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Blood pressure measurement: we should all do it better!¹

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'Because blood pressure (BP) measurement is a simple procedure, it is taken for granted that all graduates from medical training programmes have the ability to record accurate, precise and reliable BP readings. However, research since the 1960s has shown this assumption to be false. Most health professionals do not measure BP in a manner known to be accurate and reliable. If you doubt this statement watch as BPs are taken in your own clinical setting to determine whether the guidelines discussed herein are followed and then examine recorded readings for signs of observer bias.' This citation is taken from a chapter by Carlene and Clarence Grim, both very experienced BP researchers and teachers, in a recent book.² Earlier, these authors published a curriculum for the training and certification of BP measurements for the healthcare providers.³

BP measurement is nowadays recognised as probably the most commonly performed clinical procedure. Nurses, physicians, medical students and even patients measure BP routinely. BP can be measured directly (intra-arterially) or indirectly. The first method represents the 'gold standard' for BP measurements but is invasive, requiring arterial cannulation and is therefore only used in particular (research) circumstances. The indirect method is widely used in both daily practice and research.

Many BP measuring devices have been developed in the last decades. However, measurement of BP using a mercury sphygmomanometer and a stethoscope according to the Korotkoff's auscultatory principle remains the cheapest and most accurate (when compared with intra-arterial readings), and is considered the noninvasive gold standard, providing that the measurement is performed correctly. The tendency to ban the use of mercury, a toxic substance, in clinical practice is leading to mercury sphygmomanometers being replaced by alternative instruments. Most of these

devices are based on the oscillometric principle. However, only a limited number of them have already been validated. Several factors affect indirect BP readings.

FACTORS RELATED TO PATIENT

Some of the factors affecting the BP are related to the person in whom the BP is being measured, commonly referred in the literature as biological variation (*table 1*).

Rest period

It has been recommended that the BP should be measured after several minutes rest to allow the BP to stabilise.^{4,7} However it is not exactly known how long the rest period should be. Average drops in the systolic BP (SBP) of 9 and 14 mmHg, respectively, have been reported after a rest period of four and eight minutes prior to the BP measurement. The decrease was less evident in the diastolic BP (DBP), amounting to 3 and 4 mmHg, respectively, for the same rest intervals.⁸ These results are consistent with the results of other studies that also report a decrease of similar magnitude within the first five to ten minutes of rest.^{9,13} A longer rest period of more than 25 minutes was found to further slightly decrease the BP values, especially the SBP, but the question remains whether such a long rest period is feasible in general practice.^{9,13} On the other hand, clinical experience shows that in a few patients the BP increases if they have to wait to have their BP measured. These patients can be traced by measuring the BP both immediately after assuming supine or sitting position and after the rest period. Based on this data, it has been recommended that at least five minutes of rest should be allowed before the measurement of BP.¹⁴

Table 1

Factors that affect indirect blood pressure readings with a mercury sphygmomanometer and a stethoscope

FACTORS THAT INFLUENCE INDIRECT BLOOD PRESSURE READINGS

Related to the patient

Resting time
Diurnal variation
Seasonal variation (changing in temperature)
'White coat' effect
Pain, anxiety
Acute smoking or ingestion of alcohol or caffeine
Postprandial state
Distended bladder
Talking
Degree and type of activity
Between arm differences
Paretic arms
Special factors (arrhythmia, 'silent gap', soft Korotkoff sounds)

Related to the observer

Training
Terminal digit preference
Expectation bias
Impaired hearing

Related to the instruments and technique

Instrument accuracy (manufacture errors, maintenance, defects)
Noisy room
Cuff length and width
Tight, thick clothes under the cuff
Body posture (sitting, supine, standing)
Arm level with respect to the right atrium
Arm/wrist/finger cuff
Arm, back and feet support
Inflation and deflation rate
Parallax error

Daily variability *per se*

It has been proven in the literature that there is a substantial diurnal BP variation with a clear fall in BP during the night of up to 15%, as a result of both sleep and inactivity, reflecting the decrease in sympathetic tone.¹⁵⁻¹⁷

