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OXYGEN CONCENTRATION DURING PATIENT TRANSPORTATION IN THE AMBULANCE OF THE EMS

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Abstract:
European Resuscitation Council Guidelines for Resuscitation 2010 and Advanced Life Support Provider Course teaches that the open oxygen supply must be removed from the patient during defibrillation to the distance of minimum of 1 meter. Scientific articles describe few incidents of fire during defibrillation in oxygen – enriched atmospheres.
It was performed a series of measurement of the oxygen concentration in the ambulance vehicle of 10 cubic meters. The measurements were made in parked vehicle. Patient was seated on the stretchers and oxygen was applied with oxygen mask on high flow (15 l per minute).
The oxygen concentration was measured on different places in the ambulance car – the patient's face, on the chest, on the wall in front of the car, on the wall in the rear and on the celling. We measured temperature, atmospheric pressure and humidity together with oxygen concentration. The result of our study showed that the oxygen concentration has risen from 20.9 % at all locations of the ambulance. In certain locations the concentration has increased at least to 30 %.
It has prepared recommendations for defibrillation during oxygen administration according to the literature and our study.

Keywords: Oxygen; Defibrillation; Risk of Fire.

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1. Introduction

European Resuscitation Council Guidelines for Resuscitation 2015 (Nolan et. al, 2010) and Advanced Life Support Provider Course (ERC, 2011) teaches that the open source of oxygen (e.g. face mask, bag valve) must be removed from the patient during defibrillation to the distance of minimum of 1 meter. It is not necessary to disconnect the source of oxygen in close circuit (e.g. orotracheal intubation, laryngeal mask without leakage).

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Scientific articles describe few incidents of fire during defibrillation in oxygen – enriched atmospheres. The question is if the fire can occur in the situation of ambulance transportation, when the patient is on high flow oxygen (15 l/min) and suddenly collapse and the cardiac arrest occur and we will start with immediate defibrillation.

The first published case of fire during defibrillation is from the year 1972 (Miller, 1972). The next documented case was in the 1987 (MDSR, 1987). In the second case the personnel leave the open source of oxygen from the respirator on the chest of the patient, where the ECG leads were connected. During the 5th defibrillation attempt the fire occurred on the chest and went to the source of oxygen and burn out the respirator. In the 1995 another case was published in Scotland, where the oxygen enriched bedding ignited. Details about other case are in the article of A. A. Theodorou et al published in the Paediatrics, where there was also ignition of bedding. The result of this incident is a recommendation to avoid contact of oxygen and bedding (Lefever, 1995). The same recommendation is in the guide manual of medical oxygen gas (Conoxia, 2007).

According to the incidents reported there is few published studies, these measured the concentration of oxygen in the area of patient (Robertshaw, 1988), (Cantello, 1998), (Barker, 2001). The highest concentration was documented in the left axilla (30 %) (Robertshaw, 1988) when the bag valve mask ventilation or orotracheal intubation was used. Another study documented 21 % in the head area and 28 % in the axilla (Cantello, 1998). On the operation theatre they measured oxygen concentration up to 50 %) (Barker, 2001). In the last case the oxygen was used in 6 l per minute – the head was under the surgical gown.

2. Materials and Methods

According to the literature review based on search on PubMED (key words: oxygen OR oxygen concentration AND fire OR fire hazard OR risk of fire AND defibrillation OR sparks) were the relevant articles identified and used. The situation of our study was never published.

It was performed a series of measurement of the oxygen concentration in the ambulance vehicle of 10 cubic meters. The measurements were made in parked vehicle. Female patient (25 years old) was seated on the stretchers and oxygen was applied with oxygen mask on high flow (15 l per minute).

It was measured the oxygen concentration on different places in the ambulance car – the patient's face, on the chest, on the wall in front of the car, on the wall in the rear and on the celling – before we start the oxygen administration, during the administration (30 minutes) and another 10 minutes after the end of administering the oxygen. Finally, we opened the side door of the ambulance car to see if and how the concentration will drop.

