Prevalence of end-digit preference in recorded blood pressure by nurses: a comparison of measurements taken by mercury and electronic blood pressure-measuring devices

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Abstract

Objectives: When compared with the use of a mercury sphygmomanometer, the use of a validated digital blood pressure (BP) measuring device eliminates the risk of exposure to mercury. Digital devices are also associated with a lesser degree of end-digit preference (EDP). EDP refers to the occurrence of a particular end digit more frequently than would be expected through chance alone. There have been only a few reports from Africa on the occurrence of EDP in BP measurement. This study examined EDP in BP taken by nurses before and after the introduction of a digital BP-measuring device.

Design: The design was a retrospective study.

Settings and subjects: We reviewed the BP readings of 458 patients who presented at the dedicated clinic for people living with human immunodeficiency virus/acquired immune deficiency syndrome of Ladoke Akintola University of Technology Teaching Hospital, Osogbo, Nigeria, before and after the introduction of the digital BP-measuring device.

Outcome measures: The prevalence of end-digit zero of systolic and diastolic BP readings before and after the introduction of the digital device was compared using McNemar's test.

Results: There was a large and significant fall in end-digit zero when BP readings that were taken using the mercury and digital devices were compared (systolic 98.1% vs. 10.9%, p-value < 0.001; diastolic 97.1% vs. 14.9%, p-value < 0.001 (McNemar's test).

Conclusion: There was a significant reduction in the frequency of end-digit zero when BP was taken with the digital device rather than the mercury device. Regular training and certification of healthcare workers in BP measurement is recommended to ensure a high quality BP measurement standard.

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Introduction

The accurate measurement and recording of blood pressure (BP) is critical to many processes. These include the diagnosis of hypertension, the decision to start antihypertensive medication and the assessment of the adequacy of blood pressure (BP) control. Also included is the need for modification of treatment in those with inadequate BP control, and the recruitment of participants for clinical trials on hypertension, and by implication, the validity of such trials' findings.[1-5] Although BP measurement is one of the basic clinical skills,[6,7] studies have shown that various cadres of healthcare workers rarely conform to standardised guidelines on BP measurement. This leads to various errors.[8-13]

Rose et al[14] described three types of observer errors, namely a systematic error (where the observer consistently reads a lower value than other people); observer prejudice or bias (where the observer adjusts the BP reading to meet his or her preconceived notion of what it should be, or below a target threshold value); and end-digit preference (where the observer reads to a preferred digit more commonly than the other digits, most often to zero. This is an indicator of low quality BP measurement).

In view of the fact that mercury sphygmomanometers are calibrated in increments of 2 mm Hg, individual readings should only end in 0, 2, 4, 6 and 8. If BP measurements are carried out strictly according to guidelines, the expected prevalence of each of the digits should be 20%. On the other hand, digital devices are calibrated in increments of 1 mm Hg, so the expected prevalence of end digit 0-9 should be 10%. The prevalence of ED 0 ranged from 22-99.7% in published studies. It has been shown to occur with physicians and nurses, in primary healthcare practice, academic practice and clinical trials.[15-23]

End-digit preference can lead to underestimation or overestimation of BP, with dire consequences. Underestimation of BP can cause under-diagnosis of hypertension or under-treatment of those who have already been diagnosed with hypertension. There is a consequent increase in morbidity and mortality.[24] On the other hand, overestimation of BP can lead to over-diagnosis of hypertension, needless lifetime exposure to medication expense and attendant side-effects, an increased health insurance premium and loss of income due to loss of work or unnecessary hospitalisation.[25,26]

Due to the health hazards that are associated with exposure to mercury, in clinical practice, mercury sphygmomanometer is gradually being phased out. Validated digital BP-measuring devices are increasingly being used in clinical and research settings.[27] The use of digital devices has been found to be associated with a lesser degree of end-digit preference and hence, improvement in BP measurement.[15,28] However, there have been only a few reports from Africa on end-digit preference.[11,16] A recent report by Ayodele et al[16] documented the frequency of end-digit preference for zero in 98.5% of systolic and diastolic BP readings by traditionally-trained nurses in a hypertension specialty clinic in south-west Nigeria. To our knowledge, no report from Nigeria has investigated the hypothesis that the use of a digital manometer is associated with lesser frequency of end digit 0. This study examined the end-digit preference in BP that was taken by our nurses using the mercury sphygmomanometer and assessed the impact of the introduction of a digital BP-measuring device on the prevalence of end-digit preference.

Method

We retrospectively reviewed the medical records of patients who attended the dedicated clinic for people living with human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS). This was the only clinic in our hospital with a digital BP-measuring device at the time that this study was conducted. The study period was between 1 July 2010 and 31 January 2011. We included all patients with at least two BP readings using the mercury sphygmomanometer, and at least two BP readings using the A&D UA-767® automated digital BP-measuring device that has been clinically validated by the British Hypertension Society.[29] Standard and large cuffs were available with the BP-measuring devices. In the clinic, the patient's BP is first checked by a nurse, prior to his or her evaluation by the attending doctor. The nurses who work in this clinic had not had additional training or certification in BP measurement, aside from regular nursing training. We excluded patients who had BP recordings obtained by the mercury sphygmomanometer and who were subsequently lost to follow-up before the introduction of the digital device in the clinic. We also excluded patients who were seen after the introduction of the digital device and who had no BP recordings taken using the mercury device. Patients with documented arrhythmias were also excluded. The last two clinic BP readings that used a mercury sphygmomanometer prior to the introduction of the digital device, and the last two clinic BP readings prior to the commencement of the study, were extracted from the folder.

