Effect of Mixed Anesthesia on Cardiac Function by Phonocardiogram

Fei Han, Hong-Mei Yan, Xin-Chuan Wei, and Qing Yan

Abstract—Objective of this investigation is to further analyze the cardiac function status change by phonocardiogram during mixed anesthesia which is conducted by midazolam, skelaxin, fentanyl and propofol. The results show that blood pressure, heart rate, amplitude of $R$ wave and $T$ wave, amplitude of first heart sound ($S_1$) and second heart sound ($S_2$) about 37 subjects after anesthesia decrease compared with baseline, while the ratio of first heart sound and second heart sound ($S_1/S_2$) and the ratio of diastole duration and systole duration ($D/S$) increase. Our study demonstrates that phonocardiogram as a noninvasive, high benefit/cost ratio, objective, repeatable and portable method can be used for the monitoring and evaluation of cardiac function status during anesthesia and operations.

Index Terms—Anesthesia, cardiac function, phonocardiogram.

1. Introduction

In the course of anesthesia and operations, accurate, reliable, non-invasive and convenient measurement or monitoring of cardiac function is critical for patients, especially for heart failure patients. At present, two methods are usually used for cardiac evaluations in clinic. One is cardiac catheterization method, which is accurate and reliable, but invasive and not suitable for normal monitoring. The other is echocardiography, which is comparative expensive and inconvenient during anesthesia and operations.

Hansen PB’s early animal researches showed that there was a very close relationship between the amplitude of the first heart sound ($S_1$) and the cardiac contractility and provided the possibility of phonocardiography as a monitor of cardiac performance during anesthesia [1]. Luisada A. A. et al. suggested that heart sounds should be studied during anesthesia because the changes that occur during stress testing are highly consistent and strongly suggestive of changes in myocardial function, and they pointed out that heart sound changes during stress may be more rapid and sensitive than changes in heart rate and blood pressure [2].

In recent years, Xiao S. Z. et al. sponsored that phonocardiogram as a noninvasive, high benefit/cost ratio, and portable method can be used for the evaluation of cardiac performance at the bedside and sports field, and so on [3][4]. They even proposed some new indicators to evaluate specific cardiovascular status, such as the ratio of $S_1$ amplitude to $S_2$ amplitude ($S_1/S_2$), which can be used to evaluate the dynamically changing relation between cardiac contractility and peripheral vascular pressure, including up-regulating condition of cardiac contractility during stress; and the ratio of diastolic to systolic duration ($D/S$), which can be used to evaluate the time of blood flowing to the heart per se during diastole [5].

Early studies reported that different anesthesia regimens and anesthesia styles had different significant effects on cardiovascular function [6]. However, most of these studies were carried out by cardiac catheterization method or echocardiography in animals [7]. There is a lack of one effective, non-invasive, continuously monitoring and convenient method to evaluate the patient’s cardiovascular function during anesthesia and operations for above described reason.

Studies by Gerard R. et al. showed that heart sound characteristics can be used to monitor cardiac function during halothane anesthesia in children, and the changes occur rapidly and precede noticeably in heart rate and blood pressure [8]. In their studies, they didn’t assess the new indicators of cardiovascular status by heart sound and halothane, what they used was a single inhaled anesthetics. However, a mixed injected anesthesia of midazolam, skelaxin, fentanyl and propofol was another important anesthetic style often used in clinic. Therefore, the objective of this investigation was to further analyze the effect of mixed anesthesia on cardiac function status change trend by phonocardiogram.

2. Experiments

2.1 Experimental Subjects

After approval of the Review Committee of Sichuan University on research involving human subjects and informed consent given by every subject was obtained, we
carried out this study in Medical Center of Huaxi, Sichuan University, Chengdu, China. 37 ASA physical status I and II patients aged 18 years to 80 years presenting for urologic surgery participated in the test. In clinic, midazolam, skelaxin, fentanyl and propofol, being as mixed anesthesia, was used for patients, which dosages was determined by patients’ weight. Patients with serious cardiac disease or contraindication to mixed anesthesia were excluded.

