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Okay BAŞAK<sup>1</sup>  
Şebnem KARAZEYBEK<sup>2</sup>

## Accuracy of Sphygmomanometers

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**Abstract:** One of the factors affecting the accuracy of readings of blood pressure is the equipment used. Defects or inaccuracy of aneroid sphygmomanometers may be source of error in blood pressure measurement. We inspected 100 sphygmomanometers for physical defects and assessed their accuracy against a standard mercury manometer at four different pressure points. 46 of the 100 sphygmomanometers were determined to be intolerant (deviation from the mercury manometer by greater than  $\pm 3$  mm Hg at two or more of the test points). There were faults in the inflation-deflation system of 34

sphygmomanometers. The most common physical defects were: defective pump bulb, defective rubber tubing and indicator needles not pointing to the "zero box". There was no regular preventive maintenance program in health units. We recommend that health care providers should use mercury sphygmomanometers and have at their disposal the equipment necessary to check the accuracy of manometers.

**Key Words:** Sphygmomanometers, calibration, blood pressure measurement, Turkey.

<sup>1</sup>Adnan Menderes University, Faculty of Medicine, Department of Family Practice,  
<sup>2</sup>General practitioner, Social Security Hospital, Aydın-Turkey

### Introduction

The appropriate treatment of hypertension (HT) requires first an accurate diagnosis and HT is essentially diagnosed by measuring the blood pressure (BP) (1). The BP measurement is also an indispensable part of the usual physical examination.

Sphygmomanometer is one of the important components in the procedure of blood pressure measurement. Although they are less accurate and less reliable than mercury models, only aneroid sphygmomanometers are used especially in primary care in our country.

Many technical errors might occur relating to the equipment used in routine indirect BP measurement and influence the reading. There are numerous reports on the condition of sphygmomanometers in general hospitals and family practice, which have shown that as many as half of them may be defective (2-6). However, equivalent surveys of sphygmomanometers have not been done in Turkey.

We believe that sphygmomanometers in health care centres in Turkey have not been used cautiously, that they have led to serious diagnostic errors, and that most health care providers do not have a policy of regular maintenance of sphygmomanometers. For this purpose we examined the physical condition and accuracy of

sphygmomanometers used in primary care health centres and Social Security Hospital in Aydın, Turkey.

### Material and Methods

We tested the accuracy and physical condition of 100 consecutively available sphygmomanometers. Of the 100 sphygmomanometers, 62 were collected from 15 health centres in primary care and 38 were collected from the Social Security Hospital in Aydın, Turkey. The sphygmomanometers available in clinics and polyclinics but not in use were not included in the survey.

#### Visual assessment

The condition of each component of the sphygmomanometer was evaluated using the following criteria:

- (1) the bladder was considered defective if it was worn or torn or if it prolapsed out of the cuff;
- (2) the pump bulb was considered defective if it was cracked or excessively worn, and/or if it leaked air when being pumped, and/or if there was dirt in the inlet valve;
- (3) the rubber tubing was considered defective if there were holes or leaks and/or if excessive wear and cracking were present, and/or the length of tubing was too short;

(4) the control valve was considered defective if there was wear or air leakage in valve or dirt in filter, and/or if it was difficult to open or close the valve;

(5) the face plate was considered defective if it was cracked or broken, and/or if there was some trouble in legibility of pressure due to dirt on inside of glass tube or face plate or due to oxidisation of mercury;

(6) the gauge was considered defective if the indicator needle did not point to the "zero box" when there was no pressure in the manometer (4, 5, 7).

A component was classified as satisfactory when it was in perfect working order and unsatisfactory when it was defective according to the above criteria.

**Functional assessment**

The cuff was wrapped around a large bottle for functional assessment. It was tested whether the procedures of inflating the bladder, and halting and restarting at any desired pressure were easily performed. Also, it was examined whether rate of fall of mercury or indicator needle could be easily controlled to 2 mm Hg/s, and whether there was any loss of pressure greater than 1 mm Hg/s while the control valve was closed at 250 mm Hg of pressure.

