Influencing Factors on Indirect Measurement of Blood Pressure in Children

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In order to investigate the influence of cuff size and anthropometric values for the measurement of indirect blood pressure (IP) by sphygmomanometer, IP was measured simultaneously with the recording of direct aortic pressure (DP) by catheter tip micromanometer. Observations were made in 56 patients, aged 3 to 16 years. The majority had a history of Kawasaki disease and some type of congenital heart disease, but all were normotensive and none had aortic insufficiency and stenosis. As IP values, Korotokoff 1 sound, and Korotokoff 4 and 5 sounds were regarded as systolic and diastolic pressure values, respectively. IP measurement was performed in each subject using at least 6 types of cuffs with different widths and lengths.

The results were as follows: (1) IP was noted to have a linear correlation to DP (p < 0.01), but systolic IP tended to show higher values than those of DP. The same tendency was noted for the diastolic IP. (2) There was a negative correlation between IP/DP and cuff width/arm length (p < 0.01). (3) According to cuff width/arm length, values of IP/DP were divided into 2 groups: a group less than 0.4 and another group more than 0.4. In the former group, values of IP/DP were significantly higher than those of the other group.

The most important influencing factor on IP measurement was the cuff width in relation to the arm length. Use of a short width cuff may cause overestimation of the indirect blood pressure.

Essential hypertension plays a considerable role in the epidemiology of vascular disease in adults. Currently, much interest is being focused on essential hypertension and its possible onset during childhood. Extensive surveys of blood pressure in school children have been undertaken in Japan, for example, the "Shimane Heart Study"1-2

Although numerous studies have been done on the pathogenesis and epidemiology of hypertension, there are few studies on determination of the accuracy of indirectly measured blood pressure in childhood3 The purpose of this study was to investigate the influence of several factors on the measurement of IP in childhood.

Key words:
Sphygmomanometry
Cuff bladder
Childhood

Materials and Methods
Observations were made at rest in 56 patients who were undergoing diagnostic cardiac catheterization. 31 of them had a history of Kawasaki disease and no apparent coronary artery lesions. There were 8 cases of postoperative and 5 cases of preoperative atrial septal defect, and 2 had undergone the surgical procedure of patent ductus arteriosus. 4 were cases of postoperative ventricular septal defect (VSD) and 6 preoperative cases had VSD with a small shunt. All were normotensive and none had aortic insufficiency and stenosis. Their ages ranged from 3 to 16 years, including 13 cases from 3 to 5 years, 20 cases from 6 to 8 years and 23 cases of 9 years or more.

The patients were sedated in the usual manner with a mixture of pethidine and promethazine.

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TABLE 1  CUFF SIZE TO BE SELECTED

<table>
<thead>
<tr>
<th>Age</th>
<th>Bladder width</th>
<th>Bladder length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 3m – 2y</td>
<td>5 cm</td>
<td>a. 20 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. 15 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. 10 *</td>
</tr>
<tr>
<td>2. 3y – 5y</td>
<td>7 cm</td>
<td>a. 20 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. 15 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. 10 *</td>
</tr>
<tr>
<td>3. 6y – 8y</td>
<td>9 cm</td>
<td>a. 25 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. 18.8 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. 12.5 *</td>
</tr>
<tr>
<td>4. 9y – 12 cm</td>
<td>a. 22 cm</td>
<td>b. 16.5 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. 11 *</td>
</tr>
</tbody>
</table>

# = cuffs were commercially available
* = cuffs were handmade

60 to 90 minutes prior to the procedure. The groin of both sides was infiltrated with 0.5% lidocaine at the same time. After the completion of right heart catheterization, arterial punctures were made in the femoral artery using a 21-gauge needle. Aortic arch pressure as direct blood pressure (DP) was recorded by a catheter tip micromanometer (Miller Co.) with both derivatives of the pressure and intracardiac phonocardiography connected to an E for M recorder at a paper speed of 100 mm/second, and the signals were processed by Cath-Lab system (Hewlet-Packard Co.).

Simultaneously, indirect blood pressure (IP) with a mercury sphygmomanometer was measured by using the first Korotkoff sound to indicate the systolic pressure and the fourth and fifth Korotkoff sounds to indicate diastolic pressure. In each subject, not only the cuff which was commercially available and appropriate for age, but narrower or shorter cuff bladders were used to measure the right arm. The sizes of the cuffs used for measurement are shown in Table I.

