THE EFFECT OF THE VENOUS PRESSURE TO THE BLOOD PRESSURE SIGNALS MEASURED BY THE ELECTRONIC PALPATION METHOD

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Abstract-**This paper describes the venous pressure effect to blood pressure signals measured by the electronic palpation method. It was shown, that in 52 percent of blood pressure measurements made with inflating cuff the linear increase in venous blood pressure was also increasing palpated signal's amplitude linearly. It was found, that the strong increase in venous pressure was not the reason for increased blood pressure amplitudes. The method for determining venous pressure by the electronic method was considered. The electronic palpation method can be used for venous pressure measurement if it is made with inflating cuff and secondly with deflating cuff. In the beginning of the measurements blood pressure should be monitored in the absence of cuff pressure for determining the venous pressure at rest.**
***Keywords*- Electronic palpation, venous pressure, blood pressure monitoring**

I. INTRODUCTION

Nowadays, the most of the blood pressure (BP) devices are using deflating cuff to close the brachial artery. In earlier report was shown that the measured pressure signal is more stable during the inflation of the cuff, and it behaves more linearly with respect to cuff pressure during inflation than during deflation [1]. Also our experiences has indicate, that tonus of veins is increasing the pulses amplitudes of electronic palpation (EP) method in measurements made by inflating cuff, but anyway the EP signal is more stable. These two phenomenon could be used for determining the venous pressure non-invasively. The venous pressure is measured in clinical use invasively which makes the measurement quite risky. There is the need for non-invasive venous pressure measurement.

The EP method is based on palpation of the radial artery pulse by electronic sensor. This method has been presented in an earlier report, and it offers a clear improvement in accuracy compared to the widely used auscultation and oscillometric methods. In addition, it has a good correlation coefficient with respect to the intra-arterial blood pressure measurement [1]. The actual BP measurement in the palpation method is based on using an arm cuff to occlude the brachial artery and then detecting the pulsation of the radial artery on the wrist. The measurement can be made either during the deflation or the inflation of cuff pressure. Blood pressure variation can be monitored in the absense of cuff pressure.

II. METHODOLOGY

The blood pressure measurements were made in a medical ward at the Oulu University Hospital during spring 1997 with a group of 26 volunteers [2]. BP was measured non-invasively on the radial artery in one wrist by means of the electronic palpation (EP) method and in the radial artery of the other arm by the intra-arterial (IA) method [1]. The use of intra-arterial measurement made the thus gathered blood pressure data quite extensive and conclusive. In addition, venous pressure was measured invasively in the back of the same hand that was used in the EP method. The same measurement procedure with the EP method was repeated for every test person while they were in a sitting or lying position. All the measurements were made while the testees were resting and the environment was generally peaceful. The procedure included three different kinds of measurements with different cuff pressure profiles. During the first measurement, BP was monitored with no cuff pressure for about 1 minute. After a short break of about 1-2 minutes, the BP measurement was carried out with inflated cuff pressure. Finally, after another short break, the BP measurement was repeated, but this time with deflated cuff pressure. Before the measurement started the blood pressure sensor was positioned as accurate as possible on the heart level. The positioning error and pressure difference needed to consider in further analysis. The measurement with deflating cuff, shown in Fig. 1, is started by increasing the cuff pressure over assumed systolic pressure. A brachial artery is getting closed and no more blood is flowing into the ulnar- and radial arteries. After the cuff pressure exceeds the venous

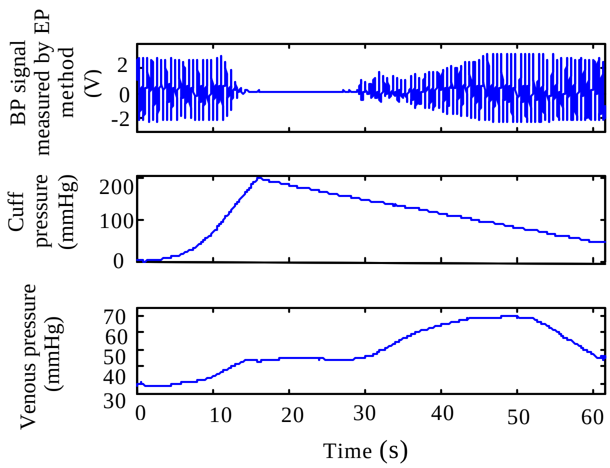

Fig. 1. Pressure signals in measurement with decreasing cuff pressure.

pressure at rest, the venous pressure is starting to increase slowly. The venous pressure is staying almost constant when the blood has flowed from ulnar- and radial arteries

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trough capillaries to the veins. When the cuff pressure starts to deflate under systolic blood pressure, the brachial artery gets open and the blood volume is increasing in the veins. Then the venous pressure achievies it's maximum value. When the cuff pressure continues descending the venous pressure decreases. Also the venous pressure decreases because it can't be higher than cuff pressure.

