IDENTIFYING DIFFERENT PATTERNS OF CAPNOGRAPHIC CURVES ON SPONTANEOUSLY BREATHING PATIENTS

Farhan Ahmad*, Norman Stein***, Shripad Kondra*, Ulrich G. Hofmann*, Holger Matz**, Hartmut Gehring***
*Institute for Signal Processing, University of Luebeck, Germany
**University of Luebeck, Institute of Biomedical Engineering, Germany
***Department of Anesthesiology, University Clinic of Schleswig-Holstein - Campus Lübeck, Germany

Abstract

CO_2 measured in the exhaled breathing air (capnometry) is one of the leading indicators of the function of ventilation and circulation and an essential part for monitoring ventilated patients. Analysing gas at the end of expiration (endtidal = et) the measured concentration of CO_2 reflects the alveolar and the arterial concentration, normally expressed as partial pressure ($PetCO_2$) and the arterial one ($PaCO_2$). Since the signal display of the measured CO_2 (capnogram) has a characteristic shape in ventilated patients, deviations might be helpful in detection of ventilation failure. Due to this high impact on diagnostic information the physicians tend to use capnography in spontaneously breathing patients too. Since this situation leads to a higher rate of capnographic shape deformation, a simple expert system is available for identification of meaningful curves.

1 Introduction

Capnography becomes more and more essential in the monitoring of spontaneously breathing patients with i.v analgesia and sedation during diagnostic interventions or in the postoperative period at the recovery room. Several systems are now available on the market for sampling exhaled gas during continuous application of oxygen. The gas supply on one side and the breathing pattern on the other may influence the gas sampling visible on the deformation of the capnographic shape. Due to this effect the displayed data of the endtidal CO_2 partial pressure ($PetCO_2$) varies in a large range and demonstrates furthermore an increased difference to the arterial PCO_2. ”InCAP” (**In**telligent **Cap**nography) is a software tool for analysing the raw capnographic data files in order to identify shapes similar to that of “normal” defined capnogram.

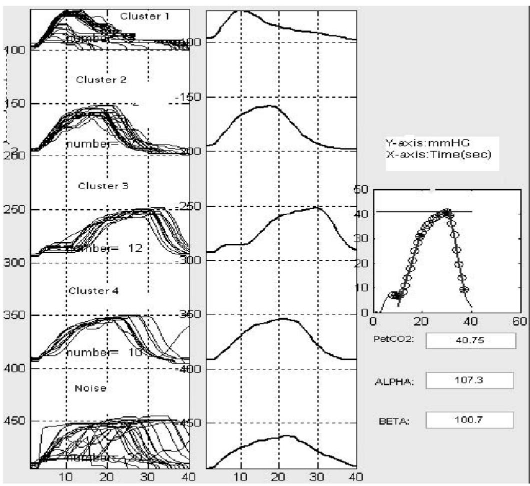

Fig. 1: Left Column: Capnogram belonging to one specific class. Middle Column: Mean capnogram for each group of class. Right: (Example) Analysed capnogram with alpha, beta, and $PetCO_2$ values for cluster 3.

2 Methods & Material

Capnograms are digitised with 10Hz. A clustering algorithm depending on user-defined time-scale (between 3 to 8 minutes) is used to classify the capnograms. This process assigns each capnograms to different classes. Capnograms of one class are represented by their mean curve. Each capnogram class is further analysed with a specific algorithm to identify its correct $PetCO_2$, alpha and beta value. (**See Fig. 1**)

2.1 Clustering Algorithm

The algorithm first identifies capnogram events by simple thresholding procedure. All identified capnogram events are stored as matrix elements. This matrix is divided into 3 subsequent parts. Each part is decomposed into its principal components. We remove the outliers from each part using Hotelling’s T-Square statistics (Matlab Statistical Toolbox). That way the following K-Means Clustering (Matlab) is done in 3-dimensional space only. Data is clustered into "n" numbers of clusters defined by the user. Each of these clusters is correlated with each other and then merged to "m" clusters if the correlation coefficient is high enough. These "m" classes of clusters are further analysed individually.

