The Development of Measurement and Analysis System for Carotid Pulse

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***Abstract*—Cerebral vascular disease is one of the leading causes of death in the developed countries; therefore, early detection and prevention is very important. At present, carotid artery diagnosis is mainly by the supersonic wave or the invasion-like examination method. The purpose of this study is to design a non-invasive carotid pulse measurement system with lower cost, the convenience of carrying, the high degree of accuracy and the stability of carotid elasticity detection system. Using Augmentation Index (AIx) method to analyze the carotid and radial pulse. We verify the stable characteristics in the carotid measurement system. Besides, we find the high correlation (correlation coefficient = 0.9562, p<0.001) of AIx between carotid pulse and radial pulse. It implies that we can get the information of arterial elasticity from the easily measured radial pulse rather than carotid pulse, which is not convenient to be detected. Therefore, the result is useful for application in healthcare and telemedicine.**

***Keywords*- Carotid pulse; Augmentation Index**

1. INTRODUCTION

Over the past few decades, atherosclerotic and cerebrovascular disease mortality was very high, and cardiovascular disease is the most common diseases in modern society. Cerebrovascular disease is also known as stroke. Because about two-thirds of blood throughout the brain is supplied by carotid artery, the carotid pulse is an important signal to assess the cerebrovascular disease [1]. Atherosclerosis can cause low brain oxygen levels, which led to brain damage. Under most conditions, atherosclerosis is not so sudden, and on the contrary, it is the result of vascular aging [2]. Therefore, atherosclerosis most likely occurs in old age [3], [4], [5]. Thus, how to prevent stroke and atherosclerosis are significant issues.

The traditional methods include Doppler ultrasound, magnetic resonance angiography and vascular arteriography examination for atherosclerosis [6], [7]. Checking the atherosclerosis process takes considerable resource, costs, as well as check time. This research hopes to use pressure sensors to design an carotid pulse acquiring system for measuring the elasticity of blood vessels. Besides, we make a comparison between carotid pulse and radial pulse to verify their close correlations; thus, we can replace the carotid pulse with radial pulse to predict the atherosclerotic and cerebrovascular disease. So, measuring radial pulse provides a non-invasive, simple and convenient way to detect vessel elasticity for healthcare and telemedicine. It can reduce the consumption of resources and measurement time.

2. SYSTEM ARCHITECTURE

Carotid pulse can be captured using a pressure sensor. System architecture includes a high sensitivity pressure sensor for measuring carotid artery signal. The measured carotid artery signal is an analog signal, using an instrumentation amplifier to amplify 100 times of original signal; then, use a microcontroller to convert the analog signal into digital signal. Next, we transmitted the signal through the RS232 serial port to the computer side. Finally, we use LABVIEW to process and analyze signals, as shown in Fig 1.

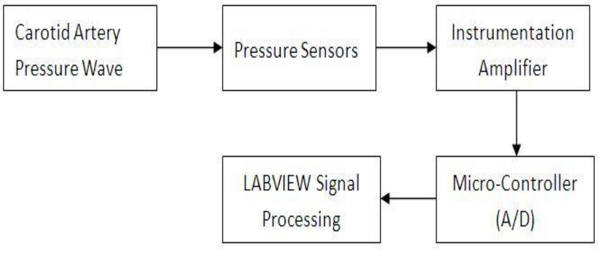

Fig. 1 System Architecture

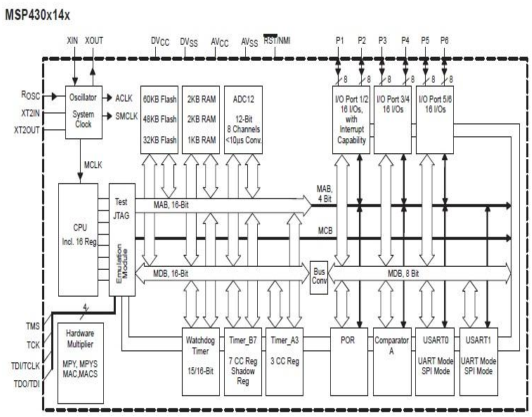

Fig. 2 Analog-to-Digit Converter

2.1. PRESSURE SENSOR

Pressure sensor is used to measure the pulse signal. Blood from the ventricle was squeezed out; it will cause expansion and contraction of blood vessels. Using this feature, the pressure sensor device placed above of the wrist will detect the radial pulse and pressure sensor over the neck artery can measure the carotid pulse. Finally, the measured pressure signal was transformed into electrical signal output, and the pressure pulse waveform can be obtained.

2.2. INSTRUMENTATION AMPLIFIER

This study uses Analog Devices AD621 instrumentation amplifier as a first stage amplifier. The AD621 is easy to use, low cost, low power, high accuracy instrumentation amplifier which is ideally suited for a wide range of applications. Operating voltage is about +2.3 V ~ +18 V. The amplification gain can be set to the gain of 10 times or 100 times. The gain resistors have been integrated inside the chip without using external resistors. The AD621 is preset to the gain of 10. A single external jumper (between pins 1 and 8) is necessary to select the gain of 100.

