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Research Article

Left Ventricular Morphology In Non-Invasive Blood Pressure NIBP

Influence of Left Ventricular Morphology and Functions in The Accuracy of Non-Invasive Blood Pressure NIBP Recording Compared to Intra-Arterial Pressure IAP - A Correlative Study

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Abstract: Non-invasive blood pressure measurement with a brachial cuff sphygmomanometer is an important assessment tool in the diagnosis and management of hypertension and disturbed hemodynamic status. However, when compared to intra-arterial BP, the accuracy of BP measured by non-invasive methods remains questionable. The study attempted to estimate the difference in blood pressure measured by the two methods, as well as analyse the impact of left ventricular morphology and functions on the magnitude of the BP difference recorded by invasive and non-invasive methods. Methods: The subjects were patients undergoing diagnostic coronary angiography for the evaluation of chest pain. The morphology and functions of the left ventricle were determined as part of the routine pre procedural screening. NIBP and IAP were measured twice during the CAG at the radial and aortic levels. Non-invasive BP was measured using a brachial cuff of mercury sphygmomanometer by the auscultatory method. Results of our study revealed that in non-invasive BP both the systolic and the diastolic pressures were higher than their corresponding recordings obtained by invasive methods. The ECHO-derived left ventricular hypertrophy and left ventricular diastolic function correlated positively with the systolic and diastolic pressure differences respectively. Conclusion: Hence we suggest evaluation of the above parameters by echocardiography after obtaining a high BP by non-invasive methods can be done before the commencement of anti-hypertensive drugs A pre-treatment echo will give a clue on the differences.

Keywords: Blood Pressure, Accuracy Non-Invasive, Invasive Pressure, Echocardiography and Left Ventricular Function

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1. INTRODUCTION

Across the globe, arterial Blood Pressure BP is the most widely estimated vital parameter to assess the hemodynamic status of an individual[1]. World Health Organization[2], Global Burden of Disease (GBD) study [3], and Non-Communicable Disease Risk Factor Collaboration report[4] the prevalence of hypertension as more than 1 billion/year. KDIGO[5]and SPRINT[6]trials emphasize the significance of accurate BP estimation since Blood Pressure value determines the treatment planning, and follow-up of various cardiovascular diseases, with elevated blood pressure being the major risk factor[7]. Literature shows that Minimal inaccuracy of ≥ 5 mmHg had resulted in misclassification of 50 million per year. BP underestimation leads to missed therapeutic intervention and elevation of cardiovascular risk[8]. BP overestimation creates iatrogenic hypotension, additional cost, and exposure to adverse effects of unnecessary treatment [9]. Since BP estimation remains as a crucial diagnostic parameter even minor error can have major public health ramifications [10]. Yet NIBP is prone for deviation from actual BP due to [11,12] white coat effect BP, inherent BP variations and non-adherence of guidelines. Since BP estimation remains as a crucial diagnostic parameter even a minor error can have major public health ramifications [13]. Intra-arterial pressure estimates the actual pressure hence considered gold standard for BP estimation[14]. IAP estimation is invasive, and needs expertise [15]. NIBP and IAP may differ due to various inherent physiological and technical causes [16,17]. Uncertainty prevails whether NIBP reflects actual BP and true agreement between aortic and brachial arterial pressures exists [18] Studies were done to check the accuracy of NIBP in various clinical settings. Differences in BP measurement may result in unnoticed underreporting of women and may clarify why women have a higher risk of developing cardiovascular disease than men for a specified brachial cuff BP. Certain findings may support the need for further research into sex-specific BP targets or the incorporation of sex-specific parameters into BP estimation algorithms. The search of a reason for inaccuracy were also studied such as ageing, obesity and technical reasons [19]. Hence, we indent to explore in depth the extent of discrepancy between NIBP and IAP and check whether the difference lie within acceptable the range. To the best of our knowledge, there are no studies that associate the ECHO parameters and the difference in blood pressures measured by invasive and non-invasive techniques. Hence, we tried to find an association between ejection fraction, left ventricular morphology, dysfunction and discrepancy in blood pressures recorded by IBP and NIBP. We expect the results of the study to provide insight on the need for extensive cardiovascular workup with an ECHO before starting the patient on drugs to control high blood pressure rather than to depend only on cuff pressure.