To assess the accuracy of sphygmomanometers, a closed system was designed according to the recommendations of the American Heart Association (AHA), and the sphygmomanometers tested were compared with a new, standard mercury sphygmomanometer at four pressure levels. The gauge was detached from the sphygmomanometer and connected to an accurate mercury manometer and an inflation bulb by using a metal T-connector and rubber

tubing. Pressure was given into the system and released down to a predetermined level on the standard mercury sphygmomanometer. Then the test gauge was read, and this reading was recorded. All measurements were taken by two observers- the authors- one of whom consistently adjusted the pressure on the mercury manometer while the other continually read the pressure level on the test manometer. Single measurements were taken at pressures of 240, 180, 120 and 60 mm Hg. (2, 4, 5, 7).

**Results**

All the sphygmomanometers in 15 health centres and Social Insurance Hospital were aneroid models except for one mercury sphygmomanometer in use in the hospital. Each of the 100 sphygmomanometers was inspected to determine the physical condition of its parts. The results of the visual assessment are shown in Table 1. The most common physical defects were: defective pump bulb (65%), defective rubber tubing (41%), and indicator needles not pointing to the "zero box" (39%).

The cuffs of 97 sphygmomanometers were of adult size and contained bladders of lengths ranging from 19 to 26 cm and widths ranging from 10 to 13 cm. Three sphygmomanometers in paediatric inpatient and outpatient clinics in the hospital had smaller cuff sizes containing bladders of lengths ranging from 15 to 18 cm and widths ranging from 6.5 to 7.5 cm. All of the 62 general practice cuffs (100%) and 30 hospital cuffs (78.9%) had bladder lengths less than the 24 cm recommended for use on normal adults. In addition, 59 (95.2%) general practice cuffs and 33 (86.8%) hospital cuffs had bladder widths less than the 13 cm recommended for use on normal adults.

Component	Test*	Results			
		Hospital (n:38)		General practice (n:62)	
		Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory
Inflation bulb		6(16)	32(84)	29(47)	33(53)
Control valve		22(58)	16(42)	46(74)	16(26)
Rubber tubing		18(47)	20(53)	41(66)	21(34)
Cuff		27(71)	11(29)	44(71)	18(29)
Bladder		34(90)	4(10)	59(95)	3(5)
Indicator needle (level of mercury)		25(66)	13(34)	36(58)	26(42)
Face plate		19(50)	19(50)	46(74)	16(26)

Table 1. Physical condition of the components of sphygmomanometers [number (%)]

\*Physical assessment has been made as expressed in the section of "Material and Methods".

Function	Test*	Results			
		Hospital (n:38)		General practice (n:62)	
		Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory
Inflation		24(63)	14(37)	57(92)	5(8)
Deflation		26(68)	12(32)	57(92)	5(8)
Leakage		24(63)	14(37)	52(84)	10(16)
Gauge accuracy		26(68)	12(32)	28(45)	34(55)

Table 2. Functional status of sphygmomanometers [number (%)]

\*Functional assessment has been made as expressed in the section of "Material and Methods".

Test pressure, mm Hg	Mean±SD pressure, mm Hg	
	Lower reading manometers (n)	Higher reading manometers (n)
	240	229.5±8.6 (23)
180	170.7±8.3 (28)	191.5±6.8 (11)
120	109.9±8.9 (27)	128.6±3.9 (9)
60	49.3±9.3 (29)	65.8±2.2 (7)

Table 3. The average readings of the lower and higher reading manometers ( $\pm 3$  mm Hg) at each of test pressure levels.

For the purposes of this study, a test manometer was defined as being intolerant if it deviated from the standard manometer by greater than  $\pm 3$  mm Hg at two or more of the test pressure levels. 34 (54.8%) of the 62 general practice sphygmomanometers and 12 (31.6%) of the 38 hospital sphygmomanometers were intolerant. In total, 46 (46%) of the 100 test sphygmomanometers were intolerant (Table 2). The average readings and the numbers of the lower and higher reading manometers at each of the four test pressure levels are shown in Table 3.