The study population comprised 458 participants. A total of 916 BP readings that were taken by the mercury sphygmomanometer, and 916 BP readings taken by the digital manometer, were analysed. The end digit of the BP readings was used for analysis. The last recorded clinic weight (kg) and height (metres) of the patients were extracted from the folder. The body mass index (BMI), (presented kg/ m^2), was calculated from weight (kg)/height^2 (m^2).[30] Patients who were on highly active antiretroviral (HAART) medications were also noted. Hypertension was defined as persistent systolic BP $\geq$ 140 mm Hg, and/or diastolic BP $\geq$ 90 mm Hg, or the use of blood pressure-lowering medications.[1]

Ethical approval for the study was obtained from the research ethics committee of Ladoke Akintola University of Technology Teaching Hospital, Osogbo, Osun State, Nigeria.

Continuous variables were summarised as means (standard deviation). Categorical variables were displayed as percentages. Distribution of the end digits of systolic and diastolic BP values that were measured using the mercury and digital devices was noted. The prevalence of end digit 0 before and after introduction of the digital device was compared using McNemar's test. A p value < 0.05 was considered to be statistically significant. Statistical analysis was carried out using Statistical Package for Social Sciences® (SPSS) software, Version 16 (SPSS, Chicago, Illinois, USA). The figures were constructed using the Microsoft Office Excel® 2007 Version.

Results

The demographic and clinical characteristics of the study population are as shown in Table I below.

The study population comprised 458 participants [121 males (26%) and 337 females (74%)]. The mean age of the study population was 38.3 ± 9.8 years (a range from

Table I: Baseline characteristics of the study population

Variables	Male (n = 121, %)	Female (n = 337, %)	Total (n = 458, %)	p-value
Mean age ± SD (years)	42.7 ± 11	36.8 ± 8.9	38.3 ± 9.8	< 0.001
Mean weight ± SD (kg)	68.1 ± 10.1	62.7 ± 13.7	64.1 ± 13.1	< 0.001
Mean height ± SD (m) (n = 419)	1.70 ± 0.07	1.61 ± 0.06	1.63 ± 0.08	< 0.001
Mean BMI ± SD (kg/m^2) (n = 419)	23.6 ± 3.6	24.2 ± 4.8	24.0 ± 4.5	0.179
Mean SBP ± SD (mm Hg): mercury device	113 ± 18	106 ± 16	108 ± 17	< 0.001
Mean DBP ± SD (mm Hg): mercury device	72 ± 12	68 ± 11	69 ± 12	< 0.001
Mean SBP ± SD (mm Hg): digital device	124 ± 21	113 ± 18	116 ± 20	< 0.001
Mean DBP ± SD (mm Hg): digital device	76 ± 13	73 ± 13	74 ± 13	< 0.001
Hypertensive	23 (19)	24 (7.1)	47 (10.3)	< 0.001
On HAART	113 (93.4)	299 (88.7)	412 (90)	0.128

BMI: body mass index, DBP: diastolic blood pressure, HAART: highly active antiretroviral therapy, SBP: systolic blood pressure, SD: standard deviation

Table II: Distribution of end-digit preference for systolic and diastolic blood pressure

Terminal digit	SBP readings (n = 916)	Percentage of readings	DBP readings (n = 916)	Percentage of readings
Mercury sphygmomanometer				
0	898	98	890	97.1
2	2	0.2	4	0.5
4	4	0.5	7	0.7
5	3	0.3	2	0.2
6	6	0.7	6	0.7
8	3	0.3	8	0.8
Digital manomter				
0	100	10.9	136	14.9
1	72	7.8	56	6.1
2	116	12.7	115	12.6
3	73	8	69	7.5
4	117	12.8	116	12.7
5	75	8.2	81	8.8
6	119	13	103	11.2
7	74	8.1	67	7.3
8	102	11.1	97	10.6
9	68	7.4	76	8.3

18-76 years). Males were significantly older than the females (42.7 ± 11.0 vs. 36.8 ± 8.9 years, p-value < 0.001). The males were also significantly heavier and taller than the females and had significantly higher SBP and DBP when BP was checked using the mercury and electronic BP-measuring devices. In addition, the males had a higher prevalence of hypertension than the females. However, there was no statistically significant gender difference with regard to the BMI and the number of patients who were on HAART.

Table II shows the distribution of end-digit preference for systolic BP and diastolic BP, when BP was taken using the mercury and digital devices.