The venous pressure doesn't act linearly when the decreasing cuff is used as shown in Fig. 1. Especially, it's making difficult to determinate systolic and diastolic EP values because the EP signal's amplitude doesn't act linearly between these two points. The main reason for this non-linearity in blood pressure pulses is a changing contact between skin and sensor. The swelling of the arm is effecting to the tightness of the wrist wrap, which is changing the skin-sensor contact.

Firstly in this research, it was aim to investigate how much the venous pressure was increasing in measurements made by increasing cuff. The measurements were made to 26 test persons two times when the test person was in sitting and in lying position. The pressure difference, mentioned before, was determined from the measurements made with deflating cuff, Fig. 2, which were made two minutes after measurements with inflated cuff.

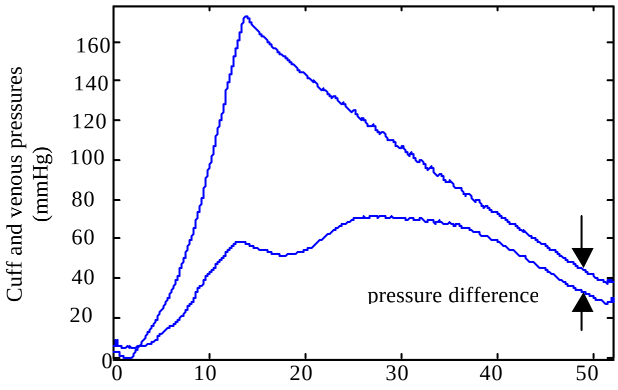

Fig. 2. Cuff and venous pressures in measurement made with decreasing cuff pressure.

As shown in Fig. 2, the venous pressure starts to increase after the cuff pressure exceeds the venous pressure at rest. In the end of the measurement both pressure curves are descending linearly. From this difference the pressure difference was determined. Next, the venous pressure at rest and maximum value was obtained from measurements made by increasing cuff pressure, Fig 3. The venous pressure at rest was determined in the beginning of the curve. As can be seen in Fig. 3, the venous pressure is constant in the beginning until the cuff pressure exceeds the venous pressure at rest. After the cuff pressure exceeds the systolic pressure and the brachial artery is closed, venous pressure achieves it's maximum value. After that it stars to decrease, because the blood volume in vein doesn't increase. The maximum point in the venous pressure curve was representing the maximum value in venous pressure.

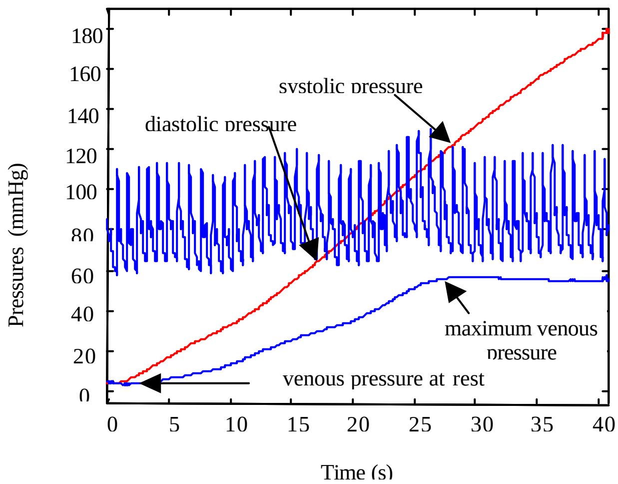

Fig. 3. Cuff , intra-arterial and venous pressures in measurement with increasing cuff pressure.

III. Results

The venous pressures at rest, analyzed from the measurements made with inflating cuff while test person was lying are compared in the Fig. 4. It can be seen on the that test persons' number 9, 11 and 26 rest pressures differs a lot within two measurements. One reason maybe increased peripherial resistance caused by pain or stress. The increasing of peripherial resistance affects to tonus of veins, which is increasing venous pressure at rest.

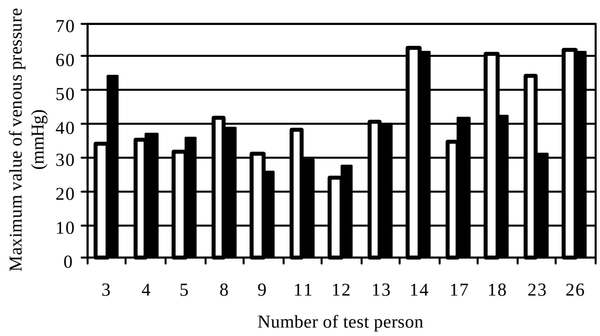

Fig. 4. Comparison of the venous pressures at rest within two different measurements made by EP method with increasing cuff pressure.