Various daytime activities induce increases in BP of different magnitude. Activities accompanied by a large increase in BP of between 10 and 20 mmHg include meetings, physical work, transportation, walking and dressing. Activities accompanied by increases in BP of up to 5 mmHg include deskwork, reading and watching television. Talking results in approximately a 7 mmHg increase in BP and should thus be avoided during BP measurement.¹⁵ Even reduced muscular activity such as inflating one's own cuff during self-recording of BP

produces an increase of approximately 12 mmHg in SBP. The BP returns to its initial level within on average seven seconds but this can take up to 21 seconds. Thus the SBP may be overestimated during self-measurement if the subject does not inflate the cuff to a high enough pressure or deflates it too quickly.¹⁸

Seasonal variability

A seasonal variation of the BP has also been suggested in the literature, showing on average 3 to 8 mmHg higher BP values during the winter than during the summer, even in patients living in a stable environmental temperature.¹⁹⁻²⁵ These differences seem to be inversely associated with the body mass index, possibly due to the increased thermoregulatory requirements of leaner individuals.²⁵ Extrapolating these observations to clinical practice, hypertensive patients may require a lower dose of anti-hypertensive medication during periods of fever or if they move to (sub)tropic countries (holidays, business).

Office vs home BP measurement

Some patients have higher BP levels when taken in the physicians' office than at home. Also the BP can be higher when measured by a physician than by a nurse or a medical student. This phenomenon is known as the 'white coat' effect. When this phenomenon is suspected, nurses rather than physicians should measure the BP and 24-hour ambulatory BP monitoring (ABPM) could be performed,²⁶⁻²⁸ or self-measurement at home.

Various sympathetic stimulators

Pain and anxiety also acutely increase the BP, probably due to increased sympathetic activity.^{29,30} The procedure should therefore be explained adequately beforehand, especially in nervous patients. Patients should also be told that there may be some minor discomfort caused by the inflation of the cuff. A distended bladder is also reported to increase the BP,^{31,32} thus patients should be advised to empty their bladder before the BP measurement.

Various stimulants

Smoking the first cigarette of the day may acutely induce a rise in BP that lasts for 15 to 30 minutes, which is likely due to the acute release of norepinephrine.³³ On the other hand, chronic smoking induces tolerance.³⁴

Ingestion of caffeine-containing beverages may induce an acute rise in BP; however, also here a certain degree of tolerance may occur with repeated consumption and it is also dependent on individual plasma half-life of caffeine.³⁵⁻³⁹ Other ingredients in coffee apart from caffeine may also be responsible for the cardiovascular activation.³⁵⁻³⁸ Eating as an activity increases BP by 8 to 9 mmHg;¹⁵ however a postprandial decrease in BP can also be noted, especially in elderly patients.⁴⁰⁻⁴³

Ingestion of alcohol can also acutely increase BP.⁴⁴ Thus smoking, eating, consuming of alcohol or caffeine-containing beverages and chocolate should be avoided for at least an hour before the measurement of BP. Otherwise, a note should be made that this is a possible confounder.

Anatomy

There has been much controversy in the literature as to whether there is a difference between the BP readings in the two arms. Some authors recommend that BP should initially be measured in both arms and if, after at least three readings significant systematic difference (>10 mmHg) is found, the BP should routinely be measured in the arm with the highest value.⁴⁵⁻⁴⁹ A special remark should be made with respect to the BP measurement in hemiplegic patients. In one study, the BP was higher in the paretic arms of patients with a spastic stroke and lower in the affected arm if the tone was flaccid.⁵⁰

Other factors

The BP measurement can be particularly difficult in patients with arrhythmias, especially atrial fibrillation, soft Korotkoff sounds or a 'silent gap'. These factors must be taken into account especially when the BP is measured using electronic devices as many of these instruments are not validated for use in such cases.⁵¹⁻⁵³

FACTORS RELATED TO OBSERVER

The person who is measuring the BP (the observer) requires meticulous and repeated theoretical and practical training and validation of his/her ability to measure the BP accurately (*table 1*).^{51,54-57} However, even when the technique of measurement is correct, a number of factors can cause a bias in the BP reading. Observers may interpret the Korotkoff sounds differently. Also, observers very often have a terminal digit preference, which in the majority of cases is 0 (75%) or 5 (25%). Moreover, observers may be influenced by the knowledge of previous BP values during serial readings (expectation bias). They may also tend to read higher or lower values at threshold levels.⁵⁴⁻⁶³ At least older (above 55 years) physicians and nurses should have their hearing tested regularly if they routinely measure BP using a stethoscope.