2.3. ANALOG-TO-DIGITAL CONVERTER

To transform the analog signal into digital pulse signal, this process requires the use of analog to digital converter (Analog-to-Digital Converter, ADC). In this study, we use the chip of MSP430F149f produced by Texas Instruments (Texas Instruments, TI) as shown in Fig.2. This chip are embedded within a 12-bit 8-channel digital to analog converter SAR, and its sampling rate can reach 200K Hz, enough to complete the sampling of pulse signal.

2.4. ANALYSIS INTERFACE OF PULSE WAVE

The analysis of signal is developed by LABVIEW software including acquiring digital signal, filtering, mathematical calculation, amplication, digital signal processing, etc. The measurement and analysis interface is shown in Fig.3 and Fig.4.

Fig.3 Measurement system

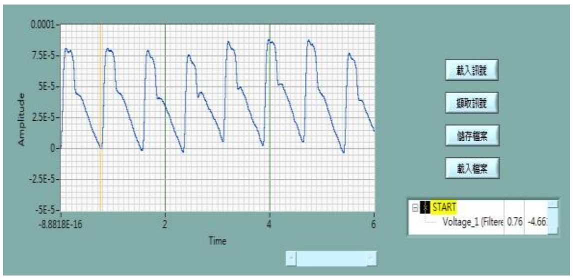

Fig.4 Analysis Interface

3. REPRODUCIBILITY OF SYSTEM

This section is to test the repeatability and stability of the system. Experimental steps are as follows: The operator test 20 subjects' carotid pulse with three times. The time interval is one hour. The peak value of carotid pulse is used as a parameter to test the repeatability. Then, the measured three peak value of each subject is plot in Fig.5. Using paired t-test, there is no significant difference ($p < 0.01$) between the measurements at the three times. Thus, the repeatability and stability of the system is reliable.

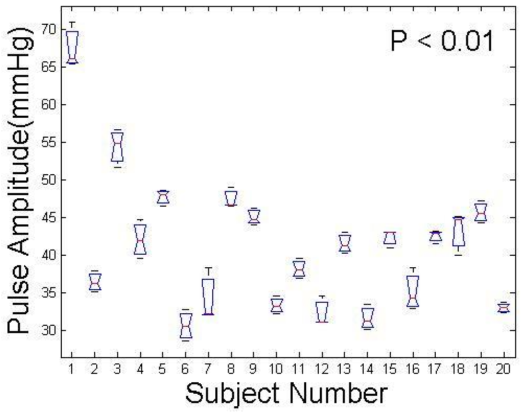

Fig. 5 Reproducibility of system

4. CAROTID PULSE ANALYSIS

In this section, we use a well-known method, Augmentation Index (AIx), to analyze the blood vessel elasticity. The augmentation index is defined in equation (1) and shown in Fig. 6.

$$AIx = \frac{P2}{SBP-DBP} \quad (1)$$

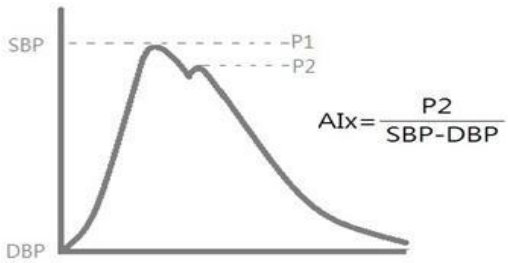

Fig. 6 Augmentation Index method

P1 corresponds to the pressure pulse waveform at peak systolic flow and is usually identified by the first shoulder of the pressure wave. P2 corresponds to the peak of the reflected wave and is usually identified by the peak of the pressure wave after the first shoulder. SBP is the systolic blood pressure, and DBP is the diastolic blood pressure. For example, the actual measured carotid pulse signal is demonstrated in Fig. 7 and Fig. 8. The first peak can be observed and the relative position of the second peak is away from the first peak, and much lower. This type of carotid pulse is usually of a healthy young people. In Fig. 9, the first peak is not obviously observed and the relative position of the second peak is higher than the first peak. We can thus know that the reflection wave is strong and the blood vessel is stiff. So, this type of carotid pulse is usually in middle and elder age.

