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Accuracy of the London School of Hygiene and Remler M2000 sphygmomanometers

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Summary

1. The accuracy of the Remler M2000, a semiautomatic portable blood pressure recorder, was assessed with the London School of Hygiene (LSH) and Hawkesley random-zero sphygmomanometers used as reference standards.

2. The Remler gave higher recordings than the LSH sphygmomanometer, the mean systolic and diastolic differences being 5·9 mmHg ($P < 0·001$) and 4·7 mmHg ($P < 0·001$) respectively. No significant difference was demonstrated between paired Remler and Hawkesley recordings.

3. When simultaneous paired LSH and Hawkesley sphygmomanometer recordings were compared, the LSH gave lower blood pressures: 7·1 mmHg ($P < 0·001$) for systolic and 3·6 mmHg ($P < 0·001$) for diastolic recordings.

4. The LSH sphygmomanometer underestimates blood pressure, partly due to a calibration error but also because the selection of end points for this device differs from other methods of blood pressure measurement.

Key word: sphygmomanometers.

Introduction

The Remler M2000 is a semiautomatic ambulatory blood pressure recorder which detects Korotkoff sounds through a microphone during cuff deflation. These are recorded on a magnetic tape superimposed on a tracing of cuff pressure [1]. When the Remler was tested for accuracy against the LSH sphygmomanometer, a mercury-in-glass manometer designed to reduce observer bias and digit preference [2], it gave higher systolic and diastolic recordings [3, 4]. However, when tested against a standard sphygmomanometer, no significant error could be found [4, 5] and the discrepancy between the two reference standards was not explained [4].

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The purpose of this study was to re-examine the Remler M2000 for accuracy and to explain the inconsistencies of earlier results.

Method

The study consisted of three comparisons: between the Remler and the LSH, the Remler and Hawkesley and between the LSH and Hawkesley sphygmomanometers.

The LSH sphygmomanometer and Remler M2000 were compared in 12 patients by using two LSH and three Remler devices as part of an inter-device variability study. Simultaneous measurements with the Remler and LSH sphygmomanometer were recorded in the same arm by connecting both devices to a single cuff through a Y-connector. Furthermore, LSH and Remler recordings were made in both arms simultaneously using two cuffs and a common inflation–deflation system so that paired Remler recordings in opposite arms could be compared with paired LSH recordings. Two trained observers took part in the study, the order of machines and observers being randomized according to a Graeco–Latin square design.

In a further 35 patients, similar paired recordings were made in the same arm by one observer using one Remler and a Hawkesley sphygmomanometer, two measurements being made in each patient.

The LSH and Hawkesley random-zero sphygmomanometers were compared in 20 patients by paired simultaneous recordings in the same arm with two observers and a two-channel stethoscope. Four pairs of recordings were made

in each patient, the order of observers being randomized. Furthermore, the LSH sphygmomanometer was tested statically against a standard mercury manometer by connecting both devices through a Y-connector to a cuff wrapped around a cylinder.

Results

In the comparison of the LSH sphygmomanometer and Remler M2000 no difference was found between observers or Remler recorders. The Remler recordings were higher than those of the LSH sphygmomanometer by a mean of 5·9 mmHg and 4·7 mmHg for systolic and diastolic pressures respectively (Table 1). In contrast, no significant difference was observed between paired Remler and Hawkesley recordings. When the LSH sphygmomanometer and standard mercury manometer were compared throughout the pressure scale, the LSH instrument gave lower recordings, the error increasing linearly with the pressure, so that, for example, at 250 mmHg, the LSH sphygmomanometer recorded 245 mmHg. All mercury manometers must be calibrated so that the lag in the rise of mercury in the glass tube, secondary to the fall of mercury in the reservoir when pressure is applied, is compensated for in the recording scale. The correction factor varies throughout the pressure scale but can be calculated from the formula

$$h_1 = h_2(d_2^2/d_1^2)$$

where h_1 is the error, h_2 the height of mercury measured in the column, and d_1 and d_2 are the diameters of the reservoir and mercury column respectively [6]. The true pressure is given by the sum of the height of the mercury column (h_2) and the correction factor at that pressure (h_1). From the diameters of the LSH sphygmomanometer reservoir and mercury column, the size of error throughout the pressure scale is consistent with a failure to calibrate the digital scale for the fall of mercury in the reservoir when pressure is applied.

In the comparison of paired LSH and Hawkesley recordings, the LSH sphygmomanometer was found to underestimate blood pressure by a mean of 7·1 mmHg and 3·6 mmHg for systolic and diastolic pressures respectively. Furthermore, the differences between the LSH and Hawkesley diastolic recordings were negatively correlated with heart rate (r −0·27, $P < 0·05$). Similarly, the differences between the LSH and Remler recordings were negatively correlated with heart rate for systolic (r −0·24, $P < 0·001$) and diastolic (r −0·36, $P < 0·001$) pressures.

TABLE 1. *Comparison of Remler, Hawkesley and LSH sphygmomanometer blood pressure recordings*

Mean pressures ± SD are shown. n, Number of recordings; NS, not significant.

Systolic (mmHg)		Diastolic (mmHg)	
Remler	LSH	Remler	LSH
$n = 153$		$n = 153$	
158·7 ± 32	152·8 ± 30·6	92·3 ± 13·1	87·6 ± 12·9
Mean bias + 5·9		Mean bias + 4·7	
$P < 0·001$		$P < 0·001$	
Remler	Hawkesley	Remler	Hawkesley
$n = 65$		$n = 63$	
159·3 ± 28·4	159·8 ± 28	99·8 ± 16·5	99·5 ± 16·7
Mean bias − 0·5		Mean bias + 0·3	
NS		NS	
LSH	Hawkesley	LSH	Hawkesley
$n = 80$		$n = 80$	
133·3 ± 36·2	140·4 ± 32·8	82·4 ± 20·3	86 ± 19·9
Mean bias − 7·1		Mean bias − 3·6	
$P < 0·001$		$P < 0·001$	

Discussion

The results of this study agree with those of Beevers [3] and Fong [4] showing that the Remler gave higher systolic and diastolic recordings than the LSH sphygmomanometer. However, this is due to the LSH sphygmomanometer underestimating blood pressure rather than an inaccuracy in the Remler M2000. The LSH sphygmomanometer underestimates blood pressure for two reasons. Firstly, the device is not calibrated for the lag in the rise of mercury in the glass column which results from a fall in the mercury level of the reservoir when pressure is applied. However, the LSH sphygmomanometer underestimates blood pressure by more than would be predicted from a calibration error alone. This can be explained by the observer selecting a different end-point for the LSH than for other sphygmomanometers, including the Remler M2000. The mercury columns of the LSH sphygmomanometer are hidden from view and at least two sounds must be heard before the observer can indicate the systolic point with confidence. Similarly with the diastolic end-point, the observer has to delay indicating the pressure until some point after the last sound has been heard, i.e. that point where a sound is expected but fails to occur. This is confirmed by the effect of heart rate on the differences between the LSH and Remler systolic and diastolic recordings and between the LSH and Hawkesley diastolic recordings. At higher heart rates the error is less, but at lower heart rates it increases to a degree depending on the rate of cuff deflation.

In conclusion, the Remler M2000 semiautomatic blood pressure recorder was found to be accurate in comparison with the Hawksley random-zero sphygmomanometer. The LSH sphygmomanometer underestimates blood pressure and should not be used as a reference standard.

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