2.2 Experimental Methods

No preoperative medications were given, and all patients had received nothing by mouth for at least 12 hours. In the operating room, a metallic 3 cm diameter heart sound sensor with a flat frequency response between 35 Hz and 20000 Hz (BIOPAC Systems, Inc., USA) was placed at the position of maximum S1 assisted by stethoscope; generally, it was between the third and fourth rib[9]. The audio signals were amplified and routed to a notebook PC (sampling rate 5000 Hz) and continuously monitored by Biopac MP150 (BIOPAC Systems, Inc., USA) from 2 minutes before anesthesia to 2 minutes after anesthesia. The waveforms were processed with Coifman fourth order wavelet basis to minimize high-frequency noise and the resulting waveforms were processed with Matlab 7.0[10][11].

The electrocardiograph (ECG) was monitored synchronously with Biopac MP150; at the same time, blood pressure and pulse oximeter et al. were monitored with anesthesia monitoring instruments (Shenzhen Mindray Bio-medical electronics Co., LTD, China).

Fig. 1. The relationship of PCG and ECG.

Two representative audio samples were selected for each patient: baseline (20 seconds), anesthesia duration (20 seconds, after anesthesia had been taking effect). The variance of heart rate, blood pressure, amplitude of R wave and T wave, amplitude of S1 and S2, ratio of S1/S2 and D/S from baseline to anesthesia duration were analyzed. The results are presented as Mean ± Std. Thereinto, the systole and diastole duration were located by classical method referred with ECG and PCG. The relationship of PCG and ECG is shown in Fig. 1. S1 which is mainly determined by the closure pressure of the mitral and tricuspid valves occurs at the end of the isometric contraction period during systole, 20~40 ms after R waves of ECG and S2 which is primarily decided by the closure pressure of the aortic and pulmonary occurs after the isovolumetric relaxation period during diastole, before or after the end of T waves[12]. As synchronous phase, it is proposed that the coordinate position of R waves is regarded as the beginning of systole duration; the coordinate location of the end of T waves is regarded as the beginning of diastole duration.

3. Results

Characteristic heart sound waveforms before anesthesia and after anesthesia are shown in Fig. 2. The amplitude of S1 and S2 after anesthesia descends obviously. Fast Fourier transform tracings for one patient before anesthesia and after anesthesia are illustrated in Fig. 3. Likewise, the amplitude of spectral edge after anesthesia drops obviously. These results are agreed with Gerard R’s early research[8].

Table 1 gives out the comparison of blood pressure, heart rate and amplitude of R wave and T wave before anesthesia and after anesthesia. From table 1, the average heart rate of 37 subjects fell from 79±13 bpm before anesthesia to 69±10 bpm after anesthesia. Similarly, after anesthesia, the average systole and diastole pressure dropped from 127±23 mmHg
and 80±14 mmHg to 84±23 mmHg and 51±14 mmHg, respectively.

As well, the amplitude of patients’ ECG descended. As the absolute amplitude of ECG may be different for different patient, we defined the value of R wave and T wave at pre-anesthesia as 1 for baseline. From Table 1, the average relative amplitude of R wave and T wave after anesthesia declined to 0.8978±0.1575 and 0.9411±0.0659, respectively.

Table 1: Comparison of blood pressure, heart rate and amplitude of R wave and T wave before anesthesia and after anesthesia

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before anesthesia</th>
<th>After anesthesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systole Pressure (mmHg)</td>
<td>84 ± 23</td>
<td>127 ± 23</td>
</tr>
<tr>
<td>Diastole Pressure (mmHg)</td>
<td>51 ± 14</td>
<td>80 ± 14</td>
</tr>
<tr>
<td>Heart Rate (bpm)</td>
<td>69 ± 10</td>
<td>79 ± 13</td>
</tr>
<tr>
<td>* R wave</td>
<td>0.8978 ± 0.1575</td>
<td>1.0000</td>
</tr>
<tr>
<td>* T wave</td>
<td>0.9411 ± 0.0659</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

* The value of R wave and T wave before anesthesia were defined as 1 for baseline

The patients’ cardiac function indicators at pre-anesthesia and post-anesthesia are shown in Table 2. Although previous animal experiments and invasive and non-invasive clinical trails have shown that there was a very close relationship between the amplitude of the first heart sound (S1) and the cardiac contractility, the absolute value of S1 amplitude can not be used to evaluate cardiac contractility, as it is affected by some factors, such as the thickness of the chest wall and cardiac function level. Therefore, relative values are usually adopted. Here, we defined the status of pre-anesthesia as baseline, represented with 1. The values after anesthesia are relative ones which are the ratio of anesthesia data to primarily data of pre-anesthesia.

