New insight of the implication blood pressure detection differences using aneroid sphygmomanometer and digital blood pressure on medical examination

Novitasari*, N G Pratiwi, S W Hidayat, W Ardiatna, A R Hidayat and I Supono

Electromedic Laboratory, Research Center for Testing Technology, Indonesian Institute of Sciences, South Tangerang, Indonesia

*novitasari@lipi.go.id

Abstract. The quality of medical devices is an important thing to establish the anamnesis, diagnosis and also treatment of patient. Arterial pressure measurement as one of the first indicators in the Hypertension Management Guidelines requires the accuracy as well as their function. Error in the detection of blood pressure should not occur during measurement because the errors will also make failure in determining the diagnosis and therapy for hypertensive patient, related on their hypertensive classification. Clinicians requires accurate medical measurement in order to monitor patients, diagnose diseases and deliver treatments. The failure of detection will certainly have diverse effects. Preliminary studies have shown that differences in results that are generated by two types of blood pressure devices, aneroid sphygmomanometers and digital blood pressure. The differences between both devices are 2 - 11.6 mmHg for Systolic and 0.8 - 10.3 mmHg for diastolic. This differences led a new insight to the accuracy of blood pressure devices that are widely used in medical circles and the critical value of the accuracy of the sphygmomanometer can be the basis for determining clinical blood pressure classification. Therefore, it is necessary for medical staff to get information about the accuracy of blood pressure devices and its critical parameters in determining blood pressure, it is also necessary for a regulation on a blood pressure classification based on the type and level of accuracy of measuring instruments.

1. Introduction
Blood Pressure measurement is an important part in physical examination of patient's health. It is one of the most commonly measured clinical parameters and the values determine of diagnostic and therapeutic decisions with measuring the strength of blood against the arterial wall when it circulates through the body. It also provide basic information on the patient's cardiovascular status, response to physical exercise, to make a basis for the selection of therapy for patients.[1] Blood pressure measurement value as an initial indication for patient health conditions in a certain range and also can be used for various purposes, both determining the scale of physical exercise in athletes, adequate nutritional intake for patients on a metabolic diet to the estimation on interference in the circulation of blood flow that has the potential to cause various disorders health, especially related to various disorders classified by World Health Organization (WHO) with Non Communicable Disease (NCD).[2]
Blood measurement techniques have been known as invasive and non-invasive. In this paper we will discuss only for the non-invasive techniques, since this technique can measure the blood pressure without causing discomfort to the patient. There are several methods used to obtain blood pressure values in non-invasive measurement techniques. However, Auscultatory and Oscillometric will be discussed in this paper, which are the commonly methods being used. Auscultation method is currently the method of gold (Gold Standard) in determining blood pressure. [15] However, the analogous blood pressure to this method generally uses mercury indicators that can be harmful to the environment, so the uses of this method developed in aneroid sphygmomanometers without using mercury in the measurements. [13] As the oscillometric method commonly use the digital blood pressure for measurement.

This paper reviews the medical implication of mal-calibrated and the importance of the accuracy of blood pressure measuring devices, by comparing two blood pressure measurement methods, which are aneroid sphygmomanometer and digital blood pressure. Thus, the objective of this paper is to provide guidance when the clinician determines arterial pressure indicated by a blood pressure value and to get information about the regulation on a blood pressure based on the type and level of accuracy of measuring instruments.

2. Measurement and Classification of Blood Pressure Values

According to WHO in the 2018 annual report on the prevalence of NCD in various countries, NCD causes 71% (41 million) deaths from 57 million deaths globally in 2016. WHO also showed in its report that the prevalence of NCD which causes the highest mortality rate in Indonesia is cardiovascular disease (35%). [2] Cardiovascular disease cause by heart and blood vessel dysfunction, such as coronary heart disease, heart failure, and stroke. Heart attacks and strokes are usually acute phenomena and are mostly caused by blockages that prevent blood from flowing to the heart or brain, one of the causes is hypertension. [3] Hypertension or high blood pressure is the strength of the blood against the arterial wall when circulating through the body which is pumped constantly through the blood vessels with excessive force. [4]

