Automatic measurement of blood pressure: evaluation of the Copal UA-231 automatic sphygmomanometer

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SUMMARY The suitability of an automatic sphygmomanometer for epidemiological work was evaluated in two studies. In the first, blood pressure measurements were made alternately on the automatic machine and on a Hawksley random zero instrument on 14 volunteers on each of four consecutive days by a single medical observer. No significant difference was found between the mean diastolic pressure obtained by each instrument but the mean systolic pressure was 5 mm higher on average on the automatic machine. In the second study, the effect of cuff position for the automatic instrument was examined. Differences between recommended and errant cuff positions of up to 4.5 mmHg were recorded but these did not reach statistical significance. These studies indicate that if used carefully this automatic instrument is suitable for survey and experimental use.

For epidemiological purposes, the manual taking of indirect blood pressure has various limitations. Of particular importance are observer effects. Rose et al detail some possible sources of observer error, including differences in mental concentration, procedure, and the interpretation of Korotkow sounds. To these may be added experimenter effects, where beliefs about the hypothesis under test may influence the observer's performance. In many studies it is impossible or impracticable to keep the observer blind to either covariates of blood pressure, such as age and weight, or the identity and order of experimental treatments. At least two manually operated sphygmomanometers have been designed to reduce observer effects but as an observer is still involved in the positioning of the cuff and in interpreting the beginning and end of the Korotkow sounds the possibility of observer effects has not been eliminated. Effects of Korotkow sound interpretation may, however, be eliminated by the use of automatic Korotkow sound detection.

There are many automatic Korotkow sound detection instruments but adequate information on their performance is rarely available. Reported here is a brief description of the UA-231 and two studies evaluating the performance of the UA-231. The first study compared the UA-231 with the widely used and accepted, manually operated Hawksley "random zero-muddler" sphygmomanometer. The Hawksley sphygmomanometer has been shown to compare well with direct intra-arterial measurement. The second study examined the effect of cuff position.

Description and operation of UA-231

The Copal UA-231 can be battery or mains powered. Korotkow sound detection is by microphone which is incorporated into the cuff. Pressure measurement range is between 20 and 280 mmHg, and the measurement cycle time, which increases with blood pressure, is around 40 seconds. The operation sequence is as follows. The brachial artery is palpated and located about 2 inches above the medial epicondyle, and the cuff is positioned with the microphone over the brachial artery at this point. The cuff inflates automatically to a level preset by the operator on the basis of the subject's estimated systolic pressure (the default level being 210 mmHg) and deflates continuously at approximately 5 mmHg per second. Systolic measurement is determined at Korotkow phase 1 (the initial detection of returning blood flow) and the diastolic measurement is determined at Korotkow phase 5 (the completed restoration of blood flow). Heart rate is estimated using the first five beats after systolic measurement. After diastolic measurement the cuff rapidly deflates, and readings are given on a liquid crystal display. This instrument is compact (case dimensions are 17 x 26 x 7 cm), light (the overall weight 1.2 Kg), and portable.

Study 1

METHOD
It was decided to compare the UA-231 and Hawksley
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sphygmomanometers in the taking of "casual" blood pressure, that is, to simulate the conditions likely to prevail in population surveys. User differences were eliminated, and the likelihood of incorrectly using either instrument was reduced as only one of the authors (JWGY), a physician, used both instruments. Although the automatic instrument was fitted and operated by the physician, he was blind to its readings until the study had been completed. To eliminate both order effects and between subject variation a cross-over repeated measures design was used. Thus 14 volunteers aged 23 to 57 (9 female) were recruited to have two consecutive blood pressure measurements taken, one with each instrument, at the same time of day on each of four consecutive days. The order in which each instrument was used was predetermined in each subject by random allocation.

RESULTS

All subjects completed the study. The range of blood pressure was wide, systolic pressures ranging from 80 to 220 mmHg while diastolic pressures ranged from 43 to 135 mmHg. Table 1 gives mean values of each day's readings for each machine. Analysis of variance showed the UA-231 to read significantly higher than the Hawksley for systolic pressure (F = 8.31; df = 1/91; p<0.01). The overall mean difference in systolic readings between the sphygmomanometers was 5.2 mmHg. The difference in diastolic pressure was small and not statistically significant (F = 0.25). The figure shows the correlation and regression between instruments for systolic and diastolic pressures. For both measurements the correlation coefficient between instruments was r = 0.96. The regression of UA-231 readings on Hawksley readings for systolic and diastolic pressure gave equations which did not differ significantly from one having a slope of 1.

### Table 1 Mean values (SD) of blood pressure readings for each machine on each day (n = 14)

<table>
<thead>
<tr>
<th>Day</th>
<th>Overall mean</th>
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<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td></td>
</tr>
<tr>
<td>Hawksley</td>
<td>117.1 (18-2)</td>
</tr>
<tr>
<td>UA-231</td>
<td>122.8 (20-6)</td>
</tr>
<tr>
<td>Diastolic</td>
<td></td>
</tr>
<tr>
<td>Hawksley</td>
<td>74.9 (14-0)</td>
</tr>
<tr>
<td>UA-231</td>
<td>76.1 (16-0)</td>
</tr>
</tbody>
</table>

Correlation and regression between blood pressure values obtained using the Hawksley and UA-231 sphygmomanometers. Values are the average for each subject over four days.

