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The phenomenon of Breathing Pattern of Weaning for Success and Failure Groups

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Abstract- **Weaning the discontinuation of mechanical ventilator, it can be regarded as a stress process[1]. It will trigger central neural feedback response to maintain the balance of our body and environments. This phenomenon is usually easily observed in breathing pattern. Weaning will caused a rhythmic change in breathing pattern. We collect data before and after weaning, weaning success and weaning failure in clinical environment. Statistical analysis methods are used to investigate this rhythm change. It also provides valuable information about respiratory system. In this paper, we showed that there is obviously difference in normalized standard deviation of after weaning data minus before weaning data between weaning success and weaning failure groups. The success groups also have lower value (bellow to zero) in after minus before weaning data than failure groups. In frequency domain, we find there is obviously difference in weaning success and weaning failure groups in total power of inspiratory time spectrum (p value=0.028). The result obtains in the time and frequency domain is the same. However, the third frequency peak power amplitude of the spectrum has the same result (p value=0.021). This phenomenon in breathing pattern may be used as a good weaning index to predict weaning success and failure.**

Keywords - **mechanical ventilator, rhythmic change, weaning, breathing pattern**

I. INTRODUCTION

Recently, mechanical ventilation is widely used in Intensive Care Unit and plays an important role in lifesaving. However, it may be associated with numerous complications. It should be discontinued as soon as possible. Many weaning indices have been developed to predict the successful discontinuation of mechanical ventilator. However, determination of the optional time to discontinue ventilator support can be very difficult. The existing weaning indexes include breathing pattern, arterial blood gas and lung mechanisms. With the help for these weaning indexes, the reintubation rate (weaning failure) still range form 7 to 19% and patients of weaning failure also have high mortality [2].

Analyzing breathing pattern can provide valuable information about respiratory system. In a patient with intact respiratory center (preserved brain stem function), which is as usual in most patients, respiratory center output is most closely associated to patients stress and physiologic condition. Many weaning parameters, such as frequency, tidal volume, rapid shallow breathing index, are related to respiratory center output.

Attention has been focused on the pattern of breathing as a guide to weaning outcome, i.e. respiratory frequency, tidal volume and rib cage-abdominal motion. It is suggested that respiratory muscle fatigue might be a primary course of failure to weaning [2]. Patients who failed a weaning trail had considerable breath-to-breath variation in relative contribution of the rib cage and abdomen to tidal volume [3].

Many methods have been used to analyze breathing pattern and respiratory central output. The most famous one is the rapid shallow index that can predict better weaning outcome. An elevated respiratory frequency is often the sign of impending respiratory failure. Tachypnea is common index of intubation for respiratory failure and index of weaning failure [4].

Additional information on respiratory center function can be obtained by an alternative approach to breathing pattern analysis. The measure of minute ventilation can be partitioned into respiratory frequency and tidal volume component whereas tidal volume can be participated into flow and inspiration time. Respiratory flow rate, especially the mean inspiratory flow rate, is employed as a measure respiratory drive.

The classic methods for analyzing breathing pattern all focused on single or mean value. For example, in rapid shallow index value above 105 is considered to be potential weaning failure and in tidal volume value less than 300 ml suggests an unsuccessful weaning outcome. Little attention is given to rhythm change. Series data may give more information than spot data. A time-series, breath-by breath plot of respiratory frequency and tidal volume in a patients who failure a weaning trial showed a rapid and fluctuated respiratory frequency.

Without external stimulation, breathing pattern is relative stable but not clockwise regularity. The regularity of breathing pattern is not studied. From clinic observation, the breathing pattern is rhythmic change in normal or lightly stressed patients, but it is more fluctuate in impending respiratory failure patients. There are few studies concerned about breathing pattern changing after weaning. In this paper, we use signal process methods (spectral analysis) to study the breathing pattern (rhythm) change before and after weaning. Then after quantification, we try to find out the difference between success and failure weaning group. We also discover the difference of result in time and frequency domain.

II. METHODOLOGY

Our experiment is bellow:

1)Patients Selection

We select twenty-nine patients, who is mechanically ventilated for more than 24 hours in Intensive Care Unit and prepared for weaning. The timing of weaning is according to the general weaning guideline and decided by the primary care physician who does not involve in this study.

2)Weaning Protocol and Data Collection

For each patient, general care and sputum suction, a fixed orifice flow sensor is connected into endotracheal tube orifice. The signals of flow are collected by Ventrak® respiratory monitor with sample rate of 100 Hz. The patient breaths form T-tube with FiO2 5% higher than the ventilator setting, which supply by an all-purpose nebulizer. The signal will be collected at least 5 min after 30 minutes of T-tube trial. No therapy or physical interruption is allowed in this period. The patient's basic information including sex, age, causes of respiratory failure, ventilator day and weaning outcome will be recorded. The failure of weaning is defined as intubation or reuse of mechanical ventilator within 48 hours of weaning. The usage of noninvasive ventilator is not regarded as weaning failure.

3)Signal Process

The Ventrak® raw data is shown as fig 1. We process the data as shown in fig2. First, we use a filter to eliminate error and noise. Then, the inspiratory time, expiratory time, cycle time and breathing pattern variability, four physiology parameters, will be identified by zero-crossing method.

4)Statistical Analysis Method

Breath-by-breath base variables will be calculated. These include mean and standard deviation. Normalized standard deviation (standard deviation/mean) is used to investigate neural control of weaning stress.