Blood pressure is the first examination in determining medical history on management procedures for cardiovascular disease, and also in the procedure for handling patients in the emergency unit. Based on the Regulation of the Minister of Health, Republic of Indonesia No. 56 of 2014, blood pressure measuring devices become one of the equipment that must be provided by health care facilities in the most important case like emergency unit. [5] Furthermore, clinical staff need to have an ability using manual or digital blood pressure because blood pressure becomes a clinical standard for many cases of disease. [6]

According to the classification of blood pressure WHO in Hypertension Fact Sheet, blood pressure is written in two values which detect systolic blood pressure and diastolic blood pressure. [4] Systolic pressure is the maximum pressure on the arteries when blood is pumped out of the left ventricle of the heart into the aorta (vessels large base) during the contraction of the ventricles to pump blood into the aorta (ventricular systole). While diastolic pressure is the lowest pressure during the heart cycle which represents when the heart is at rest (relaxation). [7]

Blood pressure measurement refers to a systemic blood pressure in large arteries that deliver blood to all parts of the body except the lungs, such as the brachial arteries in the arms. The flow of the heart's function process begins with the stimulation of the autonomic nerve which is then received by the sinatrial lymph in the right atrium. The unit of blood pressure measurement level is indicated by millimetre of mercury (mmHg). Some international health organizations, including the WHO, have classified blood pressure ranges into three level classifications as shown in Table 1 [4].

The seventh report of the National Committee on Prevention, Detection, Evaluation and Therapy of High Blood Pressure conducted periodically by the US Department of National Health Service shown a different matter. The report divides the blood pressure classification into four level classifications as shown in Table 1. Modifications to four of these classifications are based on consideration for clinicians to prevention and therapy recommendations. The clinician can recommend to recheck the
blood pressure in two years later for the first classification. For the second classification, it is recommended for recheck within one year later. The clinician will recommend a recheck within two months for the third classification and the clinician will evaluate or refer for an ongoing treatment and therapy if they are in the fourth classification.[8]

| No. | Classification                  | Systolic          | Diastolic         | Reference                                      |
|-----|--------------------------------|-------------------|-------------------|------------------------------------------------|
| 1   | Normal                         | Less than 120     | Less than 80      | WHO Hypertension Fact Sheet                    |
|     | Risk (Pre-Hypertension)        | 120-139           | 80-89             |                                                 |
|     | Hypertension                   | 140 or higher     | 90 or higher      |                                                 |
| 2   | Normal                         | < 120             | < 80              | Chobanian et al Pickering et al                |
|     | Pre-Hypertension               | 120-139           | 80-89             | U.S. Department Of Health and Human Services   |
|     | Stage 1 Hypertension           | 140-159           | 90-99             | Human Services                                 |
|     | Stage 2 Hypertension           | ≥ 160             | > 100             | National Institutes of Health                  |

Opinions about four level classifications blood pressure range were also raised by the Professional Heart and Public Education Sub Committee of the American Heart Association.[9] The classification of blood pressure determination and the related therapy carried out both are widely used by clinicians in the world. Both classifications, either from the WHO or the classification by the US Department of Health and the American Heart Association are widely used by clinicians in determining patients' hypertension status.

Classification of blood pressure requires the accuracy of the instrument. The reading may give the results that are very close to the true value because this measurement become a reference in determining the diagnosis to treatment of patients. Based on this, it is important to analyze and prevent errors in blood pressure measurement (both aneroid sphygmomanometer and digital blood pressure). Accuracy of blood pressure measurement requires an accurate sphygmomanometer and the most common error in blood pressure measurement is the non-calibrated sphygmomanometer and miscuffing.[10] Therefore, it is necessary to improve the system of calibration and proper testing of the sphygmomanometer, including the accuracy of the range of increases and decreases in blood pressure values related to the importance of influential medical pressure.

