Occlusive Multichannel Electrical impedance System Of Peripheral Vein Detection

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Introduction

The peripheral veins of the forearm are widely used for medical conditions such as requiring blood draw, drug and fluid administration. However, to gain intravenous access a clearly visible and palpable vein is used. Venous occlusion is traditionally used to enhance the venous vessels visualization due to interruption of blood outflow which makes the veins more contiguous on the skin surface. As a reason of many cases such as: the patient's obesity, decreased venous tone, small diameter of veins, poorly contoured or moving vein, abnormal location of the vein and the nursing staff skill - there is a possibility of unsuccessful punctures and injury. Development of vein visualization technology is particularly useful in such cases. The electrical impedance method of peripheral vein detection is a novel approach, which offers the advantages of being not expensive and capability of minimizing and reducing the difficulty of achieving intravenous access in many patients, especially pediatric and obese patients. The method can identify vein projection on skin surface using multichannel electrode system. The method of peripheral vein detection is based on regional monitoring the location of vein in each channel of the electrode system after applying venous occlusion to 60 mm Hg for 30 sec [1-3]. This paper presents the features of occlusive multichannel electrical impedance system of peripheral vein detection.

Materials and Methods

The experimental studies have been conducted for 11 volunteers. The depth of the studied veins varied from 1.8 mm to 6.4 mm, and the diameters from 2.2 mm to 3.5 mm. These measurements were carried out in the medical and technological center of Bauman Moscow state technical university with the observance of the asepsis rules. The vein projection on skin surface has been controlled visually and with the help of ultrasound system.

The simplified block diagram of the biotechnical system of peripheral vein detection is presented in figure 1. The device allows simultaneous measurement of electrical impedance for the required 4 channels. The frequency of the injecting current is 100 kHz and the amplitude 3 mA. The electrode system is an array of surface electrodes, has four channels of tetra-polar electrode configurations. The distance between current electrodes is 21 mm and 7 mm between potential electrodes. The A & D UA-668 tonometer has been used to achieve the venous occlusion.

The skin as well as the electrodes is pretreated with alcohol to remove stratum corneum and increase conductivity. Thus the measuring requirement can be achieved without breaking the rules of asepsis.

The system was attached without strong pressing to eliminate the possibility of blood vessel compression, electrical impedance signal was recording and simultaneously an inflation pressure of around 60-70 mm Hg is used then the cuff are deflated[4].

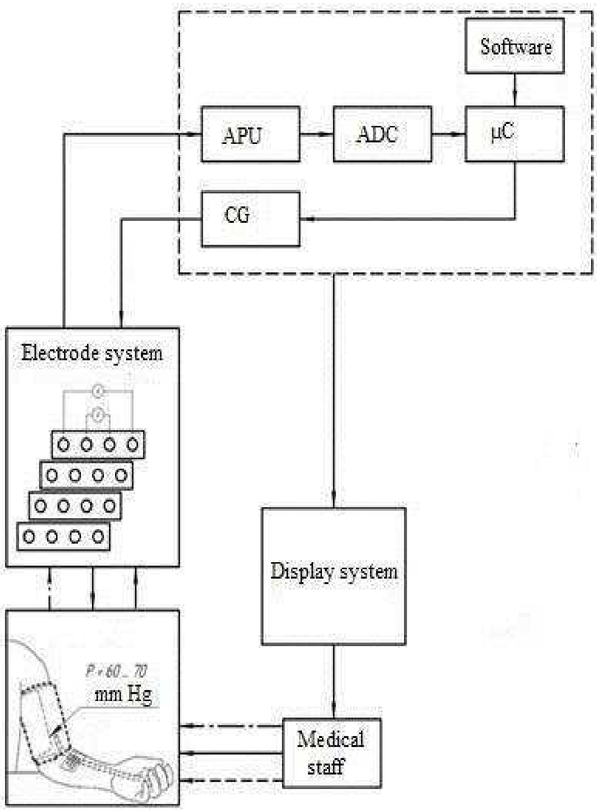

Figure 1: The simplified block diagram of the biotechnical system of peripheral vein detection; APU- analog processing unit; ADC- analog digital converter; CG- current generator; μC- microcontroller

Figure 2 shows the algorithm of peripheral vein detection using the biotechnical system. The proposed algorithm can identify vein projection on skin surface based on the analysis of amplitude-time parameters of impedance changes due to the location of vein regarding to each measuring channel. The electrical impedance values measured across all channels should strive for maximum similarity to make sure of good electrode skin contact.