FACTORS RELATED TO INSTRUMENTS AND TECHNIQUE

Instrument

The measuring device used and the measurement technique can induce large variations in BP.^{54,64} There is a

wide range of BP measuring devices on the market but unfortunately only a few of these devices have been validated according to official standards.⁶⁵ With the traditional mercury sphygmomanometers the regular control concerned three points: 1) adequate filling of the mercury reservoir; 2) replacement of the glazed tube in case of mercury precipitation; 3) replacement of the rubber connections in case of leak. But now the banning of mercury has been accepted worldwide, aneroid devices are usually chosen as substitutes, and those devices should regularly be checked against mercury (or an adequate substitute).^{66,67} There is no clear evidence about what the interval should be between the check-ups, since the interval is dependent on the situation. For example, instruments used by midwives need to be checked every six months, whereas devices used in hospitals could be initially checked after two years and then yearly. In general, the maintenance of mercury sphygmomanometers or alternatives available in many hospitals is not optimal.

When the newer devices, mostly based on the oscillometric principle, are used, it should be realised that these devices measure the mean arterial pressure and calculate the systolic and diastolic BP, based on an (industrially secret) algorithm which may vary in different devices or in newer types. The significance of the principle or algorithm is clearly demonstrated in diabetic patients. In a group of normoalbuminuric type I diabetes patients the BP measured with an oscillometric device (Dinamap) was overestimated in comparison with the same BP measured using a mercury sphygmomanometer.⁶⁸

Environment

The measurements should be performed in a quiet environment, as noisy rooms make it difficult for the patient to relax and the observer to concentrate and adequately hear Korotkoff sounds. Room temperature should be not too high or too low either.

Bladder size

The inflatable bladder size also requires attention. The length of the bladder should be enough to encircle at least 75 to 80% of the arm and the width of the bladder should be equal to about two-thirds the distance from the axilla to the antecubital space. The BP may be overestimated by using too narrow or too short bladders. The former standard bladder was 12 x 26 cm, making it possible to measure BP in subjects with an arm circumference up to 31 cm. Bladders of 13 x 36 cm were shown to be adequate for patients with arm circumferences up to 48 cm. The use of large cuffs in lean patients has yet to be clarified.^{69,70} The cuff should be placed on the bared arm, tight or thick clothes under the cuff should be avoided.

Position of body and arm

Other factors of clinical relevance for the BP measurement are the position of the patient during blood pressure measurement and the arm level with respect to the reference level of the right atrium. Most recent official guidelines for the BP measurement^{5,7,71} recommend that BP should be routinely measured with the patient in the sitting position with the arm supported at the level of the right atrium. To detect orthostatic hypotension the BP should be measured in the supine position and then in the upright position but again, the arm in which the BP is measured should be placed at the level of the right atrium in all positions. The level of the fourth intercostal space⁷² or the midsternum have been proposed as practical approximation of the right atrium level in the sitting and standing positions.⁷³ It has previously been shown that supporting the arm of the patient below the right atrium results in an over-estimation of BP of approximately 0.7 mmHg for each cm deviation from the right atrium level.⁷⁴⁻⁸⁷ Such errors can occur, for instance, in a patient who is standing with his arm hanging parallel to the body (along the side) or in a sitting patient whose arm is supported by the arm rest of the chair or by a regular office desk. Vice versa, placing the patient's arm above the level of the right atrium results in lower BP readings by the same order of magnitude as mentioned above.^{81,82} Furthermore, the assumption that the BP readings taken in the sitting and supine positions are equivalent proved to be inadequate.^{74,88-93} Especially when the patient's arm is carefully placed at the correct right atrium level, a significantly higher BP (about 9 mmHg for the SBP and about 5 mmHg for the DBP) was found in the supine than in the sitting position.^{74,93}

The arms, the back and feet of the patients should be supported to avoid any isometric physical exercise that might increase the BP.