3. Blood Pressure Measurement Techniques

Blood measurement techniques have been known as invasive and non-invasive. Invasive technique (intra-arterial) is a technique of measurement by inserting an instrument directly into the patient's blood vessels. Invasive technique is often used in the Intensive Care Unit (ICU), it causes discomfort for patients hence the use of this must be carried out to a minimum and carried out only in urgent circumstances, such as the ICU and Operating Room. In general, the procedure of this technique is inserting the appropriate catheter into the artery then the monitor will display the measured pressure wave. Blood pressure measurement can also directly provide information about recording the patient's heart rate as well as providing information related to blood pressure values. Monitoring the patient's heart rate record is needed in certain cases, because the cases can cause sudden changes in the patient's blood pressure, such as a head injury.[11],[12]

The non-invasive techniques can measure the blood pressure without causing discomfort to the patient. It is because the measurements are used outside the patient's body. Thus, non-invasive blood measurement technique become the most commonly used. It is also easier to use and does not require close supervision by a doctor. There are several methods used to obtain blood pressure values in non-invasive measurement techniques, e.g. Auscultatory, Palpation, and Oscillometric Method.

3.1. Auscultatory Method

Auscultatory method is the most commonly used measurement method. The principle of this method is to record the value of blood pressure (mmHg) when the Korotkoff sound has been heard for the first
time as a systolic pressure value and the diastolic pressure value when the sound was last heard. Korotkoff sound is the sound produced when the heart contracts (systole) and relaxes (diastole). However, the analogous blood pressure to this method generally uses mercury indicators that can be harmful to the environment, so the uses of this method developed in aneroid sphygmomanometers without using mercury in the measurements. [13]

Measurements with auscultation methods require the expertise of the medical personnel to be able to determine the sound that signifies the systole or diastolic so that the use of this method is only often used in medical examinations in hospitals or health facilities. Auscultation method is currently the method of gold (Gold Standard) in determining blood pressure, however it is not commonly used by patients for repeated monitoring at home. It is because the use of this method requires the special ability in capturing the sound of Korotkoff. [15] The measuring procedure using the Auscultation method begins with attaching and tightening the cuffs to the upper arm and then attaching a stethoscope to the brachial artery of the cuff to hear the sound. Next the cuff is pumped until the sound disappears, when the sound disappears remove the air on the pump slowly. When the air is removed should focus attention on the first sound that is heard as the pressure of Cythol. After the first sound, the blood pressure of the systole is performed. The air is re-issued until the last sound of diastole marker blood pressure.[13],[14]

3.2. Palpation Method
This method only measures the blood pressure of the systole alone without diastole blood pressure. Measuring procedure is almost the same as Auscultation method but this way only by feeling the pulse of the first time felt. This method is rarely used due to the less precise measurement results. [14]

3.3. Oscillometric Method
The method is calculating blood pressure that utilizes raised cuff pressure (inflation) to the maximum until the supra-systolic reached. In this condition, the blood flow in the branchial artery stops temporarily. It aims to extract small oscillations at heart frequency. Then the cuff pressure will be lowered at a constant rate (deflation). Oscillation pulses increase as the cuff pressure decreases. During deflation a sensor is used to measure the pressure on the cuff and detection the magnitude of the oscillating pulses of pressure. The results of the oscillation pulse extraction are then calculated with a certain algorithm. [16],[17]

In this method the pulse of the signal can be extracted and analyze into the values of Mean Arterial Pressure (MAP), Systolic Blood Pressure (SBP), and Diastolic Blood Pressure (DBP) using certain algorithms. The determination of these algorithms can differ on each brand of oscillometric devices that have their own strengths and weaknesses to develop accurate blood pressure values in a variety of measurements and situations. [9],[18-20]

There are two types of methods used in determining the algorithm, which is the method of deflation and method of inflation in digital blood pressure measuring instruments. The main difference between the two types of measurement methods is in the calculated oscillation pulse, in which the oscillation pulse deflation method is analyzed as the pressure of the systole and diastolic during the deflation period, while in the oscillation pulse inflation method During the inflation period on the next cuff of the analysis results in the form of signals to be recorded on the display.[21]