Table 2: Comparison of patients’ cardiac function indicators at pre-anesthesia and post-anesthesia

<table>
<thead>
<tr>
<th>Parameters</th>
<th>After Anesthesia</th>
<th>Before anesthesia*</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>0.9258 ± 0.3869</td>
<td>1.0000</td>
</tr>
<tr>
<td>S2</td>
<td>0.7491 ± 0.3805</td>
<td>1.0000</td>
</tr>
<tr>
<td>S1/S2</td>
<td>1.4670 ± 0.7717</td>
<td>1.0000</td>
</tr>
<tr>
<td>Systole duration</td>
<td>1.0292 ± 0.0608</td>
<td>1.0000</td>
</tr>
<tr>
<td>Diastole duration</td>
<td>1.2734 ± 0.2515</td>
<td>1.0000</td>
</tr>
<tr>
<td>D/S</td>
<td>1.2260 ± 0.2294</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

*The value of cardiac function indicators before anesthesia were defined as 1 for baseline

From Table 2, after anesthesia, the average S1 and S2 amplitude of 37 subjects fell to 0.9258±0.3869 and 0.7491±0.3805, respectively; CCCT (the increase of S1 with respect to S1 recorded at baseline) decreased 0.0742 averagely; however, S1/S2 increased to 1.4670±0.7717. Although systolic duration almost unchanged, the diastolic duration extended to 1.2734±0.2515, so that after anesthesia, D/S went up to 1.2260±0.2294.

4. Discussion

Mixed injected anesthesia of midazolam, skelaxin, fentanyl and propofol can restrain the circular system, inhibit cardiac muscle, and decrease peripheral vascular resistance obviously, especially midazolam and propofolo[13]. Peripheral vascular resistance mainly takes effect on diastole pressure, when it reduced, the pressure of diastole and systole would also reduce, especially pressure of diastole would reduce more obviously. Heart rate influence cardiac cycle directly, if it slowed down, the duration of diastole and systole would increase, and the pressure of diastole and systole would decrease indirectly, especially the pressure of diastole[14].

After the mixed injected anesthesia took effect, peripheral vascular resistance decreased greatly and heart rate slowed down in a certain extent, which both resulted in the falling of pressure of systole and diastole directly, especially diastole pressure. As a result, blood pressure decreased obviously after anesthesia as shown in Table 1.

Decreased diastole pressure made the driving pressure in closure of the aortic and pulmonary valves decrease, which was primary contributor to S2, ultimately induced the decrease in amplitude of S2. Similarly, decreased systole pressure made the driving pressure in the closure of the mitral and tricuspid valves decrease, which was major contributor to S1, finally induced the decrease in amplitude of S1 as shown in table 2.

From Table 2, it is clear that S2 decreased more obviously than S1 after anesthesia, thus the ratio of S1 amplitude and S2 amplitude rose. Therefore, S1/S2 can be used to reflect the dynamically changing relation between cardiac contractility and peripheral pressure during anesthesia.

Likely, the decrease in heart rate made diastole duration and systole duration lengthened, but diastole duration lengthened greater than systole duration, which makes D/S increased, so D/S can be used to evaluate the time of blood flowing to the heart per se.

5. Conclusion

Generally speaking, the decrease of heart rate, the rising of D/S and S1/S2, in a certain extent, are helpful for patients with healthy cardiac condition to get through anesthesia and operation. Whereas, some patients with heart diseases like brachycardiac and arrhythmia, and so on, the changes may be a burden to heart. It needs disposal carefully in clinic.

From above, the results of cardiac indicators by phonocardiogram are consisting with the relative principle of physiology and pharmacology. Our study demonstrated that phonocardiogram as a noninvasive, high benefit/cost ratio, objective, repeatable and portable method can be used for the monitoring and evaluation of cardiac function status during anesthesia and operations.

References

[1] P. B. Hansen, A. A. Luisada, and D. J. Miletich, “Phonocardiography as a monitor of cardiac performance during


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