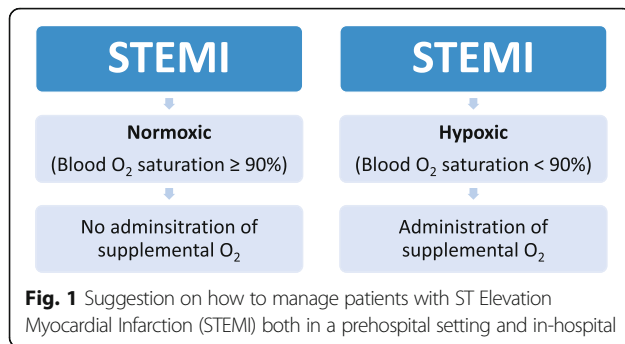
The SOCCER study was conducted in Sweden by Khoshnood et al. and aimed to evaluate the effects of supplemental O₂ in normoxic first-time STEMI patients accepted for PCI. Patients were randomized to either supplemental O₂ therapy or air. All patients underwent CMRI, while only a subset of patients underwent echocardiography. Their chest pain was scored and assessed prehospital and in-hospital with the Visual Analog Scale (VAS) [50]. Ninety-four patients underwent CMRI which showed no significant difference between the two arms in discussing infarct size, myocardium at risk and myocardial salvage index [51]. Of the 87 patients undergoing echocardiography, no significant differences could be measured between the two arms in discussing left ventricular ejection fraction and wall motion score index [52]. In a recently published sub study, 111 patients were assessed in regard to chest pain to evaluate the analgesic effect of O₂ therapy. Those randomized to the supplemental O₂ group had significantly higher median VAS and also received significantly higher amounts of morphine. The study could not show that supplemental O₂ diminished chest pain [53].

The DETO2X study was also conducted in Sweden. The main publication by Hofmann et al. included more than 6000 patients and evaluated the one-year-all-cause mortality in normoxic patients with suspected myocardial infarction randomized to supplemental O₂ therapy or ambient air. The study found no significant differences between the two arms in regard to mortality nor morbidity [55]. A sub study on patients with only STEMI (*n* = 2807) did not show any significant differences between the two arms in regard to one-year all-cause mortality, or morbidity like

Table 1 A summary of the randomized controlled trials studying the effects of O₂ therapy in patients with suspected or confirmed myocardial infarctions

Author (Year)	Study Design	Outcome	Limitations
Rawles et al. [45] (1976)	Double blind. Inclusion: Suspected MI. Patients randomized to O ₂ or air.	IS increased in patients treated with O ₂ as measured by AST. No significant differences were shown between the arms in discussing mortality, malignant arrhythmias and use of analgesics.	Only those with suspected MI was included, why it is uncertain how many who in fact did had a MI. The study was conducted pre-PCI era. IS was measured by AST. No description of how the randomization sequence was conducted.
Wilson et al. [42] (1997)	Open label. Inclusion: Confirmed MI. Patients randomized to O ₂ or air.	No significant differences were shown between the arms in discussing arrhythmias as well as ST segment changes in the ECG.	The study was conducted pre-PCI era. IS was measured by AST. 16% of those initially included, fell out and was thus not analyzed in the final analysis cohort.
Ukholkina et al. [46] (2005)	Open label. Inclusion: Confirmed MI. Patients randomized to O ₂ or air.	MaR, IS and arrhythmias were significantly lower in the O ₂ group.	The randomization process is unclear. Many have been excluded without any discussion. IS was measured by CKMB and through ECG mapping.
Ranchord et al. [47] (2012)	Open label. Inclusion: STEMI/LBBB. Patients randomized to O ₂ or titrated O ₂ .	No significant differences between the two arms in discussing IS as measured with cTn and MRI, as well as 30-day mortality.	Data is lacking for a considerable amount of the patients in regard to mortality. MRI was performed in a subgroup of patients surviving more than 30 days, thus giving rise to a possible selection bias.
Stub et al. [48] (2015)	Open label. Inclusion: STEMI. Patients randomized to O ₂ or air.	Patients in the O ₂ group had a significantly higher mean peak CK but not cTn, increased IS as measured with MRI, and a higher rate of arrhythmias as well as recurrent MI.	CK is not specific for MI. MRI was conducted in only some patients, thus giving rise to a possible selection bias. MRI showed increased IS measured in grams of the LV, but not as a percentage of the LV.
Nehme et al. [49] (2016)	Sub study. The main study was conducted by Stub et al. (2015).	For every 100 L of O ₂ given to a patient, both cTnI as well as CK, increased with 1.4% and 1.2% respectively.	See limitations for Stub et al. (2015). A little over 8% of the patients were excluded since they had no cTnI measurements.
Khoshnood et al. [51] (2017)	Single blind. Inclusion: STEMI. Patients randomized to O ₂ or air.	No significant differences between the two groups in discussing MSI, MaR and IS.	MRI was conducted in only some patients, thus giving rise to a possible selection bias.
Khoshnood et al. [52] (2017)	Sub study. The main study was conducted by Khoshnood et al. (2017; ref. 44).	No significant differences between the groups in discussing WMSI, LVEF as well as NT-proBNP.	A considerable number of patients were excluded because they, among others, denied participation after that they were initially included. This may be a source of bias.
Khoshnood et al. [53] (2018)	Sub study. The main study was conducted by Khoshnood et al. (2017; ref. 44).	Before the randomization, patients in the O ₂ group had a significantly higher VAS and also received significantly more morphine. No significant differences between the two groups in regard to VAS at the start of the PCI or median VAS decrease from randomization to PCI.	A considerable amount of the patients missed VAS rates and were therefore excluded. This may be a source of bias.
Hoffman et al. [55] (2017)	Open label. Inclusion: Suspected MI. Patients randomized to O ₂ or air.	No significant differences between the groups on all-cause mortality at 1 year.	The study may have been underpowered.
Hoffman et al. [56] (2018)	Sub study. The main study was conducted by Hoffman et al. (2017).	No significant differences between the groups in discussing all-cause mortality at 1 year, or adverse cardiac events like MI rehospitalization or cardiogenic shock.	See limitations for Hoffman et al. (2017).
Sparv et al. [57] (2018)	Sub study. The main study was conducted by Hoffman et al. (2017).	No significant differences between the groups in discussing analgesic effect, or the use of both sedatives and opiates during PCI.	Some of the included patients received opiates in the ambulance, why it may have decreased pain at the PCI.