4. Comparison of Aneroid Spyhgmomanometer and Digital Blood Pressure
Aneroid Spyhgmomanometer use Auscultatory Method, while Digital Blood Pressure use Oscillometric Method. Much research has been reported to determine the accuracy of the two methods in measuring blood pressure. The oscillometric method has also been found a long time ago but the accuracy of the results is still in doubt. Several studies have succeeded in proving that both methods are good through a series of tests, although in clinical trials the use of the oscillometric method obtained higher measurement results compared to the auscultatory method.
The comparison of the two methods in measuring blood pressure in Nigeria school children shows that systole and diastole by the oscillometric method are higher than the auscultatory. [22] The same results were obtained from other research with clinical trial measurements using the oscillometric method higher 2 mmHg. This research also concluded that the auscultatory method was relatively more stable than the oscillometric after repeated measurements of the patient. [23]

However, several studies conducted in Korea and India showed that there was less value of blood pressure using the oscillometric method than using auscultatory method. The difference in the result can be affected by various methodologies and equipment as well as algorithm differences in the oscillometric method.[24-26] The differences of oscillometric and auscultatory method are still understandable if the difference is not more than 3 mmHg, as mentioned in the United Nations Development Program guidelines for maintenance and calibration of non-mercury thermometers and clinical sphygmomanometers.[26]

Table 2. Comparison between Auscultatory and Oscillometric

| No. | Reference | Year | Age (Year) | Cuff Size (cm) | Sample Size (n) | Δ systolic (mmHg) | Δ diastolic (mmHg) | Discussion |
|-----|-----------|------|------------|----------------|----------------|------------------|------------------|------------|
| 1.  | Ibrahim OR, Afolabi KJ, Ojuawo A et al | 2018 | 6-12       | -              | 1745           | 5                | 2.60             | Oscillometric higher than auscultatory[22] |
| 2.  | Choi S, Kim YM, Shin J, Lim YH et al | 2018 | ≥ 20       | 20-35          | 745            | ≤ 2              | 6                | No difference on systolic blood pressure but diastolic blood pressure lower than auscultatory[27] |
| 3.  | Mirdamadi A, Etebari M | 2017 | ≤ 60       | -              | 117            | 3.47 ± 0.89     | 1.55 ± 0.93     | Oscillometric higher than auscultatory[28] |
| 4.  | Taksande A, Jadhav A, Vagha J | 2015 | 5-15       | 15-22          | 100            | 3 ± 0.01        | 2.88 ± 0.41     | Oscillometric higher than auscultatory[29] |
| 5.  | Liu C, Zheng D, FGriffiths C, Murray A | 2015 | 24 - 68    | -              | 20             | 1.5 ± 0.9       | 0.8 ± 0.6       | Oscillometric higher than auscultatory[23] |
| 6.  | Lim YH, Choi SY, Oh KW et al | 2013 | 20-38      | < 25 cm        | 499            | 1.9 ± 7.0       | 3.1 ± 5.5       | Oscillometric higher than auscultatory[30] |
| 7.  | Kamath N, Goud BR, Phadke KD et al | 2012 | 5-16       | -              | 1489           | 11.6 ± 24.9     | 10.3 ± 8.2      | No differences[25] |
| 8.  | Eliasdottir SB, Steinthorsdottir SD, Indridason OS et al | 2013 | 9-10       | -              | 1071           | No differences   | 3.15 ± 8        | Lower than oscillometric[31] |
Facators of Failure in Blood Pressure Measurement

Blood pressure measurement is one of the most basic elements of patient management to determine and treatment of hypertension case, but there is variation on how to reading the value. Moreover, the interpretation of the physiological meaning of blood pressure is not easy so that it can lead to a risk of clinical misclassification in patients. Hence, management and periodical verification of the aneroid sphygmomanometer and digital blood pressure accuracy are important things to do, for instance testing the control and calibration of medical instruments.\[27\]

Therefore, to obtain valid results from both aneroid sphygmomanometer and digital blood pressure, is to make sure their accuracy, precision and traceability. The traceability includes calibration of equipment as well as the evaluation and declaration of the uncertainty of measurement at every level of the traceability chain. An accurate measurement is an essential part to blood pressure control. There is a need to quantify systematic blood pressure measurement errors in primary care, consider these in the context of changing digital blood pressure use and estimate the effects of errors on cardiovascular outcomes affected by blood pressure control.\[34\],\[35\]

