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Abstract

Development of an e-Nose System for the Early Diagnosis of Sepsis in Mechanically Ventilated Patients: A Preliminary Study †

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Abstract: Sepsis is a severe condition and the major cause of mortality in the ICU. Prompt intervention decreases mortality, and non-invasive systems for early diagnosis in ICU patients are necessary. This work presents a customized e-Nose system based on non-selective chemical sensors for exhaled breath analysis. The system comprises two units: a sampling device able to collect exhaled breath from mechanically ventilated patients and an e-Nose in which the gas is analyzed. Preliminary results from a porcine model support the possibility of discriminating between healthy and sepsis subjects.

Keywords: exhaled breath; VOC analysis; chemical sensors; electronic nose; sepsis

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1. Introduction

Sepsis is a severe systemic condition resulting from the body's response to a bloodstream infection. Its development induces organ failure and hypotension, and it is the major cause of mortality in intensive care units (ICU) [1]. Early detection would allow prompt intervention and can improve patient outcomes. In recent times, analyses of exhaled breath (EB) volatile organic compounds (VOCs) [2] with e-Noses have shown potential for the early diagnosis of several diseases. In this work, we present a novel e-Nose for analyzing EB in mechanically ventilated patients to test the possibility of early diagnosis of sepsis. This device comprises specific sampling and analysis systems suitable for use in the ICU without interfering with regular patient care. Preliminary experiments were performed at Erasmus MC (Rotterdam, The Netherlands) on a porcine model in which sepsis was induced by infusion of lipopolysaccharide (LPS). The investigation compared a sepsis and control group.

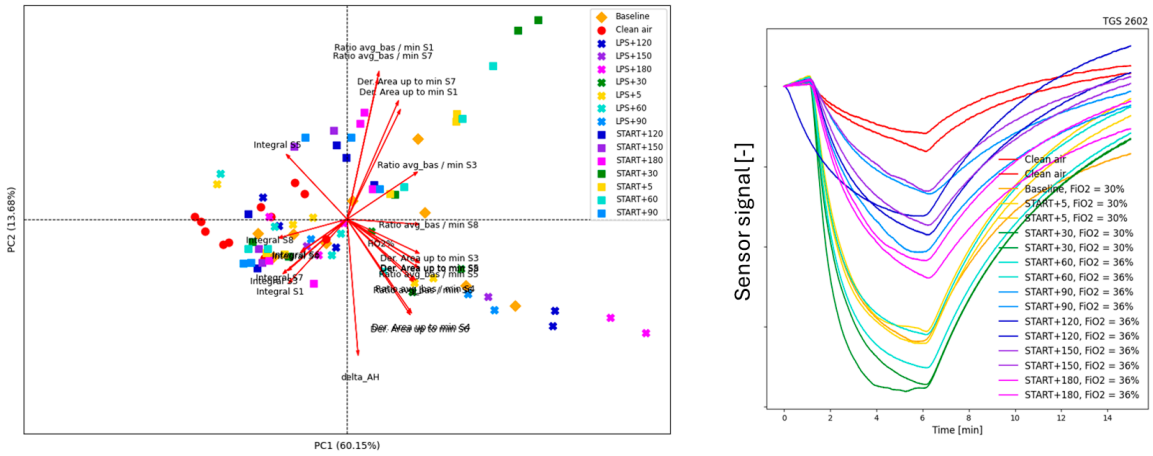
2. Materials and Methods

The system described in this paper comprises two devices: one for sampling exhaled breath and the second for analysis. The sampling system was designed specifically to collect exhaled breath in a Nalophan^{TM} bag during mechanical ventilation by automatically detecting the beginning and the end of each expiration. Once the bag is filled, it is kept at constant humidity and temperature for approximately 24 h for stabilization [3]. EB is sampled at the beginning of the experiment (baseline) and after the start of LPS infusion (at

5, 30, 60, 90, 120, 150 and 180 min after infusion), or in the corresponding timestamp after placebo sodium chloride infusion in the control group. The analysis was performed with a custom-designed e-Nose [4], with eight MOS sensors (TGS 2603 x2, TGS 2600 x2, TGS 2610 x1, TGS 2620 x1, TGS 2611 x1, TGS 2602 x1, Figaro Inc., Osaka, Japan) and one temperature and one humidity sensor (SHT21, Sensirion, Switzerland). The experiment involved the collection and analysis of EB from seven pigs (four with sepsis and three controls). The features extracted from each sensor are as follows: area under the curve, ratio between the mean resistance value in the first minute and the minimum, and the area under the smoothed derivative curve computed up to the minimum. Absolute humidity and the fraction of inspired oxygen (FiO2) set in the mechanical ventilator were also included in the set of features.

3. Results and Discussion

Figure 1 reports the principal component analysis (PCA) relevant to the analyzed samples. Despite the "rough" feature extraction conducted and the limited number of pigs considered up to now, it is already possible to observe an encouraging preliminary discrimination between sepsis (crosses) and controls (squares). As expected from n-type MOS sensors, the amplitude of the curve tends to decrease for increasing FiO_2 levels in the analyzed sample. The loading plot and the exploratory analysis of the curves suggest that further investigations are needed to study the influence of FiO_2 on the e-Nose discrimination capability and evaluate the application of compensation algorithms for this parameter.



(**a**) (**b**)

Figure 1. (**a**) PCA: scores and loading plot; (**b**) example of sensor (TGS2602) responses relevant to the analysis of one control.

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