AMI Acute Myocardial Infarction, AST Aspartate Transaminase, CK Creatine Kinase, CKMB Creatine kinase-MB, cTn Cardiac Troponin, cTnI Cardiac Troponin I, ECG Electrocardiogram, IS Infarct Size, LBBB Left Bundle Branch Block, LV Left Ventricle, LVEF Left Ventricular Ejection Fraction, MaR Myocardium at Risk, MI Myocardial Infarction, MRI Magnetic Resonance Imaging, MSI Myocardial Salvage Index, O₂ Oxygen, PCI Percutaneous Coronary Intervention, STEMI ST Elevation Myocardial Infarction, VAS Visual Analog Scale, WMSI Wall Motion Score Index



myocardial infarction and cardiogenic shock [56]. In a recent published DETO2X sub study by Sparv et al. [57] on the analgesic effect of supplemental O₂ therapy in patients with suspected myocardial infarction, there were no significant differences between the two arms in regard to pain nor the amount of morphine and sedatives received during PCI.

Table 1 summarizes all the RCTs.

Omit supplemental O₂ therapy in STEMI

The above RCTs clearly show that O₂ therapy has so positive nor negative cardiovascular effects, when used in normoxic patients with STEMI both prehospital and in-hospital. Two recent reviews and meta-analysis on the role of supplemental O₂ therapy in acute myocardial infarction, showed also no benefit of using O₂ therapy in these patients [58, 59].

In discussing supplemental O₂ therapy in normoxic STEMI patients, the evidences are clear and consistent, why all guidelines must be reformed to state that supplemental O₂ therapy in these patients should be omitted. It is, however, of high importance to point that patients diagnosed with STEMI, and who have a low blood oxygen saturation, should receive supplemental O₂. It is the routine use of O₂ therapy, with no respect to blood oxygen saturation, that should be omitted (Fig. 1). With this said, it is important to point out that the RCTs presented above does also have some limitations as the majority of them have had a small cohort, and the focus have been stable and normoxic STEMI patients. These limitations might reduce the generalizability of the studies. More studies are therefore needed in discussing supplemental O₂ therapy in hemodynamic unstable STEMI patients, patients with non-STEMI as well as unstable angina. This is especially of importance since some studies argue that supplemental O₂ therapy administered to acutely ill patients can be toxic and increase mortality and morbidity [60, 61].

Abbreviations

ACS: Acute Coronary Syndrome; CAD: Coronary Artery Disease; CMRI: Cardiac Magnetic Resonance Imaging; MI: Myocardial Infarction; O₂: Oxygen;

PCI: Percutaneous Coronary Intervention; RCT: Randomized Controlled Trials; STEMI: ST Elevation Myocardial Infarction; VAS: Visual Analog Scale

Acknowledgements

Not applicable.

Funding

Not applicable.

Availability of data and materials

Not applicable.

Author's contribution

The author read and approved the final manuscript.

Authors' information

Dr. Ardavan Khoshnood is a senior resident in Emergency Medicine, and holds a PhD in Clinical Medicine, Emergency Medicine. He is a lecturer at the Medical Faculty at Lund University, and also serves as an Associate Editor for the BMC Emergency Medicine.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Dr. Khoshnood have authored several articles on the role of supplemental O₂ therapy in patients with myocardial infarction and STEMI. Dr. Khoshnood is also an Associate Editor at the BMC Emergency Medicine.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 30 August 2018 Accepted: 11 October 2018

Published online: 20 October 2018

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