Mean:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (1)$$

Standard Deviation:

$$\hat{SD} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \qquad (2)$$

5)Frequency-domain measurement (Spectrum analysis)

The four physiology parameters are plotted into tachogram (fig.3). Then, modified covariance method is used to evaluate autoregressive coefficients. In autoregressive model, order selection is very important. We use Akaike Information Criterion to calculate the order of each case. Then, the average value is used as the autoregressive model order. Autoregressive Power Spectral Density will be calculated based on these autoregressive coefficients and order 14 (fig.4). The spectral parameters, the first three peak power ratio in low frequency will also be calculated (fig.5). [5]

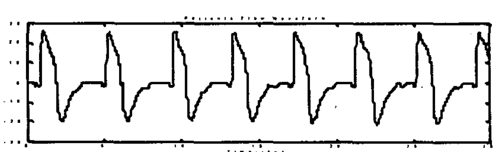

Fig 1. The Ventrak® recorded flow waveform

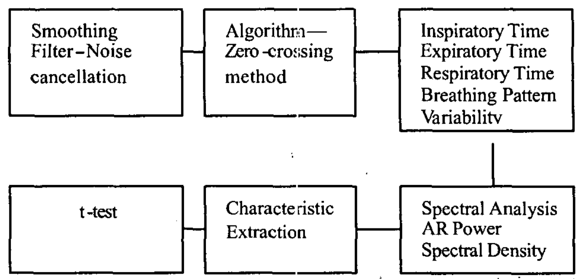

Fig 2 spectral analysis structure

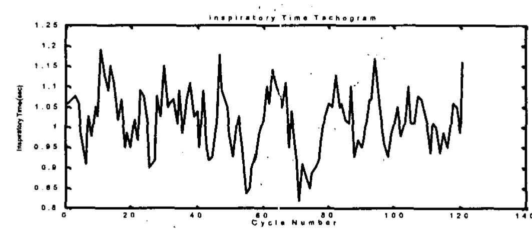

Fig3. Tachogram

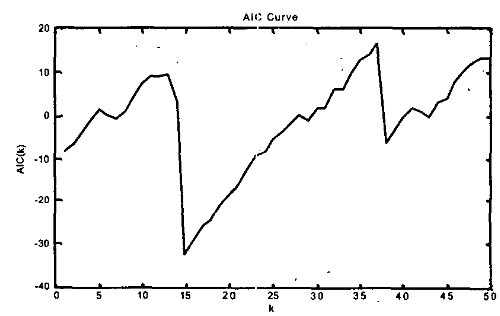

Fig4. AIC Curve

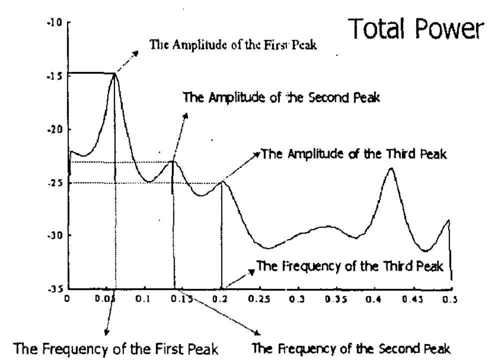

Fig5. Power Spectral Density

III. Results

In our analysis, no matter inspiratory time, expiratory time, cycle time, and breathing pattern variability, no significant difference is found for normalized standard deviation before and after weaning. This also happens in weaning success and failure groups.

TABLE I

.Peak Power Ratio of Inspiratory Time between before and after weaning

Normalized Standard Deviation	Weaning Training Success Group	Weaning Training Failure Group	Pvalue
	After weaning minus Before Weaning Training		
Inspiratory Time	-0.042 (0.095)	0.098 (0.152)	0.007a
Exspiratory Time	-0.005 (0.083)	0.063 (0.127)	0.008a
Cycle Time	-0.039 (0.071)	0.079 (0.127)	0.004a
Breathing Pattern Variability(Inspiratory Time/Cycle Time)	-0.043 (0.076)	0.049 (0.113)	0.020a
Breathing Pattern Variability (Exspiratory Time/ Cycle Time)	-0.019 (0.039)	0.069 (0.117)	0.008a

a-pared after minus before weaning data between weaning success and failure group by independent t test

if p<0.05,it means have significantdifference in t-test

However, we can find there is obviously difference in the difference value of after minus before weaning normalized standard deviation in four parameters between weaning success and failure groups. In weaning success group, the normalized standard deviation is lower than weaning failure groups, and the value are all below zero.

In frequency domain, we use seven values of after minus before weaning in statistical analysis. We find there is obviously difference in weaning success and weaning failure groups in total power of inspiratory time spectrum(p value=0.028). The third frequency peak power amplitude of the spectrum is the same result (p value=0.021).

IV. Discussion

According to the results, we consider that weaning training may help to trigger patient's automatic breathing. The central neural feedback control will make breathing pattern highly identically. It also means that the disturbance will be drastically smaller. Thus, we can consider breathing pattern as a good weaning index.

V. Conclusion

In this paper, we investigate breathing pattern using normalized standard deviation of after minus before weaning data to distinguish success and failure weaning groups. In frequency domain, the result is the similar in time domain. So it also can provide some information of respiratory system to us. This central feedback control phenomenon in breathing pattern may be used as a good weaning index to predict weaning success and failure.

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