

Sphygmomanometers in hospital and family practice: problems and recommendations

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Abstract

The accuracy and working condition of 210 sphygmomanometers were tested: 100 (50 mercury and 50 aneroid) models were used in family practices and 110 mercury models in hospitals. Faults in the inflation-deflation system were common and caused mainly by dirt or wear in the control valves. Leakage occurred in 48% of the hospital and 33% of the family practice sphygmomanometers. In the mercury models the mercury or air vents were often in an unsatisfactory condition or the calibrated glass tube dirty. The accuracy of the gauges was examined at 90 and 150 mm Hg: fewer than 2% of the mercury sphygmomanometers but 30% of the aneroid models had errors greater than ± 4 mm Hg at either pressure. Over half of the cuffs examined had bladder widths less than the recommended size, and 94% had bladders shorter than the length recommended for use on normal adults.

Mercury sphygmomanometers should be bought in preference to aneroid models as they are more accurate, less expensive in the long term, and can be maintained by the owner; they should be checked every six to 12 months depending on usage. Replacement parts should be kept readily available.

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Introduction

Previous reports on the condition of sphygmomanometers in general hospitals have shown that as many as half may be defective.¹⁻³ Equivalent surveys of sphygmomanometers in family practice have not been done. Aneroid sphygmomanometers are less accurate than mercury models,^{4,5} yet as many as one-third of family practitioners use only aneroid sphygmomanometers.⁶ The need for regular maintenance has been emphasised, but many family practitioners admit to never having their sphygmomanometers serviced,⁶ and many hospitals do not have a policy of regular maintenance of sphygmomanometers. In the present survey we examined the condition and accuracy of sphygmomanometers in hospital and family practice.

Methods

We tested the accuracy and working condition of 210 sphygmomanometers: 100 (50 mercury and 50 aneroid models) were collected from 88 family practices, and 110 mercury models were tested from two hospitals, St Laurence's Hospital (general) and the Rotunda Hospital (maternity). Aneroid sphygmomanometers were not used in these hospitals.

The operation of each sphygmomanometer was tested according to the scheme in table I. The condition of each component of the sphygmomanometer was examined according to the scheme in table II. A component was classified as satisfactory when it was in perfect working order and as unsatisfactory when there was excess dirt, undue wear, or damage that prevented correct operation of the sphygmomanometer. The dimensions of the bladder in each cuff were also measured.

Results

The tables summarise the results. As there was no significant difference between the mercury sphygmomanometers in the two hospitals the results for these were combined.

Faults in the inflation-deflation system were common. Inflation was unsatisfactory in 10 of the hospital sphygmomanometers and 41 of the family practice sphygmomanometers, and deflation was unsatisfactory in one-third of both hospital and family practice sphygmomanometers. These defects were caused mainly by dirt or wear in the control valves. The control valves were defective in 65 of the hospital and 76 of the family practice sphygmomanometers. Leakage was above the recommended limit of 10 mm Hg in 10 seconds⁷ in 53 of the hospital sphygmomanometers and in 33 of the family practice sphygmomanometers.

The mercury was in an unsatisfactory condition in 96 (87%) of the

hospital sphygmomanometers and 31 (62%) of the mercury sphygmomanometers in family practices. The calibrated glass tube was dirty in 95 (86%) of the hospital and 40 (80%) of the family practice mercury sphygmomanometers. The air vents were in unsatisfactory condition in 98 (89%) of the hospital and 40 (80%) of the family practice mercury sphygmomanometers (table II).

The accuracy of the gauge of the sphygmomanometers was examined at two pressures commonly selected to differentiate normotension from hypertension (90 mm Hg and 150 mm Hg). Fewer than 2% of all mercury sphygmomanometers tested had gauge errors greater than ± 4 mm Hg at either of these pressures, compared with 15 (30%) aneroid sphygmomanometers. Table III shows the distribution of gauge errors in both mercury and aneroid sphygmomanometers at a pressure of 90 mm Hg. A χ^2 test of the distribution of the error showed that there was a significantly greater range of errors in aneroid than in mercury gauges ($p < 0.001$).

All of the cuffs examined were of adult size and contained bladders of widths ranging from 11 to 13.5 cm and lengths ranging from 22 to 28.5 cm. Smaller cuff sizes were available in both hospitals for use on children. The dimensions of the bladders in all of the cuffs examined met the present recommendations of the American Heart Association for small-adult-sized cuffs. However, 66 (60%) hospital cuffs and 85 family practice cuffs had bladder widths less than the 13 cm recommended for use on normal adults. In addition, 94% of both hospital and family practice cuffs had bladder lengths less than the 24 cm recommended for use on normal adults.⁷

Discussion

Our most important finding was the inaccuracy of the gauges in aneroid sphygmomanometers. This is due to mechanical faults caused by knocks and jolts during use as well as to aging of the manometer. The pointers and gearing mechanisms in the aneroid machines tested were in good working order. This, together with the common use of stop pins, which prevent the pointer from falling below zero on the scale when pressure is released, gives the operator mistaken confidence in the equipment's accuracy. Inaccuracy can be detected only by checking the aneroid manometer against an accurate mercury manometer over the entire pressure range. Faults in aneroid manometers have to be corrected by the manufacturer or a servicing agent, and the difference in cost between having this done and purchasing a replacement sphygmomanometer is often so small that the latter option may be preferable.

