A New Blood Pressure Measurement Using Dual-Cuffs

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Abstract

Most automatic sphygmomanometers use oscillometric method with a blood pressure cuff. Conventional oscillometric sphygmomanometer is simple to use and it needs no peripheral device. However, the method provides no guarantee of accuracy in all circumstance, because it is based on statistics. In this paper, we propose a new oscillometric method with two cuffs. A cuff is placed on upper arm as usual and another cuff is added on forearm. By adding one more blood pressure cuff, there are two different waveforms are shown and the different characteristics between both cuffs can be compared. The results of our experiments show that it is possible to measure blood pressure using dual-cuff oscillometric method.

1. Introduction

There are two major non-invasive methods, auscultatory and oscillometric method, used for measuring blood pressure. Despite the oscillometric method became popular, auscultatory method had been commonly used and is still considered as a gold standard because of its accuracy.

Auscultatory method is based on the auscultation of Korotkoff sound (K-sound) which is generated when blood passes through a narrow vessel [1]. The sound varies as the width of the blood vessel changes. There is no sound if an artery is occluded when an inflated cuff presses surrounding the arm and the sound appears suddenly when the artery is released while the cuff deflates air. In addition, during the cuff pressure drops, the K-sound disappears gradually. Thus, a systolic blood pressure (SBP) and diastolic blood pressure (DBP) can be decided when the K-sound appears and disappears [2].

In the case of conventional oscillometric method, the pulsation, ideally, observed from the cuff pressure starts at SBP and ends at DBP [3]. However, when cuff pressure is greater than systolic pressure, it is impossible to occlude the brachial artery completely and stop arterial pulsation of the cuff even if the central part of the cuff blocks the brachial artery. Since the lateral part of the cuff has lower pressure than the center and takes arterial pulsation, it is not easy to determine SBP point. When the cuff pressure is decreased below DBP, the interference of the arterial pulsation makes judgment of DBP hard. Figure 1 depicts the pulse waveform shown before and after SBP and DBP. On the other hand, sound wave appears after SBP and it disappears near DBP.

For these reason, the estimation method is used to get blood pressure. The estimation process starts with finding mean arterial pressure (MAP) point in which the highest pulse is shown. After taking linear regression analysis of the pulse heights from the mean pressure to higher and lower, it can be considered that the systolic pressure is the point where the pulse height is 40 per cent of the MAP pulse and diastolic pressure is the point where the pulse height is 60 per cent of it [4]. The percentages are derived from statistical studies and each manufacturer uses various values. Therefore, the conventional oscillometric method has inaccurate blood pressure [5].
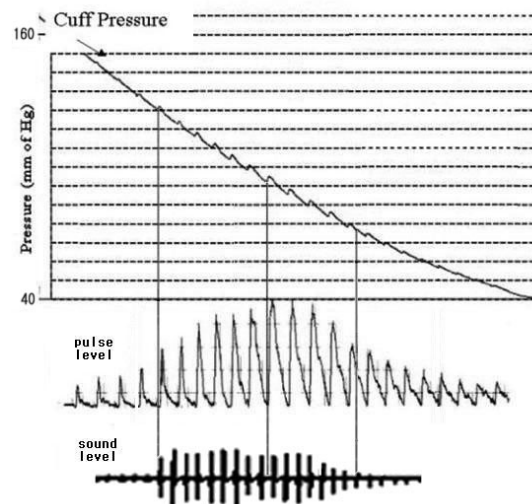

Figure 1. Comparison between auscultatory and oscillometric method.

The aim of this study is to propose a new method, dual-cuff sphygmomanometer using oscillometric method, and to solve the problems mentioned above with the new method.

2.   Methods

2.1.   Measurement concept

Each cuff has an independent pump, valve and pressure sensor so that they can be handled separately. A cuff is placed on the upper arm (proximal) and another cuff surrounds the forearm (distal) in order to occlude the region between the proximal and distal cuff (on the left side of Figure 2). Both cuffs are inflated above SBP to occlude the brachial artery and after that deflated them by 2~3 mmHg/second keeping the pressure of the proximal cuff higher than the distal. During deflation, there is no pulse if the cuff pressure is greater than SBP and the pulse appears when the cuff pressure falls as high as SBP. Similarly, if the cuff pressure is in between systolic and diastolic pressure, the pulse height measured on proximal is much higher than on distal. When the cuff pressure is decreased about DBP level, the pulse heights observed on both cuffs are almost same (illustrated in Figure 2 on the right side).
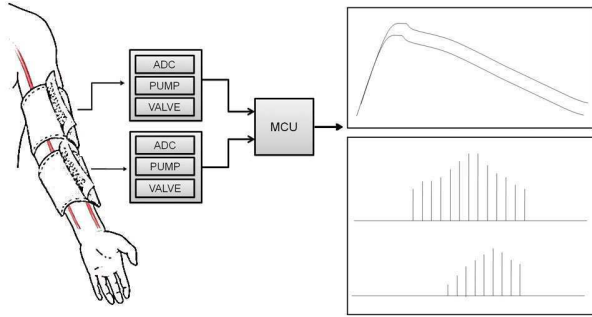

Figure 2. Measurement configuration.