1.1 Objectives

The primary objective of the study is to correlate manual NIBP with intra-arterial pressure. The secondary objective is to study the influence of left ventricular morphology and functions in the accuracy of manual NIBP recording.

2. METHODOLOGY

Observational cross-sectional study conducted at a tertiary care teaching institution in south India after obtaining the Ethical Clearance dated 08.06.2016 by the Institutional Human Ethical Committee Reg No. ECR/451/ Inst/PY/2013 Project: PhD/2016/03/06. Sample size: n=300 (effect size =0.25, alpha error = 0.05, beta error = 0.80)

2.1 Inclusive criteria

Patients of both gender aged between 30 to 75 years posted for diagnostic coronary angiogram(CAG).

2.2 Exclusion Criteria

Patients on vasoactive drugs, peripheral vascular diseases, contra indication for cuff placement and critically ill subjects. Data collection done from the routine preoperative investigations done for CAG and perioperatively during coronary angiogram.

2.3 Pre-operative Data Collection

Estimation of LV Morphology and functions: Data of the Left ventricular wall thickness, systolic and diastolic functions are extracted from the routine preoperative ECHO cardiograph done by Philip IE33 ECHO monitor with high definition ultra sound transducer probe midray DC8, L11. The American society of echocardiography's guidelines was followed to categorise the ECHO derived data [20].LV wall thickness: Inter Ventricular Septum /Posterior Wall ≤11/11 indicates normal dimension and above indicate Left Ventricular Hypertrophy. Left Ventricular systolic functions: ≥50% ejection fraction is normal systolic function.

2.4 Perioperative NIBP and IAP Recording

Four pairs of IAP and corresponding NIBP were recorded during the process of Coronary angiogram. Strict vigilance and precautions were adhered for NIBP estimation as recommended by the 2015 AHA JNC Criteria BP estimation [21] such as periodic maintenance and validation of equipment, appropriate size and cuff placement and frequent observer training.

2.5 Oscillometric BP Measurement

The NIBP measurement was done by oscillometric technique with Phillips intellivue M 90 systems with appropriately sized cuffs in the brachial area. The timing of NIBP monitoring was clearly done according to established and described protocol.

2.6 Coronary Angiogram CAG procedure

Cardiac catheterization performed via percutaneous radial artery cannulation. After pressure calibrations intra-arterial cocktail was administered and hemodynamic stabilization obtained. Through the intra-arterial needle, flexible guide wire inserted, over which vascular access sheath was placed. Appropriate cardiac diagnostic catheter was introduced via radial and advanced up to aortic root. Coronary angiogram would be done by cannulating the appropriate coronary ostia. After visualisation of the coronary vasculature, branching patterns, site of block the catheter was removed along the same path [22]. Throughout the process the IAP would be recorded from the monitor by the blinded theatre staff. Pre-CAG procedure non- invasive BP recorded while inserting the catheter into the radial artery and corresponding radial intra-arterial BP were compared. Similarly, non- invasive BP recorded while inserting the catheter into the aorta and corresponding aortic intra- arterial BP were compared. After

the CAG non- invasive BP recorded while withdrawing the catheter from the aorta and corresponding aortic intra-arterial BP were compared. Similarly, non- invasive BP recorded while withdrawing the catheter from the radial artery and corresponding radial intra- arterial BP were compared.

3. STATISTICAL ANALYSIS

Data were analysed by SPSS version 20 for both descriptive and inferential statistics. Comparison of the concomitant NIBP and IAP mean pressure difference done by "independent t test". P value <0.05 was considered statistically significant. Pearson's correlation was done to analyse the relationship between the dependent variable (systolic and diastolic mean pressure differences) with LV thickness and functions.