The mercury sphygmomanometer is basically an accurate piece of equipment that can be serviced and maintained by the owner. There are three potential sources of error in the pressure

TABLE 1—Performance of sphygmomanometers (figures are numbers (%))

| Function | Test | Results | | | | | | Fault | Remedy |
|----------------|--|-------------------|------------------|---|----------------|--------------------|--------------------|---|---|
| | | Hospitals | | Family practice | | | | | |
| | | Mercury (n = 110) | Mercury (n = 50) | Aneroid (n = 50) | Satisfactory | Unsatisfactory | Satisfactory | | |
| Inflation | Wrap cuff around large bottle; test ease of inflation and ability to halt and restart at any desired pressure | 100 (91) | 10 (9) | 27 (54) | 23 (46) | 32 (64) | 18 (36) | Defective control valve or blocked air vent | Clean or replace control valve or chamois leather |
| Deflation | Rate of fall of mercury or pointer should be easily controlled to 2 mm Hg/s | 74 (67) | 36 (33) | 28 (56) | 22 (44) | 39 (78) | 11 (22) | Defective control valve | Clean or replace control valve |
| Leakage | Inflate cuff pressure to 250 mm Hg; close control valve and note any loss of pressure greater than 10 mm Hg in 10 s. Locate source of leak by clamping | 57 (52) | 53 (48) | 29 (58) | 21 (42) | 38 (76) | 12 (24) | Defective control valve or rubber tubing | Clean or replace defective component |
| Gauge accuracy | Detach gauge from sphygmomanometer and connect via Y tube to accurate mercury manometer. Check pressures at 10 mm Hg intervals over entire pressure range. Errors of greater than ± 4 mm Hg are unsatisfactory | 109 (99) | 1 (1) | Accuracy at 90 mm Hg: 49 (98) Accuracy at 150 mm Hg: 49 (98) | 1 (2) 1 (2) | 38 (76) 35 (70) | 12 (24) 15 (30) | Loss of mercury. Blocked air vent. Mercury and glass tube in bad condition. Gearing mechanism or bellows in aneroid machine defective | Service mercury gauge. Return aneroid machine to manufacturer |

TABLE II—Condition of components (figures are numbers (%))

| Component | Test | Results | | | | | | Fault | Remedy |
|-------------------------------|---|-------------------|----------------|------------------|----------------|------------------|----------------|--|---|
| | | Hospitals | | Family practice | | | | | |
| | | Mercury (n = 110) | | Mercury (n = 50) | | Aneroid (n = 50) | | | |
| | | Satisfactory | Unsatisfactory | Satisfactory | Unsatisfactory | Satisfactory | Unsatisfactory | | |
| Pump bulb | Examine rubber. Check operation of inlet valve | 108 (98) | 2 (2) | 45 (90) | 5 (10) | 42 (84) | 8 (16) | Wear. Dirt in inlet valve | Replace |
| Control valve | Examine filter for dirt (see also leakage, inflation, and deflation tests (table I)) | 45 (41) | 65 (59) | 11 (22) | 39 (78) | 13 (26) | 37 (74) | Dirt in filter or wear in valve | Clean or replace |
| Cuff and bladder | Examine general condition of cuff. Check Velcro surfaces for wear and dimensions of bladder | 101 (92) | 9 (8) | 47 (94) | 3 (6) | 47 (94) | 3 (6) | Wear. Incorrect bladder dimensions | Replace |
| Rubber tubing | Examine condition. Check length of tubes and state of connections | 95 (86) | 15 (14) | 37 (74) | 13 (26) | 48 (96) | 2 (4) | Worn or perished rubber. Lengths too short | Replace |
| Legibility of gauge | Check legibility of pressure with falling mercury column or pointer | 45 (41) | 65 (59) | 29 (58) | 21 (42) | 43 (86) | 7 (14) | Dirt on inside of glass tube. Oxidisation of mercury | Clean or replace mercury and clean glass tube |
| Mercury | Check level of mercury and general condition | 14 (13) | 96 (87) | 19 (38) | 31 (62) | | | Loss or oxidation of mercury | Top up mercury in reservoir. Clean mercury by filtering |
| Glass tube | Examine inside of tube for dirt | 15 (14) | 95 (86) | 10 (20) | 40 (80) | | | Dirt in tube due to oxidation of mercury | Clean tube with pipe cleaner and spirit |
| Air vent | Examine chamois leather for clogging with dirt or mercury | 12 (11) | 98 (89) | 10 (20) | 40 (80) | | | Clogging of chamois leather with mercury | Clean or replace chamois leather |
| Pointer and gearing mechanism | Examine mechanism for smooth operation | | | | | 47 (94) | 3 (6) | Mechanical sluggishness due to rough handling | Return to manufacturer for service |