The patient should be asked not to move in order to stabilize the impedance values and reduce the artifact associated with patient movement. The effective measuring range determination can be achieved by the apparent resistivity of forearm soft tissues calculation. In previous paper [5] It was estimated that apparent resistivity for the used electrode system can be varied between 3, 0-5, 5 Ohm.m. The result has shown that the visualization depth, for patients with soft tissues electrical resistivity of 3,0 Ohm.m and vein diameter of 2 mm is 6 mm . The increasing of vein diameter to 5 mm, or electrical resistivity of soft tissues to 5 Ohm.m leads to visualization depth of 9 mm. Preliminary knowledge of the apparent resistivity for every patient can set the depth and size limits of visualization using the designed biotechnical system. For a more detailed analysis of electrical impedance changes during venous occlusion, the first derivative of the signal is calculated. Thus, each signal can be characterized by the following parameters: ΔZ-The phase associated with the event of rapid vein filling, Δt- the duration of the rapid vein filling.

The monitoring of electrical impedance values of the electrode system channels is conducted with simultaneous venous occlusion at cuff pressure levels of 60-70. The maximum increase in cross sectional area as well as the maximum value of ΔZ_{max} can be determined within 20-30 sec of venous occlusion.

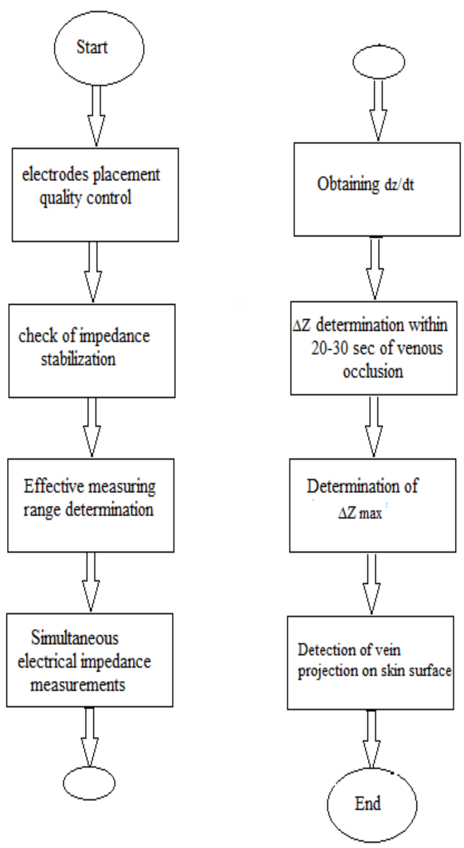

Figure 2: The algorithm of peripheral vein localization

Results

Figure.1 shows the electrical impedance change during the procedure of peripheral vein localization, the presented signals correspond to: 1- the location of 2 veins among the corresponding measuring channel; 2,3- vein location between the adjacent current and potential electrodes of the corresponding measuring channels ;4- vein location between the measuring electrodes of the corresponding measuring channel.

The first derivative shows the rate of impedance change, which reflects the rate of blood filling. The first derivative of electrical impedance signal in the localization of peripheral vein is a negative tooth that forms during venous occlusion. The prong consists of a descending part, a vertex, and an ascending part. The negative prong turns into a horizontal line.