4. RESULTS

4.1 Descriptive Statistics

Of the 300 subjects recruited, 68.3% were male and 31.7% female. Upon grouping based on the age, group II (46-60 years) had the maximum subjects 46.9%, 36.3% belonged to group I (aged 30-45years) and 17% in group III (aged 60-75 years). ECHO parameters revealed 44% with reduced ejection fraction, left ventricular wall hypertrophy was detected in 54.7% and 26.3% had diastolic dysfunction.

4.2 Comparison of NIBP with Corresponding IAP

Four pairs of systolic and diastolic non-invasive and corresponding intra-arterial blood pressures were compared by independent t test. Mean Systolic difference ranged from 4.37± 12.87 to 11.84±14.38 and diastolic difference 3.89±7.84 to 8.55±8.66. Statistically significant difference was detected in all four systolic as well as diastolic pressures p<0.005.

Table:1 Comparison of systolic and diastolic pressure in different groups and points

Parameters	N	Mean	SD	Std. Error Mean	t value	p value
Systolic NIBP I	300	148.886	23.436	1.353	9.387	0.000**
Pre Radial systolic IAP	300	140.143	20.054	1.157		
Diastolic NIBP I	300	87.250	11.753	0.678	16.850	0.000**
Pre Radial diastolic IAP	300	78.830	11.761	0.679		
Systolic NIBP II	300	134.363	16.978	0.980	12.057	0.000**
Pre Aortic systolic IAP	300	126.606	21.313	1.230		
Diastolic NIBP II	300	81.120	12.863	0.742	14.186	0.000**
Pre Aortic diastolic IAP	300	75.740	11.559	0.667		
Systolic NIBP III	300	141.590	59.828	3.454	4.434	0.000**
Post Aortic systolic IAP	300	126.426	20.931	1.208		
Diastolic NIBP III	300	79.570	10.339	0.596	9.063	0.000**
Post Aortic diastolic IAP	300	75.680	11.849	0.684		
Systolic NIBP IV	300	134.710	16.944	0.978	5.876	0.000**
Post Radial systolic IAP	300	130.346	17.671	1.020		
Diastolic NIBP IV	300	81.403	12.644	0.730	16.289	0.000**
Pre Radial Diastolic IAP	300	72.840	10.119	.584		

***Significant p<0.001*

The estimated systolic and diastolic differences were compared between groups computed based on each associated factor by Mann Whitney for significance. The mean BP differences correlated left ventricular wall thickness: Subjects with Left Ventricular Hypertrophy had more systolic pressure difference (+12.673 mm Hg) compared to subjects with normal LV wall thickness (+8.108mm Hg)

