A Transthoracic Impedance Measurement System
Applied To External Automatic Defibrillators
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Introduction
AED is a first aid device for electrical defibrillation at the scene of prehospital onset since the late 1980s[1], and the thoracic impedance measurement is an important function of AED. By the size of the thoracic impedance in 25 Ω ~ 200 Ω [2], there are many factors that can affect the thoracic impedance, including the type and area of the electrodes, electric electrodes contact conditions and so on[3]. Measuring transthoracic impedance allows AED to adjust the amount of defibrillation energy in real time based on the patient’s transthoracic impedance, and it can give early warning to dangerous conditions such as lead electrodes fall off, lead electrodes contact abnormal and so on. For bio-impedance data, a widely utilized equivalent circuit model is known as the Cole-impedance model and was introduced by Kenneth Cole in 1940[4]. Most of the solutions of AED transthoracic impedance measurement are voltage measurement after double electrodes current excitation based on the Cole-impedance model[5], which requires additional hardware circuits and algorithms, and it cannot reflect the change of transthoracic impedance between transthoracic impedance measurement and defibrillation. In order to detect transthoracic impedance without adding more hardware circuits and improve the instantaneous of transthoracic impedance detection, we proposed a new method of transthoracic impedance detection based on Ohm’s law, which combined the process of transthoracic impedance detection with the process of defibrillation. The measured results show that the accuracy of this method can meet the requirements of subsequent transthoracic impedance compensation function, and this method has certain reference significance for the development of AED impedance measurement technology.

Methods

A. High voltage detection circuit

Since the peak value of AED defibrillation current may reach more than 40A[6], the system selects the high voltage transformer to linearly convert the large current of defibrillation into a small voltage for data acquisition. As shown in figure 2, a compensating resistor of 50 Ω is set in the defibrillation circuit to limit the defibrillation current.

B. Defibrillation current detection circuit

Defibrillation current detection circuit is shown in figure 3, it detects the voltage across the energy storage capacitor. On the one hand, it feeds back to the charging circuit to ensure that the capacitor is charged to the preset voltage. On the other hand, the highest voltage value transformed by AD is recorded for the calculation of thoracic impedance. The principle of the high-voltage detection circuit is shown in figure 3.

C. AD acquisition and data processing

In the charging stage of the energy storage capacitor, two AD converters work at the same time to collect dual high voltage values. The AD circuit controls the error and helps the charging circuit charge the capacitor to a preset voltage value, and saves the peak voltage on the energy storage capacitor. When the AED stops charging, the analog-to-digital converter switches to the acquisition of the defibrillation current. When the defibrillation key, the defibrillation current detection circuit detects a very short current signal, and the ADC records the peak value and calculates the transthoracic impedance value, and this process lasts 100 microseconds.

Results and Discussion

The system was tested by simulating transthoracic impedance, Fluke Impulse 6000D defibrillator analyzer and Fluke Impulse 7000DP percutaneous pacemaker analyzer were used to simulate the rhythm of ventricular fibrillation and transthoracic impedance. After thoracic impedance preset 50Ω, 75 Ω, 100 Ω, 125 Ω, 150 Ω, 175Ω, 200 Ω, and capacitance voltage measurement is 1825 V, and the correction coefficient: K = 0.976, D = 1.294, measurement data are shown in table 1:

<table>
<thead>
<tr>
<th>Preset value of transthoracic impedance Ω</th>
<th>Vq(t)/V</th>
<th>Vout/2/V</th>
<th>Measured value of thoracic impedance Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1,825</td>
<td>0.92</td>
<td>49.2</td>
</tr>
<tr>
<td>75</td>
<td>1,825</td>
<td>0.71</td>
<td>78.5</td>
</tr>
<tr>
<td>100</td>
<td>1,824</td>
<td>0.59</td>
<td>104.6</td>
</tr>
<tr>
<td>125</td>
<td>1,825</td>
<td>0.51</td>
<td>128.9</td>
</tr>
<tr>
<td>150</td>
<td>1,825</td>
<td>0.45</td>
<td>152.8</td>
</tr>
<tr>
<td>175</td>
<td>1,825</td>
<td>0.4</td>
<td>178.1</td>
</tr>
<tr>
<td>200</td>
<td>1,825</td>
<td>0.36</td>
<td>203.5</td>
</tr>
</tbody>
</table>

The relative error %

Conclusion

This paper first describes the significance of impedance measurement in AED and proposes a simple transthoracic impedance measurement method that is attached to the defibrillation process. Then the principle and specific implementation of this method were described in detail. Through the thoracic impedance measurement verification, it is shown that this method can measure the transthoracic impedance, and the measurement accuracy meets the functional requirements of AED. The advantages of this measurement method are that it does not need to add additional hardware excitation or measurement circuit, nor does it cause unnecessary current excitation to patients, and it has better measurement timeliness. However, this method still has many shortcomings in the measurement of capacitive impedance and measurement accuracy of transthoracic impedance, and it is proposed to be improved in subsequent studies.

References