2.2 Capnogram Analysis

Once capnograms have been classified, they are further analysed by user chosen algorithm to find out $PetCO_2$, alpha and beta angle depending on the shape of the capnogram. One algorithm (presumably for the best capnogram) detects the slope at each sample point and compares this slope with its predecessor. If the slope varies considerably, the algorithm defines this sample point as an edge and marks it (leading to alpha). The next clear change in slope determines the second edge (leading to beta). Additional algorithms were developed with similar methods but with adaptations to comply with pathological shapes of the capnograms and clinical need.

2.3 Clinical evaluation

The capnographic data pool of a recent study was introduced retrospectively to this program for testing the system. Signals resulting from an et-system (Microcap® Plus sampling rate 100 msec) were employed in a randomised manner with each of 8 patients fitted with the oral/nasal FilterLine® (nasal cannula NC; Oridion, Luebeck) for measuring $PetCO_2$, and to each of 8 patients with a normal facial mask (FM) and CO_2 sampling employing the side-stream procedure.

NC	$PaCO_2$ 38.8 ± 2.3 (8 patients)		
n	$PetCO_2$	Alpha	Beta
19 ± 11	35 ± 6	108 ± 4	104 ± 10
17 ± 5	33 ± 8	109 ± 4	108 ± 9
19 ± 8	30 ± 10	111 ± 4	116 ± 15
21 ± 8	27 ± 11	111 ± 7	114 ± 13
13 ± 8	23 ± 12	110 ± 5	117 ± 17
FM	$PaCO_2$ 43,8 ± 4,7 (8 patients)		
n	$PetCO_2$	Alpha	Beta
28 ± 15	32 ± 4	106 ± 3	117 ± 7
17 ± 7	30 ± 4	106 ± 3	115 ± 6
22 ± 6	26 ± 6	108 ± 2	125 ± 14
24 ± 10	26 ± 5	117 ± 13	128 ± 17
19 ± 10	20 ± 6	111 ± 7	131 ± 11

Table 1: Each row corresponds for a cluster 1 to 4, the last row is for noise cluster, including the data of the 8 patients. The total of 1586 capnograms were analysed (NC 801, FM 785). N displays the distribution of the number of capnograms on each cluster. The corresponding data were given as mean ± SD. Since there is only one $PaCO_2$ value for each data string, it is identical on each cluster.

3 Results

Capnographic data files of spontaneously breathing patients were evaluated with this simple expert system. In contrast to the displayed $PetCO_2$ values of the monitor, the offline analysed data come closer to the reference value ($PaCO_2$) revealed by blood gas analysis. Each included file of the 8 patients consists of the raw data of 8 min with one corresponding $PaCO_2$ value. Table 1 represents the distribution according to the different clusters and the benefit of $PetCO_2$ calculation by using "InCAP". The normal range of the angles alpha and beta is 100-110° and 90°, respectively measured under the conditions of intubated and ventilated patients. The results further clearly identified, that the performance of the NC-system is superior to that of the FM.

4 Conclusion & Discussion

Intelligent capnographic analysis has been introduced retrospectively to identify capnograms with nearly a normal shape revealed from spontaneously breathing patients. In contrast to the displayed $PetCO_2$ of the device, the value given by this software reflects substantially better the alveolar concentration of CO_2.
With the described tool, any physician is able to analyse capnograms that might be representative for the actual situation of the patient at a predefined time and on several steps. Since the recent program is only able to analyse data files retrospectively. The development for online processing is the clear next focus. Intelligent capnographic analysis is able to distinguish between curves of normal shape and those of abnormal shape or artefacts. This will help to identify those curves representing $PetCO_2$ values within the expected range of $PaCO_2$.

5 Literature

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