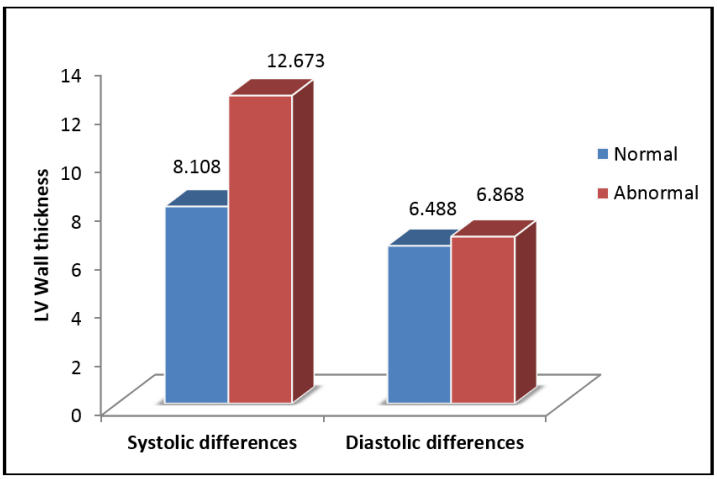
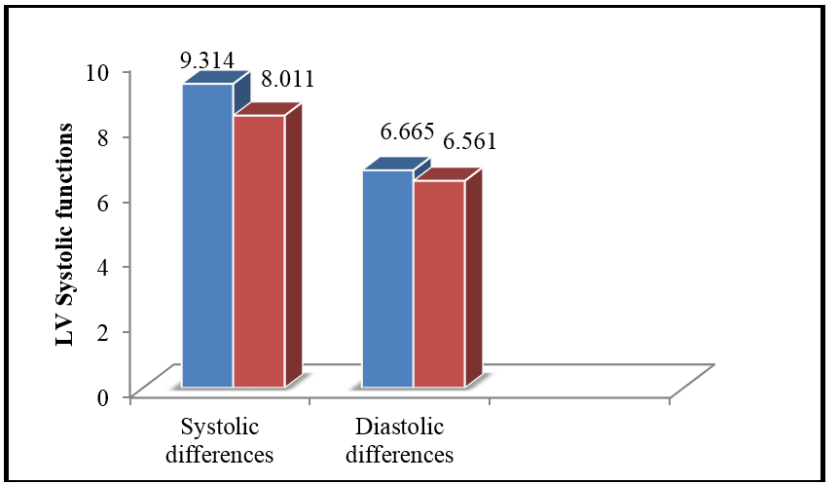


Fig 1BP difference with reference to LV wall thickness

When mean BP differences were correlated left ventricular systolic functions no statistically significant difference noted in systolic and diastolic pressure difference between groups with normal and abnormal LV Systolic function.

4.3 *Predictors of Outcome*

The significant BP differences were seen with diastolic function of the left ventricle. The predictor of outcome of a significant blood pressure change was also seen with the left ventricular hypertrophy.



When mean BP differences were correlated left ventricular diastolic function, subjects with diastolic dysfunction showed statistically higher diastolic BP difference (+8.36 mmHg) compared to the subjects with normal diastolic function (+5.24mmHg) p<0.05

Fig 2 BP difference correlated to LV systolic functions

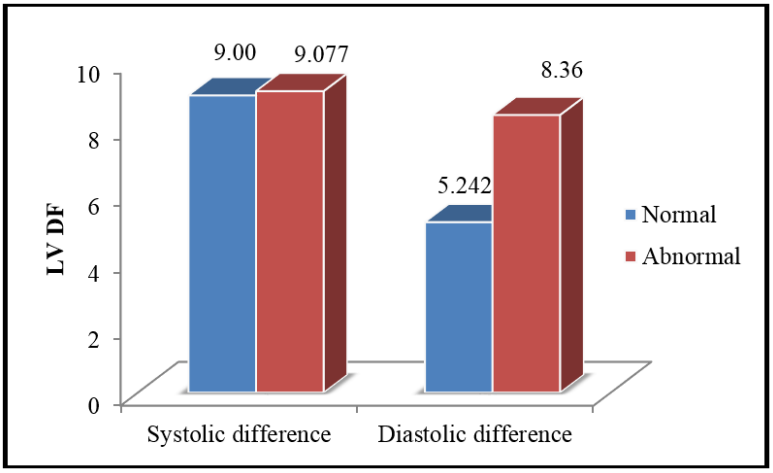


Fig 3 BP differences correlated to LV diastolic function

4.4 *Correlation of LV Morphology and Function with NIBP Estimation*

Pearson's correlations coefficient "r" is used to correlate each associated factor with Non Invasive cuff pressures Vs. Intra Arterial Pressure difference. Correlation is significant at p= 0.01 levels (2 tailed). Systolic pressure difference was positively correlated with LVH (r=0.156), diastolic pressure difference with LVDF (r=0.117).

