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TITLE: RESPIRATORY WAVEFORMS RECOGNITION USING ARTIFICIAL NEURAL-NETWORKS SYSTEMS

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In order to evaluate the feasibility of on-line pattern-recognition ventilator alarm systems, we studied the capabilities of neural-networks to identify breathing modes from their tracings of gas flow, airway pressure (PAW), and esophageal pressure (PES). Studied ventilatory modes included spontaneous, pressure supported, and mechanical pressure controlled breathing.

After institutional review board approval and patient informed consent, airway gas flow, PAW, and PES waveforms were recorded from 13 patients undergoing general anesthesia. Pressure support and spontaneous breathing waveforms were obtained from all patients. Pressure controlled ventilation waveforms were recorded from four patients. 920 waveforms were selected for processing. Waveforms were reduced to the inspiratory part, and their periods were adjusted to 1.5 seconds by linear interpolation. Four training and testing groups were assembled. On each group, data from 12 subjects were used for training, and data from the remaining subject were used for testing. Single-hidden-layer back-propagation neural-networks were used for all experiments. Input to the neural-networks consisted of one to three waveforms; while the output was always three neurons: one for each ventilatory mode. Training and testing of all neural-networks were done using the Explorenet 3000 package (HNC, San Diego, CA) running on an IBM PS/2-70-486 workstation.

The results expressed as the number of correct (positive or negative), unknown, and incorrect (false positive or false negative) ventilatory mode assignments are shown in the table. The neural-network recognized breathing patterns correctly 98.4% of the time.

MODE	correct	unknown	incorrect
PSV	369	4	0
CONTROLLED	371	2	0
SPONTANEOUS	361	12	0
AVERAGE	367	5.4	0

We conclude that neural-networks can be effectively used for respiratory waveforms recognition. Real-time respiratory waveform recognition may become part of smart alarms systems. This may result in increased safety in patients undergoing mechanical ventilation.

A493

Title: Transcutaneous CO_2 Monitoring in SICU Patients At 42°C Probe Temperature Shows Good Correlation with Arterial pCO_2.

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Introduction: Transcutaneous CO_2 ($PtcCO_2$) monitoring is a technique where carbon dioxide is measured at the skin surface with a heated Severinghaus CO_2 electrode. This technique has been used for over 10 years, however, it has not found widespread acceptance for use on adults. Problems with this acceptance are (1) the actual $PtcCO_2$ value must be adjusted to reflect the arterial CO_2 ($PaCO_2$), (2) more than one adjustment factor (AF) has been proposed and (3) the probes must be heated to increase the correlation with the $PaCO_2$. The commonly used probe temperatures (PT) are between 43.5 and 44.5°C risking skin burns if left in place for > 4 to 8 hours. The purpose of this study was to determine, for adult SICU patients, which of two of the proposed AFs is more accurate and whether 42°C PTs can produce reliable results.

Methods: Institutional review board approval was obtained. Patients with arterial cannula in place who required arterial blood gas analysis for clinical reasons were eligible for the study. The first phase involved 2 Novametrix 840 transcutaneous monitors with CO_2 only probes, set at 42°C PT and 44°C PT, respectively. The second phase involved 2 SensorMedics FasTrac monitors with CO_2 only probes, set at 43.5°C PT and 42°C PT, respectively. The protocols were the same for each phase. Each monitor was configured to display the unadjusted $PtcCO_2$ value and calibrated with 5% and 10% CO_2 gas. The probes were applied to the anterior chest or upper abdomen. Each patient had two probes at the different PTs describe above. The following data were collected: simultaneous $PtcCO_2$ for each probe and $PaCO_2$ by blood gas analysis, uncorrected for patient temperature. The $PtcCO_2$ values were adjusted by using the methods of Monaco (M)[1] and of Severinghaus (S)[2]. M's AF is the $PtcCO_2$ divided by 1.61. S's AF is the $PtcCO_2$ multiplied by $e^{(.045*(37-PT))}-4$, so that the $PtcCO_2$ adjustment is PT dependent. Regression analysis and bias and precision determination were preformed. The limits of agreement are defined as the bias ± 2 precisions.

Results: 31 patients were studied in phase 1 and 30 patients in phase 2. Table 1 compares $PaCO_2$ vs $PtcCO_2$ for each brand monitor and using each of the two AFs. Figure 1 shows the regression curves and equations for S's adjusted SensorMedics data.

Discussion: The highest agreement between $PaCO_2$ and $PtcCO_2$ was with the SensorMedics monitors. This group showed good correlation at both the 43.5°C and 42°C PTs using S's AF, showing that 42°C PT is a viable option for CO_2 monitoring in SICU patients using this technique.

References:

1. AM REV RESPIR DIS 1983;127:322-324
2. ACTA ANAESTH SCAND 1978;68:118-122

TABLE 1

$PaCO_2$ vs $PtcCO_2$	r	Regr. Slope	Bias ± s.d. (mmHg)	Limits of Agreement	n
Novametrix					
42°mon[1]	0.88	1.1	-3.3±3.3	-10.0 to 3.4	121
44°mon[1]	0.83	0.93	-2.6±3.8	-10.2 to 5.0	112
42°sev[2]	0.88	1.4	2.1±4.8	-7.5 to 11.6	121
44°sev[3]	0.83	1.1	-0.7±4.5	-9.7 to 8.2	112
SensorMedics					
42°mon[1]	0.85	0.71	-4.8±3.1	-11.0 to 1.4	118
43.5°mon[1]	0.88	0.82	-3.1±2.6	-8.3 to 2.1	119
42°sev[2]	0.85	0.92	0.0±3.4	-6.8 to 6.8	118
43.5°sev[4]	0.88	0.99	-0.6±2.9	-6.4 to 5.2	119

1. $mon = P_{tc}CO_2/1.61$
2. $sev = P_{tc}CO_2 \cdot e^{(.045(37-42))}-4$
3. $sev = P_{tc}CO_2 \cdot e^{(.045(37-44))}-4$
4. $sev = P_{tc}CO_2 \cdot e^{(.045(37-43.5))}-4$

FIGURE 1