TABLE III—Percentage distribution of gauge errors at 90 mm Hg in mercury and aneroid sphygmomanometers

| Error (mm Hg): | < -7 | -7 | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | > 7 |
|----------------|------|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|-----|
| Mercury | | | | | | | | | | | | | | | | | |
| Aneroid | 8 | 2 | 6 | 4 | 8 | 2 | 8 | 12 | 20 | 4 | 8 | 4 | 4 | 6 | | 4 | |

gauge—namely, the mercury, the glass tube, and the air vent. Mercury may leak from the gauge, causing underestimation of pressure, and this fault may be corrected by topping up the mercury in the reservoir. The interior of the glass tube may become dirty due to oxidation of the mercury, giving poor legibility of the gauge and causing the mercury to adhere to the tube when the pressure is released, resulting in overestimation of blood pressure. Poor legibility of the gauge also makes it difficult to use the sphygmomanometer, which can add further error. Oxidised mercury may be cleaned by filtering or be replaced, and the glass tube may be cleaned easily using a pipe cleaner and spirit. Blockage of the air vent, due to clogging of the chamois leather with mercury, inhibits entry of air into the glass tube when the pressure is released. This causes an upward drag on the mercury during deflation and leads to overestimation of blood pressure. A severely blocked air vent also makes inflation difficult and becomes evident when the mercury is slow to respond to an increase or decrease in pressure. The vent may be cleaned easily in most models or the chamois leather replaced.

The unsatisfactory condition of the mercury, glass tubes, and air vents in most mercury sphygmomanometers is due principally to the lack of maintenance of these components, though some family practice sphygmomanometers had been recently serviced. Although the condition of the components of mercury sphygmomanometers was unsatisfactory in a high proportion of cases, this did not affect their performance as assessed in table I. The unsatisfactory state of these components, however, makes blood-pressure measurement more difficult, with a greater likelihood of error.

Other faults detected were in the inflation-deflation system and were common to both mercury and aneroid sphygmomanometers. The most common source of error was the control valve, which when defective may cause leakage, making it difficult to control the release of pressure, which thus leads to underestimation of systolic and overestimation of diastolic blood pressures. This fault may be corrected easily and cheaply, sometimes by simply cleaning the filter or alternatively by replacing the control valve at the cost of only a few pounds. Leakage may also be caused by perished or punctured rubber tubing, which must be replaced.

The better condition, in general, of the inflation-deflation system in hospital sphygmomanometers is probably due to more frequent, though irregular maintenance.

This study found that the dimensions of most of the bladders used in adult-sized cuffs in both hospital and family practice do not meet the present recommendations of the American Heart Association.⁷ The recommended bladder dimensions of 13 × 24

cm were chosen to give a bladder width that is greater than 40% of the circumference and a bladder length that is greater than 80% of the circumference of most adult arms. Some investigators⁸⁻¹⁰ have favoured longer bladders of 35-40 cm. Bladders of this length would fully encircle the arm of 99% of adults and reduce errors in blood-pressure measurement.¹¹ Use of bladders of inadequate dimensions, as in most of the cuffs examined here, leads to overestimation of blood pressure with the possibility of misdiagnosing normotensive patients as hypertensive.

On the basis of these findings we make the following recommendations.

To the purchaser—Mercury sphygmomanometers are recommended in preference to aneroid models because they are more accurate, less expensive in the long term, and can be maintained by the owner. They should be checked for faults every six to 12 months depending on usage. If aneroid sphygmomanometers are used they must be checked over the entire pressure range against an accurate mercury manometer every three to six months depending on use. The purchaser is advised to check bladder length, which must be at least 24 cm; for obese patients larger bladders are needed. It is also advisable to purchase an additional control valve and to ensure that there is a pipe cleaner with mercury sphygmomanometers.

To the manufacturer—Manufacturers, anxious to reduce costs, should avoid introducing components of inferior quality such as plastic control valves, thin rubber in the bladder, plastic rather than glass calibrated tubes, and shortened rubber tubing. An instruction booklet for maintenance should be included with all mercury sphygmomanometers, and a replacement control valve, chamois leather filters, and a pipe cleaner should be supplied. Bladder dimensions should be revised occasionally to meet current recommendations.

To hospitals—Many hospitals do not have a policy for regular maintenance of sphygmomanometers. All sphygmomanometers in use in hospitals should be mercury models and should be serviced every six months. To minimise damage and facilitate accurate measurement mercury manometers on wheel stands are recommended for use on the wards. Replacement pump bulbs, control valves, chamois leathers, and rubber tubing should be kept readily available.

We acknowledge the support and assistance of Ciba Laboratories and in particular their representative Kevin Kelly; Surgical Distributors Ltd; and the Royal College of Surgeons in Ireland. We also thank all hospital staff and family practitioners who kindly co-operated in the study.

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(Accepted 11 June 1982)