OTHER FACTORS

The bladder should be rapidly inflated to avoid prolonged discomfort for the patient, but slowly deflated at a rate of 2 to 3 mmHg per beat or per second, to accurately record the BP to the nearest 2 mmHg. Failure to do this may result in either too high or too low BP readings.⁹⁴ On the other hand, deflation can be speeded up in second and third readings, especially when there is an increase in pulse pressure (e.g. 224/62 mmHg) since otherwise the procedure may become too painful and pain may increase the BP further.

The centre of the sphygmomanometer scale should be placed at the same level as the eyes of the observer to avoid the parallax effect. According to this effect, higher BP will be read when the observer is watching from

below the scale and vice versa, lower BP will be read when watching from above the scale.⁵⁷

In the last decades, the attention of clinicians and researchers has been very much focused on the development of new BP measuring techniques, with complicated expensive devices operating on various principles. Measuring the BP according to the 100-year-old Korotkoff's auscultatory principle, with a mercury sphygmomanometer and a stethoscope, is sometimes regarded as obsolete. However, when performed in a correct and standardised manner, this technique provides us with one of the best predictors of the patient's cardiovascular status and future events. We subscribe to the point of view of Messerli *et al.*¹ that we should respect and treasure this simple clinical tool. More efforts should be made to standardise the procedure, to implement this standard in practice, to intensively train all medical professionals in correctly measuring the BP and raise awareness of its possible pitfalls.

CONCLUSIONS

BP measurement can be learned by every doctor, nurse, technician and vascular trainee. But one of them, usually the doctor, should be well informed about all the pitfalls, shortcomings, algorithms, and about the validation status of the devices. The doctor should also organise the maintenance procedures of the devices in his/her department. Every co-worker should be controlled at regularly intervals and every newcomer should be trained to become a certificated BP observer.

REFERENCES

1. Messerli FH, White WB, Staessen JA. If only cardiologists did properly measure blood pressure. Blood pressure recordings in daily practice and clinical trials. *J Am Coll Cardiol* 2002;40:2201-3.
2. Grim CM, Grim CE. Manual blood pressure measurement - still the gold standard. In: Weber MA, editor *Hypertension Medicine*. New Jersey: Humana Press Inc, 2001:131-145.
3. Grim CM, Grim CE. A curriculum for the training and certification of blood pressure measurements for health care providers. *Can J Cardiol* 1995;11(Suppl. H):38H-42H.
4. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo LJ, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure. *JAMA* 2003;289:2560-72.
5. European Society of Hypertension - European Society of Cardiology guidelines for the management of arterial hypertension. *J Hypertens* 2003;21:1011-53.
6. Practice Guidelines For Primary Care Physicians: 2003 ESH/ESC Hypertension Guidelines. *J Hypertens* 2003;21:1779-86.