Much research has been conducted to identify the causing of blood pressure error. Table 3 shows its factors for both aneroid sphygmomanometer and digital blood pressure equipment.\[9\],\[36\],\[37\]

| No. | Factors Error                                      |
|-----|---------------------------------------------------|
| 1.  | Uncalibrated measurement                          |
| 2.  | Differences method on blood pressure measurement  |
| 3.  | Adequate rest time                                |
| 4.  | Diurnal variation                                 |
| 5.  | Room temperature                                  |
| 6.  | Clinic atmosphere                                 |
| 7.  | Pain                                              |
| 8.  | Anxiety                                           |
| 9.  | Smoking                                           |
| 10. | Humidity                                          |
| 11. | End interference                                  |
| 12. | Inappropriate cuff size and placement             |
| 13. | Posture                                           |
| 14. | Inflation-deflation rate                          |
| 15. | White coat syndrome                               |

The most are white coat syndrome that occurs in older men or women. White coat syndrome is a syndrome of elevated blood pressure in only one condition when medical personnel perform to blood pressure examination. These are happened because the consumption of certain drugs before blood pressure testing, anxiety about diagnosis, not at an optimal physiological time for taking patient blood measurement, noisy place to measure blood pressure, the effect of increasing blood pressure from room temperature and certain food stimuli, such as alcohol, caffeine, nicotine, and exercise in the 30 minutes before blood pressure measurement. In addition, body movements during blood
measurements can also affect, such as crossing legs, talking, and mental burden (psychological factors).[38-40]

Although medical staff correlate most of the variations in blood pressure measurement with white coat syndrome, errors in measuring blood pressure using a sphygmomanometer can also be caused by the technical blood pressure performance, operator error, and physiological factors.[31]

Based on that the importance of standardizing blood pressure equipment, training in use techniques and ensuring the accuracy of equipment will reduce the risk of errors in measurement. Both aneroid or digital blood pressure need the schedules periodical inspections and calibrations. In addition, the selection of cuffs must also be a concern, the selection of cuff shows the best and accurate results on a free and blank arm, as well as the selection of cuff sizes according to the diameter of the arm. The inspection of blood pressure measurement should be based on the critical value of circulation process on human body and the uncertainty value of measurement.[1]

6. Conclusion

The differences between aneroid sphygmomanometer (auscultatory method) and digital blood pressure (oscillometric method) are 2-11.6 for systolic and 0.8-10.3 for diastolic. These errors in blood pressure value tend to shift the measurement results from the true value and can cause low detection or excessive detection of disease, so it has direct implications for the therapy and treatment that is carried out. Therefore, a performance safety test is needed to ensure measurement results during the inspection process, even the best medical instruments and equipment can be affected by environmental changes, continuous use and other factors that cause loss of accuracy. Systematic measurement and periodical examination of blood pressure measurement is needed to the range of blood pressure classification also that forms the basis for clinicians in determining and mapping of patients with or without hypertension. The accuracy of the two types of blood pressure measurement needs to be done with a threshold of measuring each type of sphygmomanometer, both by using the auscultatory or oscillometric method. This is needed of large research and range assessment about the development of both blood pressure measurement to make sure the validation and it will make the digital blood pressure will be the gold standard too in physical examination.

The accuracy of the two types of blood pressure measurement that have different determination techniques also need to be considered by clinicians in determining the classification range of blood pressure. It is important as a prevention of medical errors that can cause permanent pain, disability or in some circumstances cause death.

Acknowledgments

Authors would like to express gratitude to Indonesian Institute of Sciences for conference funding.

References

[1] Frese EM, Fick A, Sadowsky H S. Blood Pressure Measurement Guidelines for Physical Therapists. Cardiopulmonary Physical Therapy Journal. 2011; 22(2):6-13.
[2] WHO. Non Communicable Diseases Country Profiles 2018. Geneva: WHO; 2018; p. 10.
[3] WHO. Health Topics. Geneva: WHO; 2017 [updated 17 Mei 2017; cited 24 April 2019]. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).
[4] WHO. Hypertension. New Delhi: Department of Sustainable Development and Healthy Environments WHO Region Office for South-East Asia; 2011 [updated September 2011; cited 24 April 2019]. Available from: http://www.searo.who.int/entity/noncommunicable_diseases/media/non_communicable_diseases_hypertension_fs.pdf.
[5] Kemenkes. Peraturan Menteri Kesehatan No. 56 Tahun 2014 2014. Jakarta: Kementerian Kesehatan;
[6] PBIDI. Panduan Keterampilan Klinis Bagi Dokter di Fasilitas Pelayanan Primer. I ed. Jakarta: Persatuan Besar Ikatan Dokter Indonesia; 2017; p. 470.