There were faults in the inflation-deflation system of 34 (34%) sphygmomanometers. The functional status of the test sphygmomanometers is shown in Table 2.

## Discussion

Even when purified from all errors, indirect BP measurements do not completely reflect the intra arterial pressure. It is, therefore, highly important to avoid all preventable errors caused by an improper technique of BP measurement and inaccurate sphygmomanometers.

One of the most significant findings obtained by our study was that nearly no mercury sphygmomanometers were used in health care centres in Aydın, Turkey. In the report of JNC V (1993) and in protocols of some international HT organisations, it has been suggested that mercury sphygmomanometers should be used, and if aneroid models are to be used, then they should be

checked at an interval of 6-12 months (2,3,8-11). Rationality of this recommendation is that frequent use causes the metal bellows of the aneroid gauges to lose their elasticity, especially in higher pressures. In addition, any trauma to the instrument may disrupt the gear system, thus increasing a tendency to faulty measurement throughout the entire scale (4).

Our results reveal some suspicion about the accuracy of sphygmomanometers used particularly in health centres in primary care. 54.8% of the sphygmomanometers in primary care have shown pressure deviation exceeding the recommended tolerance of error at two or more test pressure levels. This is greater than the intolerance rates reported by some studies in the literature (4-7). As seen in Table 3, BP readings with test sphygmomanometers are more likely to be inaccurate at higher pressures. Intolerant sphygmomanometers have a tendency to underestimate the patient's actual BP. The most common physical defect leading to inaccuracy of manometer appears to be indicator needles not pointing to the "zero box" (39%). Faults in aneroid manometers have to be corrected by the manufacturer. But this correction procedure is nearly impossible in Turkey.

This is because the equipment used for BP measurement is all imported in our country and there is also no servicing agent. For this reason, if an aneroid manometer is determined to be inaccurate, then

purchasing a new sphygmomanometer should be preferred.

One of three sphygmomanometers had functional faults in their inflation-deflation system. The most common sources of error leading to functional insufficiency were defective pump bulb (65%), defective rubber tubing (41%) and leakage of the control valve (32%). Any difficulty of inflating the bladder due to any wear, cracking, holes, tear of these components or dirt in filter can cause venous distension of the forearm and a concomitant low flow, thereby producing the auscultatory gap. In addition, difficulty in control the release of pressure leads to underestimation of systolic and overestimation of diastolic blood pressures. Repairable nature of the defects of the inflation-deflation system shows the importance of the regular maintenance.

Our study determined that the dimensions of most of the bladders in both hospital and general practice sphygmomanometers do not meet present recommendations of the AHA and British Hypertension Society (BHS) (10,11). According to the AHA and BHS, a normal adult-sized bladder should have at least dimensions of 13x24 cm and 12x26 cm respectively. Use of bladders of inadequate dimensions leads to overestimation of BP. This increases the possibility of misdiagnosing normotensive patients as hypertensive.

## Conclusion

According to the results of this study, the functional and physical conditions of sphygmomanometers used in primary and secondary care settings are insufficient and defective. The readings of aneroid manometers in bad condition, with in many cases wrong zero calibrations, do not agree in a simple calibration procedure with readings

of a new mercury manometer.

We recommend that mercury sphygmomanometers should be used in primary and secondary care settings, which are more accurate, less expensive in the long term and can be maintained by the owner. If aneroid models are used, they must be checked at an interval of 6 months and health care providers should have at their disposal the equipment necessary to check the accuracy of aneroid manometers as designed according to recommendations of the AHA and used in our study. In addition, replacement pump bulbs, control valves, and rubber tubing should be kept readily available. Furthermore, we think that health care providers have to keep in mind the possibility that sphygmomanometers in bad condition can cause misreading.

The general conclusion of the study is that the sphygmomanometers should be better serviced. We also emphasise that standards and recommendations for the use and preventive maintenance of sphygmomanometers should be constituted in consistent with medical practice of our country and that the clinician and the hospital staff consistently assess their equipment according to this audit. As stated by Hussain and Cox, a formal audit of the use of sphygmomanometer in general practice may encourage and improve accuracy and uniformity in BP recording (12).

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