7. Williams B, Poulter N, Brown M, Davis M, McInnes G, Potter J, et al. British Hypertension Society guidelines for hypertension management 2004 (BHS-IV). [Summary]. *BMJ* 2004;328:634-40.
8. Bakx JC, Netea RT, Hoogen HJM van den, Oerlemans G, Dijk R van, Bosch WJHM van den, et al. The influence of a rest period on blood pressure measurement. *Huisarts Wetenschap* 1999;42:53-6.
9. Loo JM van, Peer PG, Thien TA. Twenty-five minutes between blood-pressure readings: the influence on prevalence of isolated systolic hypertension. *J Hypertens* 1986;4:631-5.
10. Shimada K, Ogura H, Sadakane N, Kawamoto A, Matsubayashi K, Ozawa T. Differences within visit blood pressure changes in outpatient clinic. *Hypertension* 1987;10:465-6.
11. Mancia G, Casadei R, Groppelli A, Parati G, Zanchetti A. Effect of stress on diagnosis of hypertension. *Hypertension* 1991;4(suppl.3):56-62.
12. Armitage P, Rose GA. The variability of casual blood pressure. *Clin Sci* 1966;30:325-35.
13. Puddey IB, Jenner DA, Beilin LJ, Vandongen R. Alcohol consumption, age and personality characteristics as important determinants of within-subject variability in blood pressure. *J Hypertens* 1988;6(Suppl 4):S617-9.
14. World Health Organization - International Society of Hypertension guidelines for the management of hypertension. *J Hypertens* 1999;17:151-83.
15. Clark LA, Denby L, Pregibon D, Harshfield GA, Pickering TG, Blank S, et al. A quantitative analysis of the effect of activity and time of the day on the diurnal variations of blood pressure. *J Chronic Dis* 1987;40:671-9.
16. Sternberg H, Rosenthal T, Shaniss A, Green M. Altered circadian rhythm of blood pressure in shift workers. *J Hum Hypertens* 1995;9:349-53.
17. Casiglia E, Palatini P, Colanelli G, Ginocchio G, Di Menza G, Onesto C, et al. 24 h rhythm of blood pressure and forearm peripheral resistance in normotensive and hypertensive subjects confined to bed. *J Hypertens* 1996;14:47-52.
18. Veerman DP, Montfrans GA van, Wieling W. Effects of cuff inflation on self-recorded blood pressure. *Lancet* 1990;335:451-3.
19. Fujiwara T, Kawamura M, Nakajima J, Adachi T, Hiramori K. Seasonal differences in diurnal blood pressure of hypertensive patients living in a stable environmental temperature. *J Hypertens* 1995;13:1747-52.
20. Cheung AK, Yan G, Greene T, Daugirdas JT, Dwyer JT, Levin NW, et al. Seasonal variations in clinical and laboratory variables among chronic hemodialysis patients. *J Am Soc Nephrol* 2002;13:2345-52.
21. Minami J, Kawano Y, Ishimitsu T, Yoshimi H, Takishita S. Seasonal variations in office, home and 24 h ambulatory blood pressure in patients with essential hypertension. *J Hypertens* 1996;14:1421-5.
22. Andersen UO, Henriksen JH, Jensen G, Copenhagen C, Heart Study Group. Sources of measurement variation in blood pressure in large-scale epidemiological surveys with follow-up. *Blood Press* 2002;11:357-65.
23. Prasad GV, Nash MM, Zaltzman JS. Seasonal variation in outpatient blood pressure in stable renal transplant recipients. *Transplantation* 2001;72:1792-4.
24. Brueren MM, Schouten BJ, Schouten HJA, Weel C van, Leeuw PW de, Ree JW van. No relevant seasonal influences on office and ambulatory blood pressure. Data from a study in borderline hypertensive primary care patients. *Am J Hypertens* 1998;11:602-5.