Table :2 Pearson's correlation of associated factors with the blood pressure estimation

Parameters		EF	LVDF	LVH
Systolic difference	Pearson Correlation	-.014	-.026	.156*
	Sig. (2-tailed)	.814	.376	.942
	N	1200	1200	1200
Diastolic difference	Pearson Correlation	-.090	.117**	.061
	Sig. (2-tailed)	.120	.000	.034
	N	1200	1200	1200

5. DISCUSSION

Results of the study show cuff method overestimated both systolic and diastolic BP (Mean systolic difference: + 4.37-11.84 mm Hg, Mean diastolic difference: +3.89 - 8.46 mm Hg) and a maximum bias of SBP: +11.84mmHg [-16.34 to 40.01 mmHg]. Differences are beyond standards accepted by British Hypertension Society [23][Highest grade of accuracy 60% differences within 5 mm Hg]. Earlier researcher on ICU settings confirm our observation were Sara and Lehmann [24,25]. Sara et al observed overestimation of systolic NIBP (high bias around 27 mm Hg) and underestimation diastolic BP (around 7 mmHg) in ICU setting. Lehmann et al, reported that Non-invasive Systolic BP is recorded more inaccurate compared to Diastolic BP. Picone et al on his systemic review on the studies on BP recordings reported discrepancy of cuff pressure is profound in prehypertensive and stage I Hypertension [26]. Physiologist attribute the cause of inaccuracy to inherent factors and technical variations of both methods [27]. They are site of recording, vessel morphology, hemodynamic properties, "Systolic wave amplification" [narrow prominent systolic peak] happens as waves travel from central elastic arteries to peripheral stiffer arteries [28]and principle of estimation of NIBP and IAP. Hence it is proved that there exists discrepancy between the indirect and direct BP recording. The extent of influence of associated factors such as age, obesity and hemodynamic status of the individual were explored [29,30]. Our study analysed the correlation of left ventricular wall thickness and functions. Analyzing the influence of LV morphology and functions with BP estimation revealed two new unique findings not available in literature. Overestimation of systolic cuff pressure was augmented in subjects with LVH. Overestimation of diastolic pressure was increased in subjects with ventricular diastolic dysfunction. Hence the ECHO parameters LVH and diastolic dysfunction could give us a hint regarding the accuracy of the NIBP recording. A solitary BP value that falls outside the expected range should be inferred with warning and the expected range should be inferred with warning and should not be interpreted as a definitive indicator of clinical deterioration. Additional measurements should be taken and averaged if a measurement is abnormally high or low. Whenever possible, BP values should be graphed within ranges. This may lessen the impact of inaccuracy sources and limit the scope for misinterpretations based on likely misleading changes[31]**.** Regular blood pressure measurement in people under the age of 35 is much more likely to misidentify hypertension than to correctly diagnose it. Because the 10-year coronary risk seldom exceeds 5% in adults under 35, physicians should use caution when diagnosing hypertension-perhaps at a higher threshold. Blood pressure monitoring is most useful in people who have specific indications or coronary risk factors[32]. When the cuff is too small in relation to the arm circumference, it causes a deliberate overvaluation of auscultatory BP, but not when it is properly sized[33]. With oscillometric measurements obtained with a specially designed wide-range cuff, no obvious error is usually observed. The practical BP measurement [34]technique has good accuracy, is simpler, and requires less measurement pressure on healthcare providers, and can optimise the utility of BP measurement, diagnosis of hypertension, and control in fast - paced primary health care settings.

6. RECOMMENDATIONS

The emphasis is on adherence to BP estimation guidelines, caution in starting, vigilance in managing, and following up on hypertension. In warranted patients, a detailed workup on left ventricular functions and morphology is recommended prior to pharmacological intervention. Caution is required when estimating blood pressure and initiating pharmacological intervention in vulnerable populations such as the elderly, young borderline hypertensives, and unstable patients with high blood pressure.

7. LIMITATIONS

The research was carried out in a single location. A multicentric study with healthy subjects would broaden the scope. The study population consisted of patients undergoing diagnostic angiography, so there is a preponderance of men, the elderly, and the obese. There is no data from a normal individual to compare.