It was measured temperature, atmospheric pressure and humidity together with oxygen concentration.

It was used Dräger X-am® 5600 device with XXS sensor for the CH_4, O_2 a CO. For the oxygen concentration was used DrägerSensor XXS O_2 with range of 0 – 25 % with measurable variation

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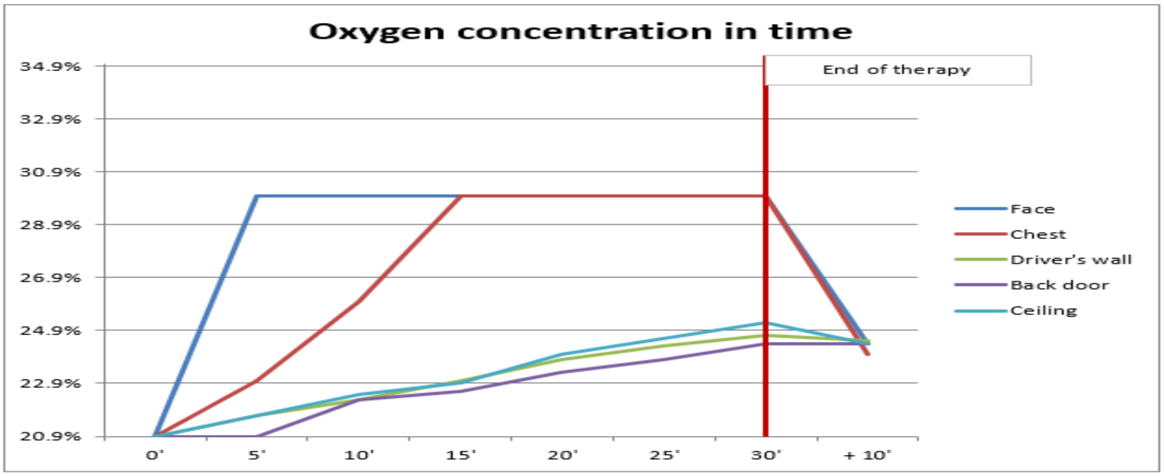
of 0,1 %. We also used another device GasAlert MicroClip XL with sensor for the H_2S, O_2 a CO with the range of 0 – 30 % with measurable variation of 0,1 %.

3. Results and Discussions

The result of our study showed that the oxygen concentration has risen from 20.9 % at all locations of the ambulance. In certain locations the concentration has increased at least to 30 %.



Graph 1: Oxygen concentration in time according to the area of the ambulance car

Chart 1: Environment measurement and oxygen concentration in time according to the area of the ambulance car

Parameter	**Time**							
	0'	5'	10'	15'	20'	25'	30'	+ 10'
Temperature (°C)	22.7	21.9	21.4	21.3	20.9	21.0	20.7	21.1
Pressure (hPA)	987	987	987	987	987	987	987	987
Humidity (%)	40%	42%	43%	44%	46%	46%	47%	51%
Oxygen concentration								
Face	20.9 %	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	24.4 %
Chest	20.9 %	23.0 %	26.0 %	30.0 %	30.0 %	30.0 %	30.0 %	24.0 %
Driver's wall	20.9 %	21.7 %	22.3 %	23.0 %	23.8 %	24.3 %	24.7 %	24.5 %
Back door	20.9 %	20.9 %	22.3 %	22.6 %	23.3 %	23.8 %	24.4 %	24.4 %
Ceiling	20.9 %	21.7 %	22.5 %	22.9 %	24.0 %	24.6 %	25.2 %	24.4 %

Chart 2: Oxygen concentration after opening the door of the ambulance

Area	**Time**		
	+ 10'	+ 11'	+ 14'
Oxygen concentration			
Face	24.4 %	22.0 %	20.9 %
Chest	24.0 %	22.0 %	20.9 %
Driver's wall	24.5 %	24.0 %	20.9 %
Back door	24.4 %	24.0 %	20.9 %
Ceiling	24.4 %	24.0 %	20.9 %