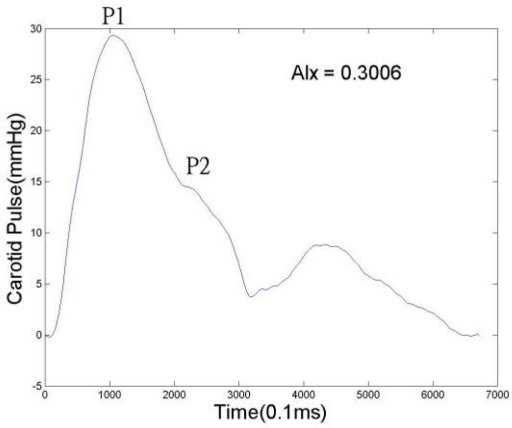

Fig. 7 A 21-year-old subject with AIx = 0.3006

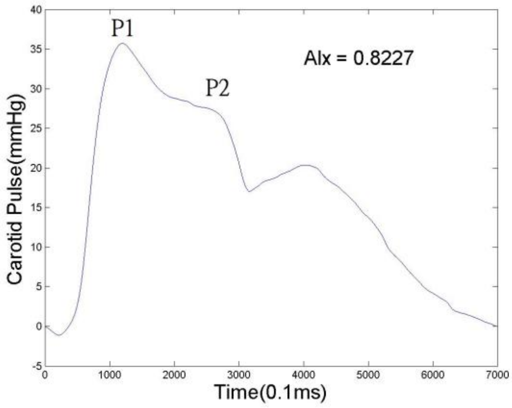

Fig. 8 A 35-year-old subject with AIx = 0.8227

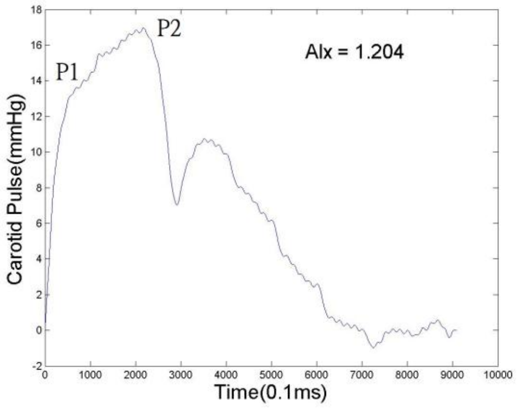

Fig. 9 A 50-year-old subject with AIx = 1.204

This study recruited approximately 20 people, aged about 20 to 76 years old. In the experiment, both the radial pulse and carotid pulse were measured. We used the augmentation method (AIx) to analyze the elasticity of carotid artery and radial artery under various ages. Experimental results of carotid pulse were shown in Fig. 10. The higher the age, AIx values will be larger on behalf of bad blood vessel elasticity [9], [10], [11]. Besides, the relationship of AIx between carotid pulse and radial pulse is shown in Fig. 11 [8], [12].

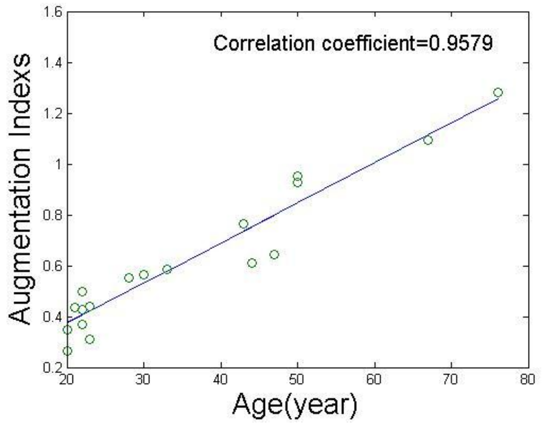

Fig.10 Relationship between age and Augmentation Index

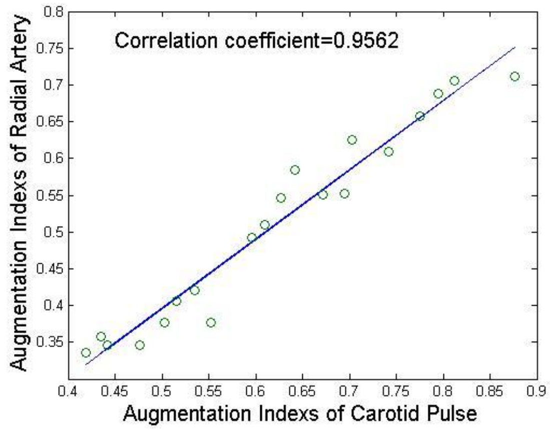

Fig. 11 Relationship of Augmentation Index between carotid pulse and radial pulse

5. CONCLUSION

To measure the carotid pulse to achieve the purpose of assessment of the degree of hardening of arteries, this study develops a carotid pulse measurement system. The system is designed by a low cost chip (MSP430F149f) and Labview software. Experimental results verify its stability and reproducibility. Next, we use the Augmentation Index (AIx) method to analyze the arterial elasticity of measured carotid pulse. Analysis results indicate that the hardening of arteries increases with age, and it accords with the well-known physiological knowledge. That further validates the system characteristics. We can thus use this system to detect the disease of carotid atherosclerosis. Besides, we find the high correlation of AIx between carotid pulse and radial pulse. It implies that we can get the information of arterial elasticity from the easily measured radial pulse rather than carotid pulse, which is hard and not convenient to be detected. Therefore, the result is useful for application in healthcare and telemedicine. In the future, we hope to conduct further analysis with more subjects to strengthen our inference.

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