25. Kristal-Boneh E, Harari G, Green M, Ribak J. Body mass index is associated with differential seasonal change in ambulatory blood pressure level. *Am J Hypertens* 1996;9:1179-85.
26. Pickering TG. Blood pressure monitoring outside the office for the evaluation of patients with resistant hypertension. *Hypertension* 1988;11(Suppl II):96-100.
27. Pickering TG. Blood pressure measurement and detection of hypertension. *Lancet* 1994;344:31-5.
28. Mancia G, Parati G, Pomidossi G. Alerting reaction and rise in blood pressure during measurement by physician and nurse. *Hypertension* 1987;9:209-15.
29. Brand HS. Cardiovascular responses in patients and dentists during dental treatment. *Int Dent J* 1999;49:60-6.
30. Brand HS, Gortzak RA, Palmer-Bouva CC, Abraham RE, Abraham-Inpijn L. Cardiovascular and neuroendocrine responses during acute stress induced by different types of dental treatment. *Int Dent J* 1995;45:45-8.
31. Funke PJ, Prabhakar NR, Hertle L, Runkel N, Dahlheim H. Plasma renin activity and cardiovascular changes in patients with chronic bladder distension. *Urol Int* 1982;37:363-8.
32. Ishikawa T, Sato J, Nishino T. Acute changes in bladder volume produce minimal cardio-respiratory responses in lightly anaesthetised humans. *Can J Anaesth* 2000;47:786-91.
33. Groppelli A, Giorgi DM, Omboni S, Parati G, Mancia G. Persistent blood pressure increase induced by heavy smoking. *J Hypertens* 1992;10:495-9.
34. Okubo Y, Suwazono Y, Kobayashi E, Nogawa K. An association between smoking habits and blood pressure in normotensive Japanese men: a 5-year follow-up study. *Drug Alcohol Dep* 2004;73:167-74.
35. Dusseldorp M van, Smits P, Lenders JW, Thien T, Katan MB. Boiled coffee and blood pressure. A 14-week controlled trial. *Hypertension* 1991;18:607-13.
36. Smits P, Schouten J, Thien T. Cardiovascular effects of two xanthines and the relation to adenosine antagonism. *Clin Pharmacol Ther* 1989;45:593-9.
37. Dusseldorp M van, Smits P, Thien T, Katan MB. Effect of decaffeinated versus regular coffee on blood pressure. A 12-week, double-blind trial. *Hypertension* 1989;14:563-9.
38. Corti R, Beggel C, Sudano I, Spieker L, Hanseler E, Ruschitzka F, et al. Coffee acutely increases sympathetic nerve activity and blood pressure independently of caffeine content. Role of habitual versus nonhabitual drinking. *Circulation* 2002;106:2935-40.
39. Watson JM, Sherwin RS, Deary IJ, Scott L, Kerr D. Dissociation of augmented physiological, hormonal and cognitive responses to hypoglycemia with sustained caffeine use. *Clin Sci* 2003;104:447-54.
40. Smith NL, Psaty BM, Ruten GH, Lumley T, Yanez D, Chaves PHM, et al. The association between time since last meal and blood pressure in older adults: the Cardiovascular Health Study. *J Am Geriatr Soc* 2003;51:824-8.
41. Westenberg M, Lenders WM, Thien T. The course of blood pressure after a meal: a difference between young and elderly subjects. *J Hypertens* 1985;3(suppl 3):S417-9.
42. Lipsitz LA. Orthostatic hypotension in the elderly. *N Engl J Med* 1989;321:952-7.
43. Lipsitz L, Nyquist R, Wei J, Rowe J. Postprandial reduction in blood pressure in elderly. *N Engl J Med* 1983;309:81-3.
44. Potter JF, Watson RDS, Skan W, Beevers DC. The pressor and metabolic effects of alcohol in normotensive subjects. *Hypertension* 1986;8:625-31.
45. Petrie JC, O'Brien ET, Littler WA, Swiet M de. Recommendations on blood pressure measurement. *BMJ* 1986;293:611-5.