[7] Barret K E, Barman S M, Boitano S, Brooks H L. Ganong's Review of Medical Physiology. Twenty-Third Edition ed. United States: The McGraw-Hill Companies, Inc; 2010.

[8] Chobanian AV, GL B, Black HR, Cushman WC, Green LA, Izzo JL, et al. Seventh Report Of The Joint National Committee On Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: The JNC 7 Report. JAMA. 2003; 289(19):2560-72.

[9] Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, et al. Recommendation for Blood Pressure Measurement in Humans and Experimental Animals: Part 1: Blood Pressure in Humans: a Statement for Professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. Hypertension. 2005; 45(1):142-161.

[10] Tavakoli Golpaygani A. Why Should We Have a Periodic Safety and Performance for Medical Devices. J Biomed Phys Eng. 2007:1-6.

[11] Gupta B. Invasive Blood Pressure Monitoring [Available from: https://www.wfsahq.org/components/com_virtual_library/media/81574a863feeed2ee3ac5c8c824abe0-35c06d5dc14372e5d743d057a889ab42-Invasive-Blood-Pressure-Monitoring--Update-28-2012-.pdf].

[12] Hendrayana YH, Riyadi MA, Darjat. Rancang Bangun Alat Pengukur Tekanan Darah Otomatis Menggunakan Metode Oscilometry Berbasis Raspberry PI Model B+. Transmis. 2016; 18(1).

[13] Mlawanda G, Peter M, Srini G. An Analysis of Blood Pressure Measurement in a Primary Care Hospital in Swaziland. African Journal of Primary Health Care and Family Medicine. 2014:1-9.

[14] Susan B. Clinical Practice Guideline: Non-Invasive Blood Pressure Measurement with Automated Devices, 2012. Schaumburg: Emergency Nurses Association;

[15] Sorvoja H, Myllyla R. Non Invasive Blood Pressure Measurement Methods. Molecular and Quantum Acoustics. 2006; 27.

[16] Babbs CF. Oscillometric Measurement of Systolic and Diastolic Blood Pressures Validated in a Physiologic Mathematical Model. 2012 [Available from: http://www.biomedical-engineering-online.com/content/11/1/56].

[17] Jilek J, Fukushima T. Oscillometri Blood Pressure Measurement: The Metodology, Some Observations and Suggestions. Biomedical Instrumentation and Technology 2005; 39:237-241.

[18] Moraes JCTB, Cerulli M, Ng PS. Development of a New Oscillometric Blood Pressure Measurement System Computers in Cardiology. 1999:467-470.

[19] Chen S, Groza VZ, Bolic M, Dajani HR. Assesment of Algorithms for Oscillometric Blood Pressure Measurement. Instrumentation and Measurement Technology Conference. 2009:1763-7.

[20] Forouzanfar M, Dajani HR, Grova VZ, Bollic M, Rajan S, Batkin L. Oscillometric Blood Pressure Estimation: Past, Present and Future. IEEE reviews in Biomedical Engineering. 2015; 8:44-63.

[21] Microlife Corporation. Inflation Mode Technology, 201828 Januari 2020.

[22] Ibrahim OR, Adedoyin TO, Afolabi KJ, Ojuawo A, Makualu OA, Abdullahi MB, et al. Comparison of Auscultatory and Oscillometric Blood Pressure Measurements Among School Children in Nigeria. Int J Med Health Sci. 2018; 7(2).

[23] Liu C, Zheng D, FGriffiths C, Murray A. Comparison Repeatability of Blood Pressure Measurements Between Oscillometric and Auscultatory Methods. Computing in Cardiology. 2015; 42:1073-76.