Systolic Correlation r = 0.96  
Regression UA-231 = -6.8 + 1.1 Hawksley

Diastolic Correlation r = 0.96  
Regression UA-231 = -5.0 + 1.07 Hawksley

Study 2

METHOD

To investigate the effect of cuff position on readings from the UA-231 the optimal position as described by the manufacturer was compared with two errant positions. The optimal position is the pulse point approximately 2 inches along the brachial artery from the medial epicondyle. A proximal errant position was defined as the pulse point as far up the brachial artery as the cuff would allow. A lateral errant position was defined as the point overlying the biceps tendon. To be able to account for carry-over effects of repeated measurements a balanced design was used where each cuff position followed each other cuff position in order of measurement an equal number of times for the group as a whole. Twelve volunteers aged 25 to 56 (6 female) were recruited to have three consecutive blood pressures taken, one in each position.

RESULTS

All subjects completed the study. Systolic blood pressure ranged from 91 to 196 mmHg, and diastolic
blood pressure ranged from 44 to 124 mmHg. Table 2 gives actual mean blood pressure values and mean values adjusted for order and residual effects for each cuff position. For the adjusted mean systolic pressure, a maximum difference of 3.5 mmHg occurred between positions and for the adjusted mean diastolic pressure a maximum difference of 4.5 mmHg occurred between positions. No consistent pattern of cuff position differences was found between systolic and diastolic pressure. Analysis of variance showed no significant cuff position effects for systolic (F = 0.17, df = 2/18) or diastolic (F = 2.42) pressure.

<table>
<thead>
<tr>
<th></th>
<th>Optimal position</th>
<th>Lateral position</th>
<th>Proximal position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>121.3 (25.8)</td>
<td>123.3 (28.1)</td>
<td>122.0 (22.8)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>75.0 (13.2)</td>
<td>81.0 (17.1)</td>
<td>78.3 (14.9)</td>
</tr>
<tr>
<td>Adjusted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>123.0</td>
<td>123.0</td>
<td>120.5</td>
</tr>
<tr>
<td>Diastolic</td>
<td>75.9</td>
<td>78.0</td>
<td>80.4</td>
</tr>
</tbody>
</table>

**Discussion**

These studies have shown the UA-231 to provide comparable diastolic estimations of blood pressure to those of a widely used and accepted sphygmomanometer but a systematic difference of 5 mmHg in systolic pressure was noted. This difference in systolic pressure was, however, no greater than might be expected between observers using the Hawksley instrument. A different systematic difference between instruments might have been found with another observer.

A limitation in this evaluation of the UA-231 was an estimation of user differences. The automation of blood pressure measurement using the UA-231 requires the user to posture the subject and fit the cuff. The effect of cuff position was investigated. Although differences in blood pressure due to posture were not studied these would not be peculiar to this instrument.8,9

Further observation on the UA-231 may be of interest. The automatic pump is mildly noisy and may be disconcerting to some subjects at first. The likely effect of the familiarity of subjects with the UA-231 on blood pressure can be shown from study 1 in which 8 out of 14 subjects were unfamiliar with the instrument at the beginning of the study. In study 1, no effect of measurement on different days, which would reflect familiarity, was detected for either systolic pressure (F = 0.21; df = 3/91) or diastolic pressure (F = 2.27). Nevertheless any effect of familiarity with UA-231 may be reduced, by operating the instrument in the presence of subjects before taking blood pressure, or removed where appropriate by using a suitable experimental design.

When measuring blood pressure the instrument emits auditory signals to indicate the beginning of measurement, the measurement of heart rate and the end of measurement. Although this may be helpful for clinical work, for research purposes it is a source of information to the subject which may contaminate the measurement, particularly in experimental situations. However, the signal can be stopped by disconnecting the signal generator inside the instrument. The heart rate estimation by the UA-231, based on an average of the first five beats after the systolic pressure, is clearly vulnerable to error from arrhythmias, and the 40 second cycle time makes it unsuitable for use in situations requiring measurement of extremely fast changes in blood pressure or heart rate. However in the majority of surveys and experiments heart rate measurement error would decrease with increased sample size, and the 40 second cycle time would be adequate. Finally, in all the 116 measurements made by the UA-231 during these studies five (4%) failures to obtain the measurement at first attempt occurred. Three of these were due to underestimation of the subject's systolic pressure and two were due to subject movement during measurement. Possible effects of this were mitigated by a quick deflation of the cuff after malfunction, allowing the measurement cycle to be repeated immediately.

In conclusion, this instrument, when used within its limitations, appears capable of producing comparable readings with a widely accepted method of indirect blood pressure measurement. Its simplicity of use and lack of observer bias make it suitable for survey and experimental use.

The Copal UA-231 may be obtained from Andrew Stephens (1947) Company, 41 Dickson Road, Blackpool, Lancashire, price £105 including p + p and VAT.

**References**

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