A study of pressure-volume characteristics of the cuff for hemodymamic parameters measurement

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Abstract— **This contribution deals with the pressure-volume characteristics of the cuffs used for blood pressure measurement. The linearity of characteristics is a very important factor for the accurate conversion from volume change to pressure change. Several cuffs were tested during the study, including new cuffs, old cuffs, cuffs with different sizes, volumes and clamping systems. Results of the measurement in the range between minimal diastolic to maximal systolic pressure have been statistically evaluated.**

Keywords— **Blood pressure measurement, cuff parameters, p-V characteristic.**

I. Introduction

Very important part of measurement system is the cuff used typically for oscillometry measurement. The cuff is important for transferring the blood pulsations from the artery to pressure sensor. During the measurement of hemodynamic parameters, not only amplitude is important, but also the shape of the pulse. The prerequisite for a meaningful measurement is linear transfer characteristics of the cuff – the change of air volume in the cuff must linearly corresponds to the pressure change on the sensor. This linearity must be kept on the range between the pressure below minimal contemplated diastolic pressure to the pressure higher than maximal systolic. It ensures that the envelope of oscillations during blood pressure measurement is not distorted by cuff non-linearity.

II. Measurement System

A commercially available industrial components ensuring accurate and reproducible measurement were used. The system is schematically described on the Figure 1.

In the beginning, the cuff is fastened around the arm phantom and the residual air is vacuumed. The initial considered volume in the cuff is zero. The reservoir with very precisely defined volume is inflated by air pump and then the needle valve is slowly released. During inflating the cuff, the pressure in reservoir and the pressure in the cuff are synchronously measured by accurate data acquisition card. Due to the exact volume knowledge and the neglecting temperature change (inaccuracy caused by temperature changes is under resolution of the data acquisition card), we can calculate the change of volume. In this calculation has to be also considered volume of the air tubes and the components. The calculated volume is recorded together with pressure in the cuff.

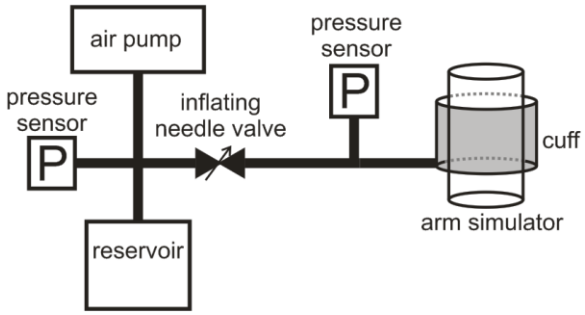

Fig. 1 Measurement system

A photo of the real measurement system is on the Fig. 2.

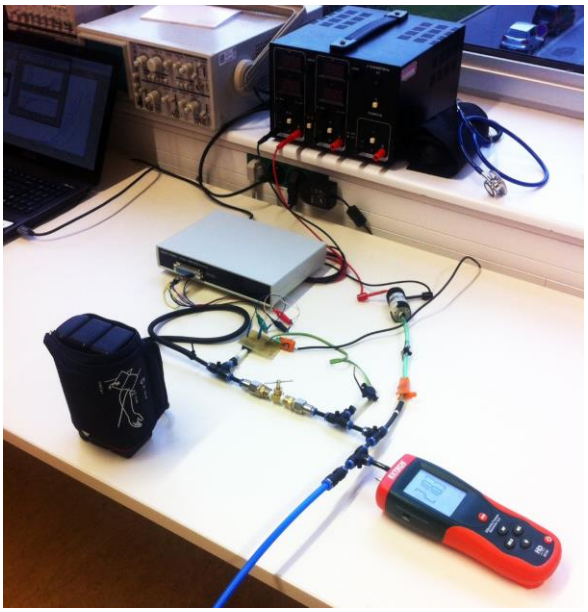

Fig. 2 Photo of the real measurement system

For the elimination of Venturi effect arising from Bernoulli equation, very short traces to sensors, rigid tubes and small speed of inflating should be used.

III. CUFF PARAMETERS

The basic cuff parameter is the size. It is also derived typical volume from the size, the length and width. For our measurement we used a total of 13 cuffs with the standard adult size and the typical total volume about 0.5 liters. Description of the measured cuffs is in Table 1.

IV. RESULTS

Although each cuff was tightened identically around a rigid arm phantom, the final volume of each cuff was not the same. The resulting volume of the cuff may depend on the width and length of the rubber part, which is stretched throughout the textile coating. It also depends on the material and cuff compliance.

The characteristics of the cuffs are in the figure 3. In the range from 50 mmHg to maximum tested pressure (around 200 mmHg), the nonlinearity is not worse than ±2.9 %. The pressure change during oscillations, where we acquire the shape of the pulse is not more than 10 mmHg. In this range, the worst non-linearity is less than 1 %. The results show that the linearity of the cuff in the range interesting for oscillometry pulsations does not cause any problems with distortion of the signal shape.

The measurements also show that old cuffs (mechanically undamaged) have similar linearity as the new cuffs. It means that the age of the cuff is not very relevant factor for evaluation of measurement accuracy.

