

Title: COMPUTERIZED ARTIFACT REJECTION FOR INDUCTANCE  
PLETHYSMOGRAPHY APNEA MONITORS

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**Introduction.** The use of epidural narcotics for pain management mandates apnea monitoring. Respiratory inductance plethysmography (RIP) is an excellent apnea monitor since it can non-invasively measure respiratory parameters on healthy and diseased patients during sleep, supine and sitting positions, and exercise. If properly calibrated, respiratory parameters such as respiration rate, tidal volume, inspiratory and expiratory flows and times are accurate to within 20%. A major source of errors in inductance monitors are motion artifacts such as arm and leg movements, rolling to the side, and coughing. The inductance signal contains both respiratory components and motion artifacts. Extraneous motion may be observed and noted; however this requires constant patient supervision and some movements may be missed.

To improve the accuracy of the RIP, a system was designed to process the chest and abdomen signals to automatically detect motion artifact. The system was evaluated in a volunteer study to compare the RIP monitor with a conventional Fleisch pneumotach during a variety of body movements.

**Methods.** The study was approved by the Institutional Review Board and informed consent was obtained from 20 healthy volunteers (male, 21 to 30 years). They were simultaneously monitored with the Resptrace RIP and a Fleisch pneumotachograph. A standard mouthpiece and noseclips were used. Eight distinct movements were performed interspaced between 3 minute epochs of supine, quiet breathing: raising arms once slowly, quickly, and several times; raising legs slowly and several times; sitting up, breathing deeply and rapidly, and rolling from a supine to a lateral decubitus position. Chest (RC), abdomen (A), flow from the pneumotachograph, and a 'marker' (to document movements) were sampled at 20 Hz.

Data was processed using a first order least mean square adaptive filter that best approximates the A signal as a function of the RC signal. The difference (error) between the actual and approximated A signal is used to calculate the next output from the filter. The error is minimized as the output approaches a constant which relates RC to A (the value varies with each individual). Movements change the relationship thus changing the amplitude of the filter output. After the movement, the output returns to the previous baseline value.

To calibrate the RIP, a multi-linear regression was done with the A, RC, and flow

signals to calculate the calibration constants for the following equation:

$$\text{Flow} = b \cdot dA/dt + c \cdot dRC/dt + d$$

b and c=calibration constants, d=offset.

These values are normally calculated as the patient breathes through a pneumotachograph during an initial 2 minute calibration period. They are then used to calculate tidal volumes on a breath by breath basis. The calibration values (b, c, and d) are usually assumed to remain constant. However, body movements not related to breathing will dramatically change the values. In order to document the effect of body movements on the RIP calibration constants, the calibration procedure was performed on all the data during the study session. A window of 128 points was used for each regression. The window was shifted by one sample interval and the regression repeated until all the data was processed. The calibration values and the filter output were plotted vs time.

**Results.** There were a total of 170 movements. The calibration values (b, c, and d) changed on 137 out of 170 documented movements (81%). This implies that a RIP with only one initial calibration would have been inaccurate during 81% of the movements. The filter detected 122 (89%) of those movements where calibration values changed. The filter only detected 9 movements where there was no change in the calibration constants.

**Discussion.** Implementing this real time algorithm for monitoring with the RIP will improve the accuracy by detecting 89% of the movements which may cause false alarms and errors in respiratory rate, volume, and flow calculations. This should significantly improve its effectiveness as an apnea monitor for use with epidural narcotics. More accurate respiratory assessments could also be made during sleep studies, pulmonary, evaluations, or exercise evaluations.

#### References.

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