46. American Society of Hypertension recommendations for routine blood pressure measurement by indirect cuff sphygmomanometry. *Am J Hypertens* 1992;5:207-9.
47. Perloff D, Grim C, Flack J, et al. Human blood pressure determination by sphygmomanometry. *Circulation* 1993;88:2460-70.
48. Campbell NRC, Chockalingam A, Fodor JC, McKay DW. Accurate, reproducible measurement of blood pressure. *Can Med Assoc J* 1990;143:19-24.
49. Haynes RB, Birkett NJ. Tips on measuring blood pressure in adults. *Hypertens Canada* 1984;3.
50. Dewar R, Sykes D, Mulkerrin E, Nicklason F, Thomas D, Seymour R. The effect of hemiplegia on blood pressure measurement in the elderly. *Postgrad Med J* 1992;68:888-91.
51. O'Brien E, Petrie J, Littler W, Swiet M de, Padfield PL, O'Malley K, et al. The British Hypertension Society protocol for the evaluation of automated and semi-automated blood pressure measuring devices with special reference to ambulatory systems. *J Hypertens* 1990;8:607-19.
52. Stewart M, Gough K, Padfield PL. The accuracy of automated blood pressure measuring devices in patients with controlled atrial fibrillation. *J Hypertens* 1995;13:297-300.
53. Imai Y, Abe K, Sasaki S, Minami N, Munakata M, Sakuma H, et al. Clinical evaluation of semiautomatic and automatic devices for home blood pressure measurement: comparison between cuff, oscillometric and microphone methods. *J Hypertens* 1989;7:983-90.
54. Bailey H, Bauer JH. Review of common errors in the indirect measurement of blood pressure. *Sphygmomanometry. Arch Intern Med* 1993;153:2741-8.
55. Bruce NG, Shaper G, Walker M, Wannamethee G. Observer bias in blood pressure studies. *J Hypertens* 1988;6:375-80.
56. Nielsen PE, Oxenboll B, Astvad K, Gyntelberg F. Auscultatory measurement of blood pressure performed by the doctor on duty. *Acta Med Scand* 1975;198:35-7.
57. O'Brien ET, O'Malley K. ABC of blood pressure measurement. The observer. *BMJ* 1979;2:775-6.
58. Hla KM, Vokaty KA, Feussner JR. Observer error in systolic blood pressure measurement in the elderly. A case for automatic recorders? *Arch Intern Med* 1986;146:2373-6.
59. Stewart MJ, Padfield PL. Measurement of blood pressure in the technological age. *Br Med Bull* 1994;50:420-42.
60. Chapman JM, Clark VA, Coulson AH, Browning GG. Problems of measurement in blood pressure surveys. Inter-observer differences in blood pressure determinations. *Am J Epidemiol* 1966;84:483-94.
61. Villegas I, Arias IC, Botero A, Escobar A. Evaluation of the technique used by health-care workers for taking blood pressure. *Hypertension* 1995;26:1204-6.
62. Neufeld PD, Johnson DL. Observer error in blood pressure measurement. *CMAJ* 1986;132:633-7.
63. Stoneking HT, Hla KM, Samsa PG, Feussner JR. Blood pressure measurement in the nursing home: are they accurate? *Gerontologist* 1992;32:536-40.
64. Campbell NRC, McKay DW, Chockalingam A, Fodor JC. Errors in assessment of blood pressure: blood pressure measuring technique. *Can J Pub Health* 1994;85 (Suppl 2):S18-21.
65. Kaplan N. Measurement of blood pressure. Kaplan's Clinical Hypertension. 8th edition Philadelphia: Lippincott Williams & Wilkins, 2002:25-55.
66. Canzanello VJ, Jensen PL, Schwartz GL. Are aneroid sphygmomanometers accurate in hospital and clinical settings? *Arch Intern Med* 2001;161:729-31.
67. Jones CR, Khanna M, Rushbrook J, Poston L, Shennan AH. Are aneroid devices suitable replacements for mercury sphygmomanometer [abstract]. *J Hum Hypertens* 2000;14:843.
68. Vervoort G, Wetzels JF, Lutterman JA, Berden JH, Thien T, Smits P. The impact of blood pressure measurement methods on the amount of differences in blood pressure levels between patients with normoalbuminuric type 1 diabetes and healthy controls. *J Hum Hypertens* 1999;13:117-22.
69. Bakx C, Oerlemans G, Hoogen H van den, Weel C van, Thien T. The influence of cuff size on blood pressure measurement. *J Hum Hypertens* 1997;11:439-45.
70. O'Brien E. Review: a century of confusion; which bladder for accurate blood pressure measurement? *J Hum Hypertens* 1996;10:565-72.
71. World Health Organisation (WHO)/International Society of Hypertension (ISH) statement on management of hypertension. *J Hypertens* 2003;21:1983-92.
72. Guidelines for the management of mild hypertension: Memorandum from a WHO/ISH Meeting. *Hypertension* 1993;22:392-403.
73. Ramsay L, Williams B, Johnston G, MacGregor G, Poston L, Potter J, et al. Guidelines for the management of hypertension: report of the third working party of the British Hypertension Society. *J Hum Hypertens* 1999;13:569-92.
74. Terent A, Breig-Asberg E. Epidemiological perspective of body position and arm level in blood pressure measurement. *Blood Press* 1994;3:156-63.
75. Kahn MH. The position of the arm in blood pressure measurement. *Am J Med Sci* 1919;158:823-9.
76. Merendino J, Finnerty FA. Importance of the position of the arm on the level of arterial blood pressure. *JAMA* 1961;175:51-3.
77. Mitchell PL, Parlin RW, Blackburn H. Effect of vertical displacement of the arm on indirect blood pressure measurement. *N Engl J Med* 1964;271:72-4.
78. Webster J, Newnham D, Petrie JK, Lovell HG. Influence of arm position on measurement of blood pressure. *BMJ* 1984;288:1574-5.
79. Mariotti G, Alli C, Avanzini F, Canciani C, Di Tullio M, Manzini M, et al. Arm position as a source of error in blood pressure measurement. *Clin Cardiol* 1987;10:591-3.
80. Parr GD, Poole PH. Effects of sphygmomanometer type and position of the arm on blood pressure measurement. *J Hum Hypertens* 1988;2:153-6.
81. Jungvall P, Thorvinger B, Thulin T. The influence of a heart level pillow on the result of blood pressure measurement. *J Hum Hypertens* 1989;3:471-4.
82. Netea RT, Bijlstra PJ, Lenders JWM, Smits P, Thien T. Influence of the arm position on intra-arterial blood pressure measurement. *J Hum Hypertens* 1998;12:157-60.
83. Netea RT, Lenders JWM, Smits P, Thien T. The arm position is important for blood pressure measurement. *J Hum Hypertens* 1999;12:157-60.
84. Steen MS van der, Pleijers AMLJ, Lenders JWM, Thien T. Influence of different supine body positions on blood pressure: consequences for night blood pressure/dipper-status. *J Hypertens* 2000;18:1731-6.