V. CONCLUSION

The volume-pressure curves that we measured with our measuring system did not demonstrate a big difference

Table 1 Measured cuffs

ID	Cuff manufacturer	Marking	Description	Age and usage
1	Omron	HEM-CR24	Extent 22-32 cm, unformed, rigid packaging made of synthetic fabrics, high quality Velcro fastener	2 years, less than 50 uses
2	Omron	HEM-CR24	Extent 22-32 cm, unformed, rigid packaging made of synthetic fabrics, high quality Velcro fastener	4 years, less than 50 uses
3	Omron	-	Extent 22-32 cm, unformed, inflexible, bulky packaging made of synthetic fabrics, quite worn Velcro fastener	7 years in ICU, everyday use
4	Omron	M CR17	Extent 22-32 cm, unformed, inflexible, bulky packaging made of synthetic fabrics, high quality Velcro fastener	8 years, less than 200 uses
5	Omron	ComFit Cuff H-CL22	Extent 22-42 cm, formed, inflexible, reinforced casing made of synthetic fabrics, high quality Velcro fastener	New, unused
6	Advisor	Adult 11	Extent 22-32 cm, unformed, formless, nylon casing rigidly connected to the cuff, low quality Velcro fastener	2 years, less than 150 uses
7	Hartmann	Type M-1	Extent 22-32 cm, unformed, quality cuff in inelastic soft case, high quality Velcro fastener	2 years, less than 150 uses
8	Henry Schein	-	Extent 22-32 cm, unformed, high-quality cuff in inelastic soft case, high quality Velcro fastener	New, unused
9	No-name	-	Extent 22-32 cm, unformed, soft and slightly springy case, high quality Velcro fastener	2 years, less than 150 uses
10	Fukuda Denshi	CUF-129MR	Extent 22-30 cm, unformed, strongly reinforced, high-quality processing, nonelastic, high quality Velcro fastener	1 years, less than 150 uses
11	Fukuda Denshi	CUF-129ML	Extent 22-30 cm, unformed, strongly reinforced, high-quality processing, nonelastic, high quality Velcro fastener	1 years, less than 150 uses
12	Fukuda Denshi	CUF-138MR	Extent 22-30 cm, formed on a right leg above the ankle, strongly reinforced, high-quality processing, nonelastic, high quality Velcro fastener	1 years, less than 150 uses
13	Fukuda Denshi	CUF-138ML	Extent 22-30 cm, formed on a left leg above the ankle, strongly reinforced, high-quality processing, nonelastic, high quality Velcro fastener	1 years, less than 150 uses

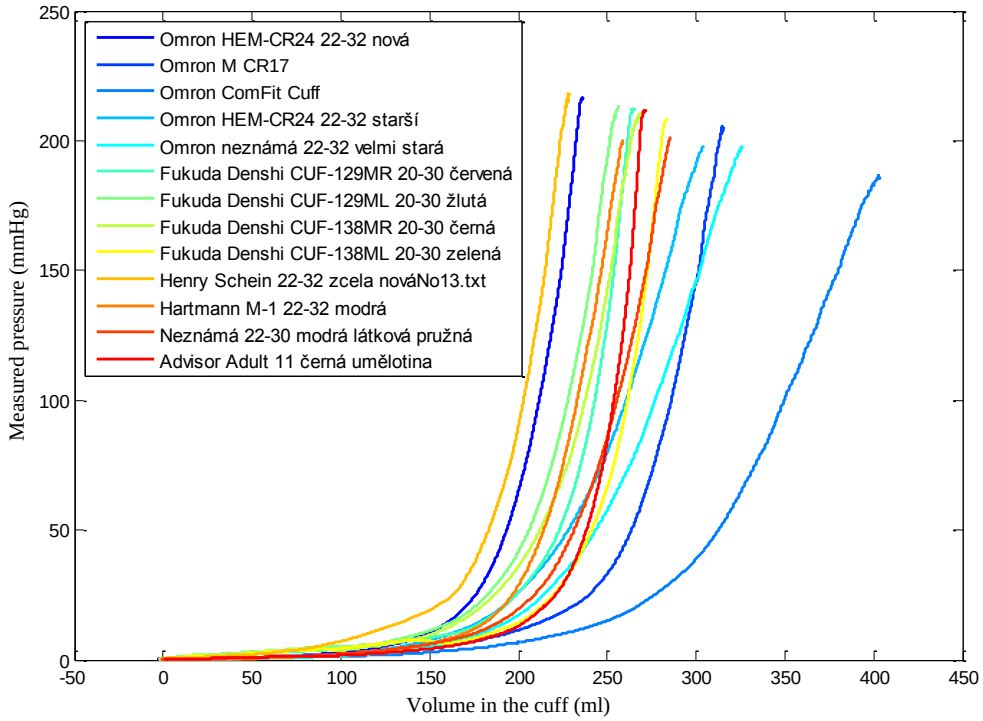

Fig. 3 Results of the measurement

among the cuffs, which could affect the accuracy of noninvasive blood pressure greater than normally tolerated deviations from the true value.

The measurements also show that the age of the cuff is not very relevant factor for evaluation of measurement accuracy. Both new and old cuffs have similar linearity and the primary reason for replacing the old one by the new one is mainly mechanical damage of the cuff or weak fixation system.

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