8. CONCLUSION

According to the findings of our study, there is a discrepancy in the BP recorded by non-invasive and invasive methods. It is necessary to concentrate on the factors that influence the magnitude of the discrepancy in BP recorded by invasive and non-invasive methods. In this regard, ejection fraction and left ventricular dysfunction are important predictors of diastolic blood pressure discrepancy. As a result, we recommend echocardiography to estimate left ventricular functions and morphology in patients with hypertension who are being treated. The clinical implications of echo parameters in elderly and young borderline hypertensives before starting pharmacotherapy for effective blood pressure management to maintain homeostasis cannot be overstated.

9. AUTHORS CONTRIBUTION STATEMENT

RS and BA – data collection and manuscript, KJ – statistics and overall supervision, SPS = concept and design

10. CONFLICT OF INTEREST

Conflict of interest declared none.

11. REFERNCES

1. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN et al. Recommendations for blood pressure measurement in humans and experimental animals: part 1: Blood pressure measurement 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. Circulation. 2005 Feb 8;111(5):697-716. doi: 10.1161/01.CIR.0000154900.76284.F6, PMID 15699287.
2. World Health Organization. Global status report on non-communicable diseases 2014. Geneva: World Health Organization; 2014.
3. Forouzanfar MH, Liu P, Roth GA, Ng M, Biryukov S, Marczak L et al. Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg,