85. Cavelaars M, Tulen JHM, Man in 't Veld AJ, Gelsema ES, van den Meiracker AH. Assessment of body position to quantify its effect on nocturnal blood pressure under ambulatory conditions. *J Hypertens* 2000;18:1737-43.
86. Parati G. Blood pressure reduction at night: sleep and beyond. *J Hypertens* 2000;18:1725-9.
87. Netea RT, Elving LD, Lutterman JA, Thien T. Body position and blood pressure measurement in patients with diabetes mellitus. *J Intern Med* 2002;251:393-9.
88. Jamieson JM, Webster J, Philips S, Jeffers AT, Scott AK, Robb OJ, et al. The measurement of blood pressure sitting or supine, once or twice? *J Hypertens* 1990;8:653-60.
89. Carel RS, Silverberg DS, Shoenfeld Y, Eldar M, Snir C, Mor G. Changes in blood pressure in the lying and sitting positions in normotensive, borderline and hypertensive subjects. *Am J Med Sci* 1983;285:2-11.
90. Turjanmaa MHV, Kalli TS, Uusitalo AJ. Blood pressure level changes caused by posture change and physical exercise: can they be determined accurately using a standard cuff method? *J Hypertens* 1988;6 (Suppl Dec):S79-S81.
91. Zachariah PK, Sheps GS, Moore AG. Office blood pressures in supine, sitting and standing positions: correlation with ambulatory blood pressures. *Int J Cardiol* 1990;28:353-60.
92. Netea RT, Smits P, Lenders JWM, Thien T. Does it matter whether blood pressure measurements are taken with patients sitting or supine? *J Hypertens* 1998;16:263-8.
93. Netea RT, Lenders JWM, Smits P, Thien T. Both body and arm position significantly influence the blood pressure measurement. *J Hum Hypertens* 2003;17:459-62.
94. Kaplan NM, Lieberman E. Measurement of blood pressure. *Clinical hypertension*. Seventh ed. Baltimore: Williams & Wilkins, 1998:19-39.