The respective prevalence of end digit 0 for systolic and diastolic BP was 98.1% and 97.1% respectively, when BP was taken with the mercury sphygmomanometer. The prevalence of end digit 0 for systolic and diastolic BP was 10.9% and 14.9 respectively, when the BP was taken using the digital manometer. The frequencies for the even-end digits (2, 4, 6 and 8) were higher than those of the odd-end digits (1, 3, 5 and 7). The overall lowest digit frequencies were digit 1(7.8%) and digit 9 (7.4%) for systolic BP readings, and digit 1 (6.1%) and digit 7 (7.3%) for diastolic BP readings. There was a large and significant fall in end digit 0 when readings that were taken using the mercury and digital devices were compared (systolic BP 98.1% vs. 10.9%, p-value < 0.001; diastolic BP 97.1% vs. 14.9%, p-value < 0.001 (McNemar's test).

Discussion

We found a high prevalence of end digit 0 in the BP that was taken by our nurses using the mercury device. The frequencies of end digit 0 of 98.1% for systolic BP, and 97.1% for diastolic BP in this study are similar to the 98.5% to 99.7% that was obtained by traditionally trained nurses as reported by Roubsanthisuk et al[23] and Ayodele et al.[16] However, these frequencies of end digit 0 were higher than the 20-54% reported by hypertension specialist clinics outside Africa.[20-22]

The high frequency of end digit 0 indicated that our nurses are rounding BP to the nearest 10 mm Hg. The lower frequency of end-digit preference in hypertension specialist clinics, compared to our setting, can be attributed to the frequent training and certification in BP measurement of the nurses who work in specialist hypertension clinics.[20-22] Reports have shown that traditionally trained health personnel, who have not received additional training in BP measurement, do not follow recommendations and guidelines on BP measurement. They often display a high end-digit preference frequency.[8,9,11,13,16-19,22,23] The good news is there is considerable evidence that regular training of healthcare workers on BP measurements, with frequent monitoring and feedback on data quality, minimises end-digit preference and improves the quality of BP measurement. This is the case, even when the BP measurements are carried out using a mercury sphygmomanometer.[3,5,21-24]

The use of an automated BP-measuring device resulted in a better distribution of end digit and a significant reduction in the prevalence of end digit 0. This is consistent with earlier reports.[15,28] However, there was still a slight increase in the prevalence of end digit 0 for systolic BP (10.9%) and diastolic BP (14.9%). The frequencies of even end digit were clearly higher than the odd end digit. This is consistent with the report by Burnier et al.[15] The reason for the increased frequency of even end digits over odd end digits is not known. However, Burnier et al[15] raised the possibility that errors may have occurred during the transfer of the BP values from the digital device to the case folder. They suggest that healthcare workers may have unconsciously preferred to record even, rather than odd, digits. We did not investigate for such an error, but it could be avoided by electronic transferring or printing the BP records from the electronic device to the folder. Although the use of electronic devices may help in reducing or eliminating end-digit preference, it does not eliminate other errors, such as inaccurate cuff selection and application, incorrect cuff positioning, an inadequate rest period and the posture of the subject.[7] Thus, in order to ensure correct measurement of BP, healthcare workers must be trained in BP measurement and regularly certified.[21] Regular monitoring and feedback on end digit and number preference should be implemented to minimise observer bias and measurement errors.[5]

In recent times, debates abound in the literature on whether mercury sphygmomanometer should be retained in clinical practice for BP measurement. This is in view of the toxicity of mercury, following contamination of the environment.[31,32] While a memorandum of understanding on the elimination of mercury waste, that was signed between the United States Environmental Protection Agency and the American Hospital Association, has resulted in the voluntary withdrawal of mercury manometers from hospital settings in the US since 1998,[7] no such memorandum of agreement exists between the Nigerian Environmental Protection Agency and hospitals in Nigeria. Thus, it is likely that mercury manometers are still in use in many hospitals and clinics in Nigeria and perhaps many parts of Africa. The low cost of purchasing and maintaining mercury manometers (there is no need for electricity or a battery); its simple design (it is a gravity-based unit with easy calibration); its arguably infrequent need for repair; its validation in many clinical circumstances against direct intra-arterial BP measurements; and the rarity of reported health problems associated with exposure to elemental mercury that is enclosed in sphygmomanometer; will make the continued use of mercury manometers more attractive than digital devices in hospitals and clinics in Nigeria and many parts of Africa.[32]

Our study had a few limitations. In view of the retrospective nature of the study, we could not assess whether our nurses rounded off the BP values up or down to the nearest 10 mmHg (judging by the high frequency of end digit 0). We were not able to assess whether the BP measurement were carried out strictly according to the guidelines on BP measurement.

In conclusion, our study showed a high prevalence of end digit 0 in BP measurements that were taken with a mercury sphygmomanometer, and a significant reduction in the frequency of end digit 0 and better distribution of end digits among BP values that were obtained using the automated device. We envisage that mercury manometers are likely to remain the main instrument for BP measurement in most hospitals in Nigeria and many countries in Africa. We recommend regular training and certification of healthcare workers in BP measurement. Regular monitoring and feedback on end digit and number preference should be carried out in order to ensure a high quality standard in BP measurement.

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