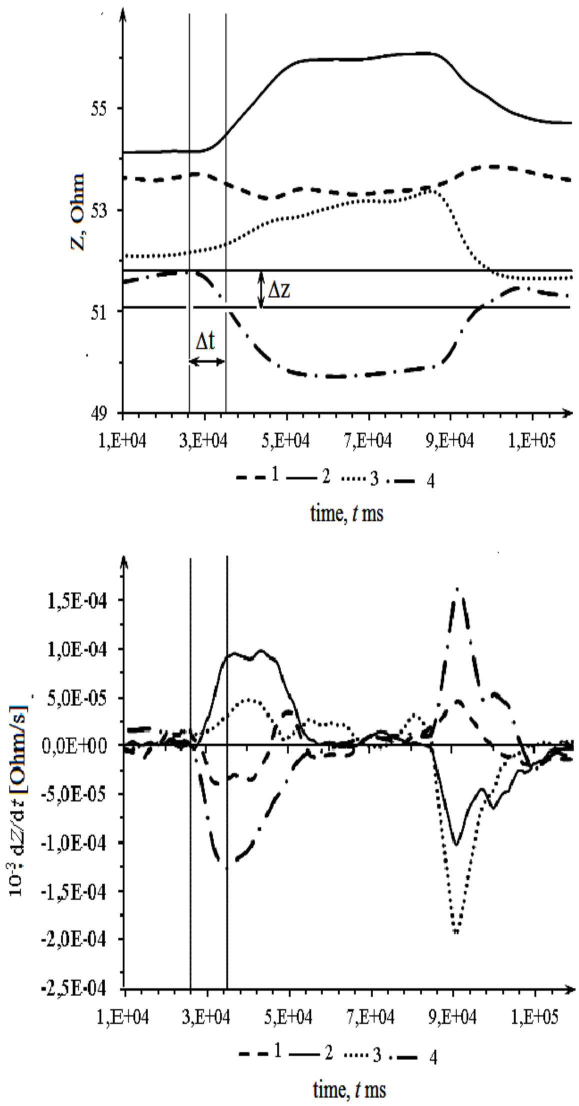

Figure 1: The electrical impedance change during the procedure of peripheral vein localization

The negative tooth of the first derivative shows a decrease in resistance during the blood vessel filling. The projection of the negative tooth vertex of the first derivative on the corresponding part of the electrical impedance signal is the point at which the blood filling rate of the vessel reaches a maximum. The ascending part of the negative tooth of the first derivative reflects the process in which the filling of the vessel continues, but at a slower rate. The table 1 shows the results of experimental studies for 11 volunteers. The analysis of the obtained results showed the effectiveness of the electrical impedance method of peripheral vein localization for obese patients, it was noted that such patents are characterized by a higher value of the base impedance and a high value ΔZ.

Table 1: Result of Experimental Studies

Volunteers	ΔZ, Ohm	Δt,sec	h, mm	d,mm	Zbase, Ohm
1	1,36	28,8	1,8-2	2,5-2,8	44
2	0,74	29,3	1,8-2	2,3-2,5	59
3	1,72	24,5	4,9-5,2	2,8-3	132
4	0,68	28,6	2-2,3	2,2-2,5	46
5	1,36	17,6	3,2-3,5	2,8-3	88,9
6	0,94	13,5	5,5-6,2	2,9-3,1	129
7	5,52	16,2	5,2-6,4	3,2-3,5	105
8	7,8	20,4	5,2-6,4	3,5-3,8	141
9	2,72	11,2	5,2-5,9	2,8-3,2	128
10	3,2	18,2	5,2-5,9	2,8-3,2	122
11	1,4	9,2	1,2-2,1	2,6-2,8	81

Conclusions

The occlusive multichannel electrical impedance system of peripheral vein detection has been proposed. The system is based on regional monitoring the location of vein in each channel of the electrode system after applying venous occlusion to 60 mm Hg for 30 sec. The system can determine the vessel location using the satic approach, thus the peripheral vein projection is marked on the skin surface then the procedure is performed without real-time measuring. The system also is a prerequisite for future developing of robot-assisted venipuncture system. Thus, the coordinates of the venous vessel projection on skin surface will be transmitted by the software in order to perform the puncture automatically. Due to the distance shift between measuring channel which is 3,5 mm the system can provide the projection of vein center on skin surface with accuracy 1,75. As the venous occlusion enlarges the vein diameter not less than one and a half [5], the obtained accuracy is acceptable for peripheral vein detection as the system can detect veins with minimum diameter 2 mm before occlusion.

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