[24] Park MK, Menard SM, Yuan C. Comparison of Auscultatory and Oscillometric Blood Pressure Arch Pediatr AdDlesc Med. 2001; 155:50-3.
[25] Kamath N, Goud BR, Phadke KD, Iyengar A. Use of Oscillometric Devices for the Measurement of Blood Pressure—Comparison with the Gold Standard. Indian J Pediatr. 2012; 79:1230-2.

[26] Project GGHW. Guidance on Maintaining and Calibrating Non-Mercury Clinical Thermometers and Sphygmomanometers, 2011 United Nation Development Programme;

[27] Choi S, Kim YM, Sin J, Lim YH, Choi SY, Choi BY, et al. Comparison of the accuracy and errors of blood pressure measured by 2 types of non-mercury sphygmomanometer in an epidemiological survey. Medicine. 2018; 97(25):1-10.

[28] Mirdamadi A, Etebari M. Comparison of manual versus automated blood pressure measurement in intensive care unit, coronary care unit, and emergency room. Arya Atheroscler. 2017; 13(1):29-34.

[29] Taksande A, Jadhav A, J V. Comparison between automated and manual sphygmomanometer for measuring blood pressure in children. J Nepal Pediatr. 2015; 35(1):13-17.

[30] Lim YH, Choi SY, Oh KW, Kim Y, Cho ES, Choi BY, et al. Comparison between an automated device and a manual mercury sphygmomanometer in an epidemiological survey of hypertension prevalence. American Journal of Hypertension. 2013; 27(4):537-45.

[31] Eliasdottir SB, Steinthorsdottir SD, Indridason OS, Palsson R, Edvardsson VD. Comparison of aneroid and oscillometric blood pressure measurements in children. The Journal of Clinical Hypertension. 2013; 15(11).

[32] Nelson NR, Quinn S, Bowers-Ingram L, Nelson JM, Winzenberg TM. Cluster randomized controlled trial of oscillometric vs. manual sphygmomanometer for blood pressure management in primary care (CRAB). American Journal of Hypertension. 2009; 22(6):598-603.

[33] Mant J, McManus R. Measurement of Blood Pressure in Primary Care: Must be Done Carefully. BMJ Group's Global Online Clinical Community. 2011; 342:342-43.

[34] Faris VNR, Mondeca G, Souza BD, Pereira AA, Arencibia RV, Milagre ST. An investigative case study at local hospital into the current reliability of blood pressure sphygmomanometers. Res Biomed Eng. 2017 : 33(1): 21-30.

[35] Greiver M, Kalia S, Voruganti T, Aliarzadeh B, Moineddin R, Hinton W et al. Trends in end digit preference for blood pressure and associations with cardiovascular outcomes in Canadian and UK primary care: a retrospective observational study. BMJ Open. 2018.

[36] Pickering TG, Ogedegbe G. Principles and techniques of blood pressure measurement. Cardiology Clinics. 2010; 28(4):571-86. PMid:20937442. http://dx.doi.org/10.1016/j.ccl.2010.07.006.

[37] Tolonen H, Koponen P, Naska A, Männistö S, Broda G, Palosaari T, Kuulasmaa K. Challenges in standardization of blood pressure measurement at the population level. BMC Medical Research Methodology. 2015; 15(1):33. PMid:25880766. http://dx.doi. org/10.1186/s12874-015-0020-3.

[38] Court C, Stevens R, Sanders S, Ward A, McManus R, Heneghan C. How Accurate Are Your Sphygmomanometers? A Cross-Sectional Observational Study. Biomedical Instrumentation and Technology. 2011; British Journal of General Practice.

[39] Ostchega Y, Prineas RJ, Paulose-Ram R, Grim CM, Willard G, Collins D. National Health and Nutrition Examination Survey 1999-2000: effect of observer training and protocol standardization on reducing blood pressure measurement error. J Clin Epidemiol. 2003; 56(8):768-774.

[40] Jones CA, Valle M, Manrins S. Using Survival Analysis to Explore Female Cardiac Rehabilitation Program Adherence. Appl Nurs Res. 2001; 14(4):179-186.