2.2.   Implementation

The algorithm starts with finding beats. Figure 3 shows a whole flow of the proposed algorithm. First, the critical points of each beat have to be found in that the processes are based on the peak shape (height and waveform) analysis. The cuff pressure signal, however, has slope and it makes extracting the beats difficult. Because of that, a high pass filter (2nd order Butterworth filter, the cutoff frequency 0.7 Hz) is applied to flatten the slope. Then it is easy to find the beats of the proximal cuff. After that, the peaks are extracted from the beats by using zero crossing point. Between two zero crossing points, there must be a maximum or a minimum point and the point is detected as either a positive or a negative peak point. These peak points are used in recognizing the peaks of distal cuff.
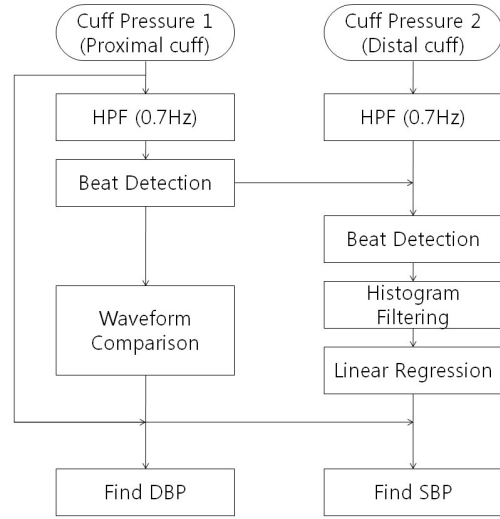

Figure 3. Flowchart of the proposed method

The peaks of each cuff are used in different ways. First, SBP point is detected by analysing the peaks of distal cuff. Now, the peaks have to be sorted whether it is useful or not for finding SBP point. In order to pick out the useful peak points, histogram is implemented. Note that there are many peak points with circle have similar height in the early period in Figure 4. Those points have high density in the histogram graph and are removed from the set which is used in linear regression analysis.

In the case that the set of points fits to a straight line, y = a + bx, the equations

$$na + b\sum x_i = \sum y_i$$
$$a\sum x_i + b\sum x_i^2 = \sum x_i y_i$$
$$\hat{b} = \frac{n\sum x_i y_i - \sum x_i \sum x_i y_i}{n\sum x_i^2 - \left(\sum x_i\right)^2} \qquad (1)$$
$$\hat{a} = \bar{y} - b\bar{x}$$

where all summations are from i=1 to n, and where $\bar{x}$ and $\bar{y}$ are the means of x and y, can be used to get the line [6].

Next, DBP point can be found from the proximal peaks. Although two cuffs are applied to get different features, signals observed from both cuffs are very similar. Nevertheless, there are a few differences between both cuffs. Near DBP point, the waveform of the proximal cuff pressure is distorted by pulsation reflecting from the distal cuff. By comparing waveform of serial peaks, the DBP point can be detected.

3. Results

Peak height plot of both cuffs is indicated in Figure 4. The dots are measured from proximal cuff and the circles are from distal cuff. Note that a distinct difference between the dots and the circles in the beginning. When the histogram is applied from the first point to the MAP point, it removes the points at first part from the data set and five points from the positive peak and seven points from the negative peak are selected. After taking linear regression analysis with those points, the SBP point is found.
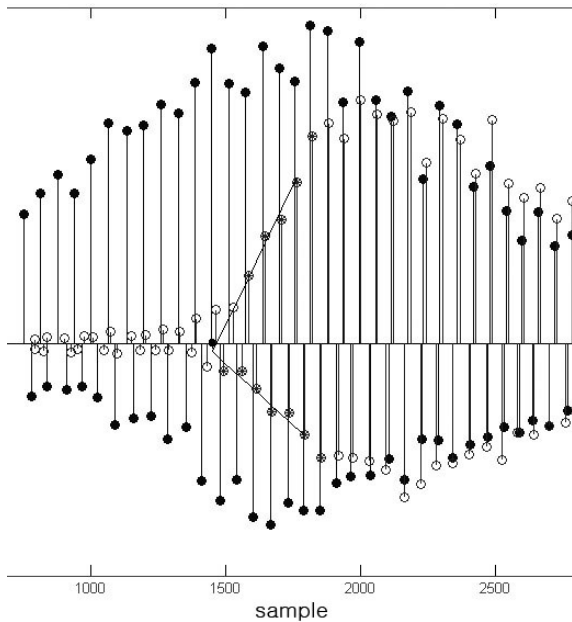
Figure 4. Pulse heights are measured from both proximal and distal cuff. The circles with star mark inside are used for calculating linear regression and the dot on the base line is the point where the positive and negative linear regression lines are crossing.

