Abstract: This paper addresses a biomechanical-based approach to analyze breathing sound for monitoring the physiological states of anesthetic patients undergoing operations. The mini-microphone is set up in the bite block to record glottal signals. An average vibration parameter adopted to describe the degree of diversity among these signal amplitudes of the inspiration and expiration. The preliminary results show that the proposed average vibration parameter of the inspiration is different from the expiration both in spontaneous and artificial ventilation produced by respirator during anesthesia. The spontaneous and artificial ventilation can be identified through the average vibration parameter of the inspiration under a 95% significant level. These two results can be applied in a breathing sound monitoring system for anesthetic patients and give us a good discrimination between spontaneous respiration and artificial ventilation.

Introduction

Breathing Sound is one of the most important physiological signals, especially for the unconscious anesthetized patients. Consequently, monitoring breathing sound is necessary for the patients undergoing operations. Up to now, monitoring of respiration is still based on hearing by anesthesiologist’s ear. However, hearing by ear cannot monitor continuously for a long period and will lost some danger signals such as tongue drop, abnormal endotracheal tube, laryngospasm and bronchospasm beforehand.

Past work [1] carried out the monitoring system, which can monitor respiration through frequency spectral analysis. But threshold values’ selection for distinguishing inspiration, expiration and respiration pause is a problem to affect the performance. Several other studies [2][3] investigated the wheezing-episode detector based on breathing sound spectrogram analysis. These methods were developed based on too many subjective criteria and lacked scientific verifications and proofs.

In clinical, a computerized assistive respiratory monitor device/system is important to help the medical clinician keeping the unconscious anesthetic patient. This study describes a more reliable and faster method for analyzing and monitoring breathing sounds of anesthetic patients. Through this analysis, the breathing sound can distinguish the inspiration and expiration in the same respiration and identify the spontaneous respiration and artificial ventilation. The aim of this study was to establish a breathing sound monitoring system to automatically locate and identify physiological states of anesthetic patients through breathing sound in order to alarm danger situations for the medical personnel to avoid surgical risks.

Methods

Analyses were performed on the three subjects undergoing surgeries. A computer recorded the breathing sound from the mini-microphone hidden in the bite block through an analogue to digital converter. Breathing sound database was recorded about ninety seconds for each subject in two different kinds of situations, spontaneous respiration and artificial ventilation produced by respirator, after anesthesia in a wave format of sampling rate 16K Hz and 16 bits.

The system architecture is shown in figure 1. The breathing sound database was normalized and pre-filtered by a five order Butterworth analogue filter with a cut off frequency of 1500 Hz. These signals were then processed by two steps in order to monitor breathing sound and identify the physiological states. They are described as follows:

The first step is to calculate the energy contour [4] of the glottal signal to mark the positions of the respiration. The normalized signal is divided into many frames to estimate the corresponding energies $E$ as described in Equation (1).

$$E = \sum_{n=1}^{N} X^2(n)$$

where $X(n)$ is glottal signal of a frame and $N$ is the frame size and set as 512. These energies are smoothed and plotted as the energy contour for the input glottal signal as shown in figure 2.
In figure 2, the peak (circle) between two troughs (star) is marked as the inspiration or expiration segment for the further identification.

In the second step, the marked inspiration or expiration positions are then identified by the average vibration parameter (AVP), which measures the diversity and damping effect of a breathing sound passing through the glottal cavity and is defined as:

$$AVP(X) = \frac{VP(X)}{X}$$  \hspace{1cm} (2)

where $VP(X)$ is the vibration parameter for the corresponding signal segment and defined as:

$$VP(X) = \frac{\sum_{m=1}^{M} \log(\text{abs}(X(m)))}{M}$$  \hspace{1cm} (3)

$M$ is the segment size. $X$ is the average amplitude of the glottal signal and defined as:

$$\bar{X} = \frac{\sum_{m=1}^{M} \text{abs}(X(m))}{M}$$  \hspace{1cm} (4)

**Results and Discussion**

The presented method was applied on three cases of anesthetic patients undergoing surgeries to monitor breathing sounds. AVPs of inspiration and expiration for these cases are estimated according to equation (2). These parameters are analyzed by paired T-test to classify these patterns. The preliminary results are shown in Table 1. AVP in inspiration is different from expiration both in spontaneous respiration and artificial ventilator produced by respirator. Especially in the inspiration segment, the AVP shows the significant discrepancy. This is because the mechanism of spontaneous inspiration is different from the inspiration of mechanical ventilation. The former is the natural airflow caused by the lower pulmonary pressure. The latter is the artificial airflow caused by the respirator. The difference of AVP between these two kinds of inspirations can be applied to identify the physiological states to distinguish spontaneous respiration or mechanical ventilation produced by respirator for an anesthetic patient.

<table>
<thead>
<tr>
<th>Average Vibration Parameter</th>
<th>Spontaneous Respiration</th>
<th>Artificial Ventilation</th>
<th>mean±std</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspiration</td>
<td>0.000143±</td>
<td>0.000179±</td>
<td>0.000164±*</td>
</tr>
<tr>
<td>Expiration</td>
<td>0.000121±</td>
<td>0.000116±</td>
<td>0.000118±*</td>
</tr>
</tbody>
</table>

Table 1. Paired T-test for the difference between inspiration and expiration for spontaneous respiration and artificial ventilation (df=10)

**Conclusion**

In this study, the AVP is proposed to classify the different respiration situations to establish a breathing sound monitoring system. The analysis results for three cases give us a great encouragement that the AVP indeed can be applied to distinguish inspiration and expiration. Moreover, the AVP can also identify spontaneous respiration and respiration produced by ventilator of an anesthetic patient. The future work of the breathing sound monitoring system is to automatically detect physiological states and alarm danger situations of anesthetic patients such as tongue drop, abnormal endotracheal tube, laryngospasm and bronchospasm for the medical personnel to avoid surgical risks. The system will also be a great benefit to the asthma and respiratory care patients.

**References**


Figure 2: The respiration signal and energy contour