Anthropometric parameters including age, height, weight, arm length, arm circumference and skinfold thickness on triceps were measured in each subject at the same time. Arm length was recorded as the distance of the acromion to the olecranon of the right arm. The arm circumference was measured at the marked midpoint of the distance of the acromion to the olecranon without skin compression. The skinfold thickness was measured at the mid-portion of the upper arm on the tricipital muscle by a Harpenden’s caliper.

The means, standard deviations, correlation coefficients, regression equations and scattergrams were calculated and paired- simple t-tests were performed using a microcomputer.

RESULTS

Figure 1 demonstrates the relationship between DP and IP, using the standard cuff bladder. For systolic pressure, their correlation was good (r = 0.81) and was described by the linear regression equation Y = 0.86X + 20.20. But systolic pressure determined by the indirect method showed somewhat higher values than those measured directly. Likewise, for diastolic pressure, the correlation between DP and IP, selected either at the fourth or fifth Korotkoff sound, was relatively good with coefficients of, respectively, 0.51 and 0.31. Basically, the same tendency as for the systolic pressure was noted for the indirect method of blood pressure measurement.

Figure 2 shows the relationship between the

![Graph 1](image1.png)

**Fig.1. Direct and indirect systolic pressure in children (more than 3 yrs).**

![Graph 2](image2.png)

**Fig.2. Systolic pressure ratio and cuff width to arm length ratio.**
blood pressure ratio, which is systolic IP divided by DP as the reference pressure, and the ratio of cuff width to arm length. The regression equation was $Y = -0.58X + 1.28$ with a correlation coefficient of $-0.49$. From this equation, in order to obtain an identical IP to DP, one should use a cuff with a ratio of cuff width to arm length of 0.48.

According to the ratio of cuff width to arm length, the patients were arbitrarily divided into 2 groups: a group with a ratio of less than 0.4 and a group with a ratio of over 0.4 (Fig. 3). There were significant differences in blood pressure ratio between the groups on using several kinds of cuff bladder.

In terms of the relationship between the systolic pressure ratio and the ratio of cuff width to arm circumference, there was a relatively good correlation ($r = -0.40$), with a regression equation of $Y = -0.32X + 1.22$. However, no specific correlation was noted in the relationship between systolic pressure ratio and ratio of cuff length to arm length, or in the relationship between systolic pressure ratio and skin fold thickness.

**DISCUSSION**

In previous reports, the authors demonstrated that a measurement bias does exist under the prevailing practice of cuff bladder selection.\textsuperscript{5–6} The American Heart Association recommends use of an inflatable bladder which is 20 per cent wider than the diameter of the limb on which it is applied.\textsuperscript{5} Steinfield et al. also showed that more accurate IP could be obtained using wider cuffs than those used previously.\textsuperscript{5}

There is no doubt that use of a cuff that is too narrow for the subject gives falsely high systolic and diastolic pressures. Since the pressure in the cuff is transmitted most effectively at its center, a cuff which is too narrow will result in poorer compression of the artery and a higher inflation pressure will be required to induce vascular sounds.\textsuperscript{5} This makes the systolic pressure reading higher than that in the artery.

In this study, it was shown that one of the factors that determines the accuracy of indirectly measured blood pressure is the relationship between cuff width and arm length. In order to obtain the most accurate IP with a systolic pressure ratio of 1.0, the optimum ratio of cuff width to arm length should be 0.48 according to the equation derived from the current study. This result allows estimation of the degree of error that will be encountered when the ratio of cuff width to arm length is not optimal. As shown in Fig. 2, 5% overestimation of blood pressure would occur when a cuff width to arm length of about 0.4 is encountered. Translating this figure into the arm sizes for various cuffs shows that the 12-cm cuff will provide values for systolic pressure that are 5% high when the arm

is 12/0.4 = 30 cm in length.
If a ± 5% error criterion is accepted, the range of arm length for a 12-cm cuff width should be up to 30 cm. The smaller (9 cm) cuff should accommodate an arm length of up to 22.5 cm and the next smaller cuff (7 cm) up to 17.5 cm.

REFERENCES
5. WHO technical report series, No. 715, 1985 (Blood pressure studies in children.)