From the lower in Figure 5, variation of the peak shape can be noticed. From SBP point to near DBP point through MAP point, the peak shapes are sharp. However, as it passes DBP point the sharpness is decreasing. There are three asterisked peaks in Figure 5. Among those points, the sharpness of the peak changes obviously and the DBP point may places there.

When the SBP point and the DBP point are found, these can be used to get SBP and DBP as shown in Figure 6. Actual blood pressure is taken out by checking blood pressure at the point corresponding to the SBP and the DBP point. In this case, the SBP and DBP of a subject were known as 112 and 72 by the auscultatory method. Using the proposed method, SBP and DBP are identified as 110 and 76.
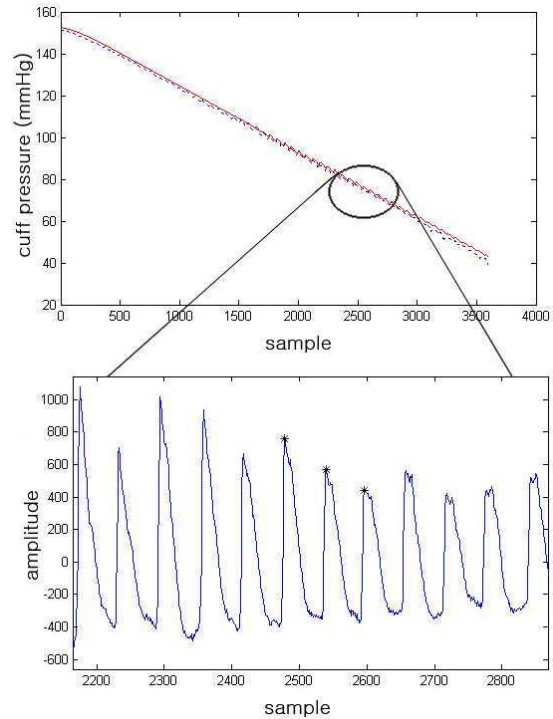
Figure 5. Distortion of peak waveform near DBP point observed from the proximal cuff. The shape of peak is becoming blunt.
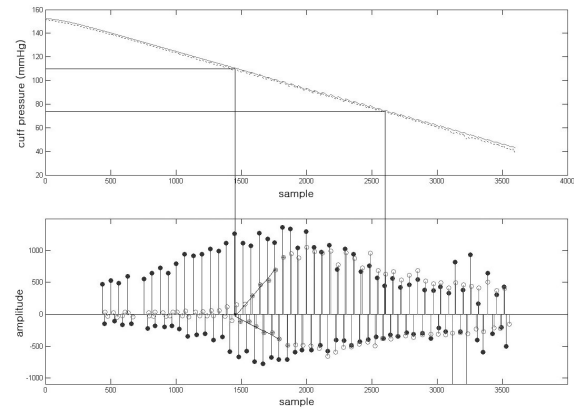
Figure 6. SBP and DBP identification on the original cuff pressure graph using SBP point and DBP point.

4. Discussion and conclusions

A purpose of this study is to investigate a possibility of measuring blood pressure using dual cuffs. As we thought before the experiment has done, there was some noticeable difference between using one cuff and two cuffs. Moreover, because of that difference, we were able to get the SBP and DBP not from the statistics but the

actual data.

In the further study, the SBP and DBP detecting algorithm can be improved. In this study, the method that finds DBP was unclear and was done by hand and it needs to be changed. Also, there is a thing has to be done when a measuring device will be developed. Since carrying, keeping and using two cuffs at one time maybe troublesome, the cuff should be changed into handy form like two tubes in a cuff.

In conclusion, the presented method of measuring blood pressure using oscillometric method with dual cuffs shows a possibility to check a proper blood pressure even though it includes a little room for improvement.

References

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