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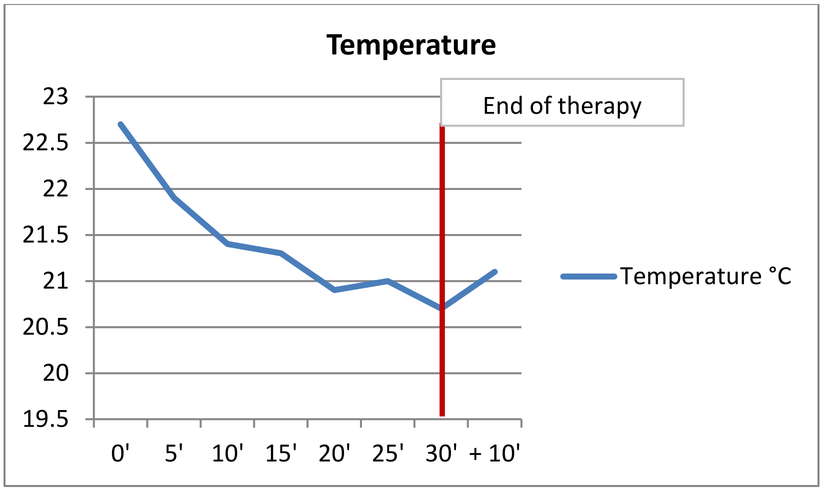
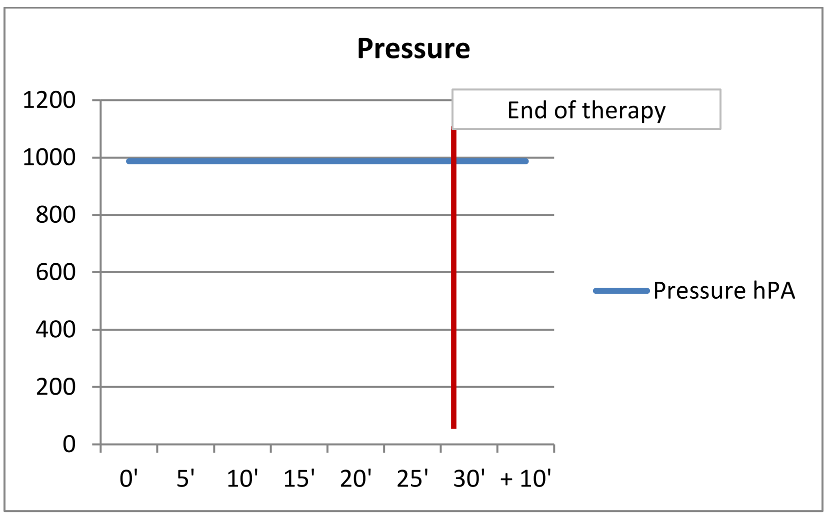
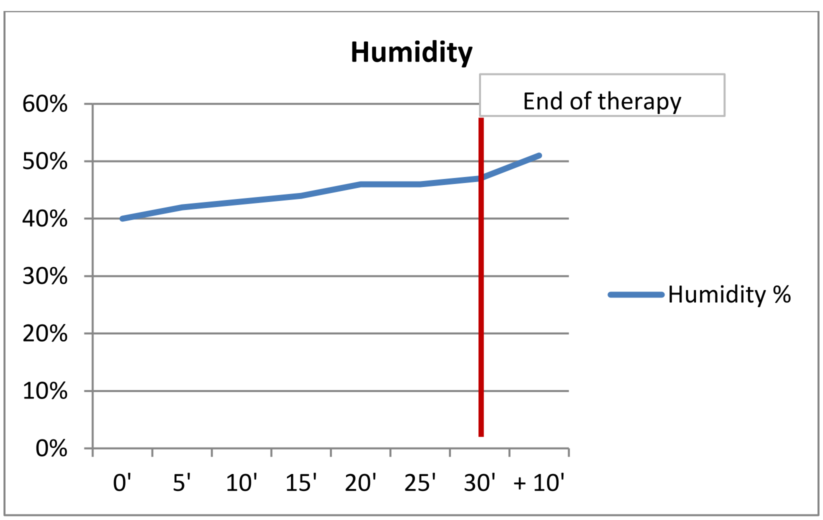