In Fig. 5 are compared the maximum venous pressures, which were analyzed from the same measurements mentioned before. It can seen on the Fig. 5 that test persons' number 3, 9, 11, 17, 18 and 23 maximum pressures differs a lot within two measurements. This can be explained same way as in case of rest pressures. Also we can notice, that the test person's number one maximum pressures within two measurement were about same, but the rest pressures were differing. This could be explained by noticing that every blood pressure pulse is increasing the blood volume in veins. So the amount of pulses is directly proportional to the increase of the venous pressure before the brachial artery is getting closed. The stress is increasing the heartbeat, so the pulse rate can be different within two measurements which have last same time. For example, in the measurements made for test person number 3, the pulse rate in first measurement was 55 and in next measurement 66 beats per minute. That can explain the about 20 mmHg difference in maximum pressures.

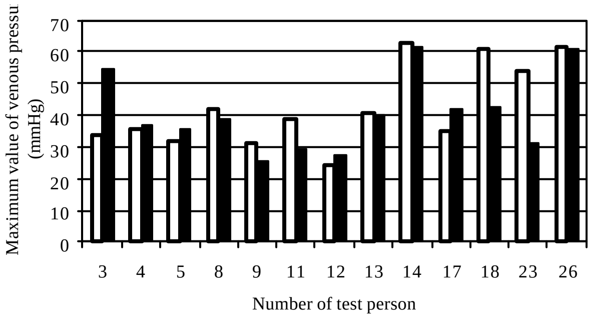

Fig. 5. Comparison of the maximum venous pressures within two different measurements made by EP method with increasing cuff pressure.

In addition, the effect of venous pressure increase to EP pulse amplitudes were investigated. The pulse amplitudes can increase linearly before the cuff pressure exceeds the diastolic pressure, because the skin-sensor contact is getting better. After the cuff pressure exceeds the diastolic pressure the pulse amplitudes are attenuating until systolic pressure, Fig. 6.

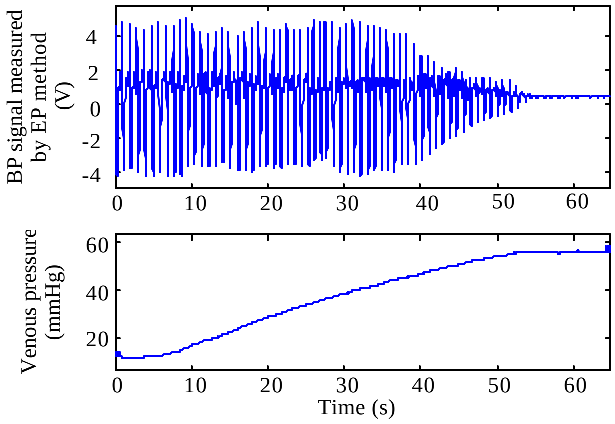

Fig. 6. Pressure signals measured with increasing cuff pressure.

The increase of EP amplitudes were analyzed by checking every measurements EP signals, and it was observed, that amplitude was decreasing in 52 % of measurements made with inflating cuff. It was shown that the large increase in venous pressure during measurement did not cause the changes in pulse amplitudes, as seen in Fig. 6. The venous pressure in Fig. 6 is increasing about 40 mmHg, but the EP signal have only normal amplitude variation. In Fig. 7 it is shown the EP signal of the measurement where the amplitude changes can be clearly seen between 15-20 seconds. In this measurement, the venous pressure was increasing about 10 mmHg.

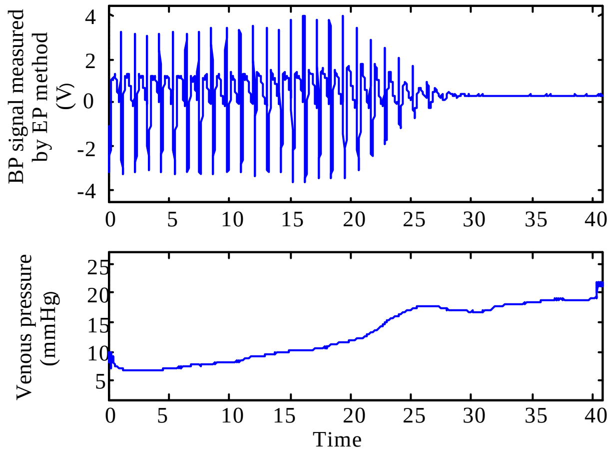

Fig. 7. Blood pressure signals measured with increasing cuff pressure.

VI. Conclusion

The venous pressure effect to blood pressure signals should be consired when the blood pressure variation is monitored by the EP method. The linear increase in EP signal amplitudes should be determined and to eliminate from blood pressure amplitudes before the normal BP variation is determined.

The electronic palpation method could be used for venous pressure measurements. The wrist wrap should be tight but enough flexible, that the skin-sensor contact is good. Then the increase in venous pressure can be seen in EP signals amplitudes. The venous pressure at rest could be then analyzed from EP signal. Then in the beginning of measurements should be the longer period in absence of cuff pressure that the EP signals amplitude can be seen stable. The point in cuff pressure when EP pulses amplitudes starts to increase would represent the venous pressure at rest.

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