Graph 2: Temperature in time of the experiment



Graph 3: Atmospheric pressure in time of the experiment



Graph 4: Humidity in time of the experiment

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The fire during defibrillation may occur in several ways. Three elements are required for combustion – flammable substance + oxidizing agent + initiator[10]. Flammable substance (fuel) may be anything around the patient. The oxidizing agent is oxygen itself. The initiating source – such as a spark – can easily occur when the defibrillation electrodes are poorly pressed, using a poor gel (e.g. a gel for laryngeal masks), using a small amount of gel or by applying the defibrillation electrode near the ECG cables or ECG electrodes (MDSR, 1994), (Hummel, 1988). Result of our study is that during oxygen administration the concentration of oxygen in the atmosphere of the ambulance car rises from 20.9 % to at least 30,0 % on the patient, which is statistically significant at $p < 0,01$ (one-tailed T-test, $p = 0.000482$). The oxygen concentration increases all over the area of the ambulance from 20.9 % to maximum of 24.7 % which is also statistically significant at $p < 0.01$ (one-tailed T-test, $p = 0.00431$). It is known, that increase of the oxygen concentration over the natural level of 20.95 % increases also the risk of fire. These situations when it is necessary to make the defibrillation as soon as possible are not so rare and to ensure safety of the patient transport, we should focus on minimise safety threats.

When we ended the therapy, the concentration began to fall. After 10 minutes the concentration dropped from 30.0 % to 24.0 % on the patient (one-tailed T-test, $p = 0.001411$, significant at $p < 0.01$) and from 25.2 % to 24.4 % inside the ambulance (one-tailed T-test, $p = 0.00001$, significant at $p < 0.01$). When we opened the door in the 40th minute of the measurement the oxygen concentration dropped radically in one minute from the 24.4 % at the face and 24.0 % at the chest of the patient to the 22.0 % (one-tailed T-test, $p = 0.001734$, resp. $p = 0.001346$, significant at $p < 0.01$). In the area of back door of the ambulance car we measured 24.0 % after the first minute with opened door. After 4 minutes the concentration in whole ambulance area dropped to the normal level of 20.9 % (one-tailed T-test, $p = 0.00925$, significant at $p < 0.01$). According to this finding we build up the recommendation – that when we open the ambulance area (e.g. opening the window) or turn on the fan (exhaustion of the air from the vehicle) it decreases the level of the oxygen concentration in the ambulance area.

The limitations of this study are the limits of the measurement devices where the maximum measurable concentration is 30 %.

4. Conclusions and Recommendations

Measurements proved that the oxygen concentration is increasing and with this also the risk of fire increases. We have prepared recommendations for defibrillation during oxygen administration according to the literature and our study:

1) Remove the oxygen supply to the distance of minimum of 1 meter from the patient before defibrillation is performed (if the oxygen is given via open circuit) (Nollan et al., 2010).
2) Do not remove the oxygen before defibrillation is performed if the circuit is closed without any leak because of the risk of dislodging the endotracheal airway (Nollan et al., 2010), (McAnulty, 1999).

To minimise the risk of sparkling during defibrillation with paddles:

1) During the defibrillation of a patient receiving oxygen, apply the defibrillator paddles firmly (i.e. with at least 25 lb of pressure) (MSDR, 1988).

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2) Do not defibrillate if the chest is coated with enough gel or saline solution to form a conductive bridge between the paddles (MSDR, 1988).
3) Ensure that the patient's ECG leads are not draped near an area of the body where delivering oxygen is likely to pocked or go undetected or where the paddles are placed (MSDR, 1988).
4) To decrease the level of oxygen concentration in the ambulances:
5) Open the window or turn on the fan (exhaustion of the air from the vehicle) during administration of the oxygen in an ambulance car.

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