1990-2015. JAMA. 2017 Jan 10;317(2):165-82. doi: 10.1001/jama.2016.19043, PMID 28097354.
4. Risk NCD, Factor Collaboration. Worldwide trends in blood pressure from 1975 to 2015: a pooled analysis of 1479 population-based measurement studies with 19.1 million participants. Lancet. 2017;389(10064):37-55. doi: 10.1016/S0140-6736(16)31919-5, PMID 27863813 (NCD. RiSC).
5. Gupta R, Gaur K, Venkata C, Ram S. Emerging trends in hypertension epidemiology in India Journal of Human Hypertension.2019;33;5878:575.
6. Zion MM, Balkin J, Rosenmann D, Goldbourt U, Reicher-Reiss H, Kaplinsky E et al. Use of pulmonary artery catheters in patients with acute myocardial infarction: analysis of experience in 5,841 patients in the Sprint registry. Chest. 1990 Dec 31;98(6):1331-5.
7. Tholl U, Forstner K, Anlauf M. Measuring blood pressure: pitfalls and recommendations. Nephrol Dial Transplant. 2004 Apr 1;19(4):766-70. doi: 10.1093/ndt/gfg602, PMID 15031326.
8. Ogedegbe G, Pickering T. Principles and techniques of blood pressure measurement. Cardiol Clin. 2010 Nov 1;28(4):571-86. doi: 10.1016/j.ccl.2010.07.006, PMID 20937442.
9. Lee JH, Kim JM, Ahn KR, Kim CS, Kang KS, Chung JH et al. Study for the discrepancy of arterial blood pressure in accordance with method, age, body part of measurement during general anesthesia using sevoflurane. Korean J Anesthesiol. 2011 May 1;60(5):323-8. doi: 10.4097/kjae.2011.60.5.323, PMID 21716961.
10. Smith L, New AHA. Recommendations for blood pressure measurement. Am Fam Phys. 2005 Oct 1;72(7):1391-8.
11. Williams B, Lacy PS, Thom SM, Cruickshank K, Stanton A, Collier D et al. Differential impact of blood pressure-lowering drugs on central aortic pressure and clinical outcomes: principal results of the Conduit Artery Function Evaluation (CAFE) study. Circulation. 2006 Mar;113(9):1213-25. doi: 10.1161/CIRCULATIONAHA.105.595496, PMID 16476843.
12. Manios E, Vemmos K, Tsivgoulis G, Barlas G, Koroboki E, Spengos K et al. Comparison of noninvasiveoscillometric and intra-arterial blood pressure measurements in hyperacutestroke. Blood Press Monit. 2007;12(3):149-56. doi: 10.1097/MBP.0b013e3280b083e2, PMID 17496464.
13. Smith L, New AHA. Recommendations for blood pressure measurement. Am Fam Phys. 2005 Oct 1;72(7):1391-8.
14. Cameron JD. Comparison of noninvasive devices for assessing central blood pressure parameters: what to compare, when and why. J Hypertens. 2013;31(1):27-31. doi: 10.1097/HJH.0b013e32835c0de8, PMID 23221925.
15. R S, S P. Comparative evaluation of accuracy of recording blood pressure either by automated oscillometric method or by sphygmomanometer in both normotensive and hypertensive patients - a prospective observational study. Asian J Pharm Clin Res. 2018;11(2, Feb):109-12. doi: 10.22159/ajpcr.2018.v11i2.21959.
16. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL et al. The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. JAMA. 2003 May 21;289(19):2560-72. doi: 10.1001/jama.289.19.2560, PMID 12748199.
17. Bordley JA, Connor CA, Hamilton WF, Kerr WJ, Wiggers CJ. Recommendations for human blood pressure determinations by sphygmomanometers. Circulation. 1951 Oct;4(4):503-9. doi: 10.1161/01.cir.4.4.503, PMID 14870262.
18. American national standard [manual]. electronic or automated sphygmomanometers ANSI/AAMI. Vol. 1992. Arlington, VA: Association for the Advancement of Medical Instrumentation; 1992. p. 10.
19. Araghi A, Bander JJ, Guzman JA. Arterial blood pressure monitoring in overweight critically ill patients: invasive or noninvasive? Crit Care. 2006 Apr;10(2):R64. doi: 10.1186/cc4896, PMID 16630359.
20. Gottdiener JS, Bednarz J, Devereux R, Gardin J, Klein A, Manning WJ et al. American Society of Echocardiography recommendations for use of echocardiography in clinical trials. J Am Soc Echocardiogr. 2004 Oct;17(10):1086-119. doi: 10.1016/j.echo.2004.07.013, PMID 15452478.
21. Bordley JA, Connor CA, Hamilton WF, Kerr WJ, Wiggers CJ. Recommendations for human blood pressure determinations by sphygmomanometers. Circulation. 1951 Oct;4(4):503-9. doi: 10.1161/01.cir.4.4.503, PMID 14870262.
22. American national standard [manual]. electronic or automated sphygmomanometers ANSI/AAMI. Vol. 1992. Arlington, VA: Association for the Advancement of Medical Instrumentation; 1992. p. 10.
23. O'Brien E, Waeber B, Parati G, Staessen J, Myers MG. Blood pressure measuring devices: recommendations of the European Society of Hypertension. BMJ. 2001 Mar 3;322(7285):531-6. doi: 10.1136/bmj.322.7285.531, PMID 11230071.
24. Peng X, Schultz MG, Picone DS, Dwyer N, Black JA, Roberts-Thomson P et al. Non-invasive measurement of reservoir pressure parameters from brachial cuff blood pressure waveforms. J Clin Hypertens (Greenwich). 2018 Dec;20(12):1703-11. doi: 10.1111/jch.13411, PMID 30450732.
25. Lehman LW, Saeed M, Talmor D, Mark R, Malhotra A. Methods of blood pressure measurement in the ICU. Crit Care Med. 2013;41(1):34-40. doi: 10.1097/CCM.0b013e318265ea46, PMID 23269127.

26. Picone DS, Schultz MG, Otahal P, Aakhus S, Al-Jumaily AM, Black JA et al. Accuracy of cuff-measured blood pressure: systematic reviews and meta-analyses. J Am Coll Cardiol. 2017 Jul 24;70(5):572-86. doi: 10.1016/j.jacc.2017.05.064, PMID 28750701.
27. Roman MJ, Devereux RB, Kizer JR, Lee ET, Galloway JM, Ali T et al. Central pressure more strongly relates to vascular disease and outcome than does brachial pressure: the Strong Heart Study. Hypertension. 2007 Jul 1;50(1):197-203. doi: 10.1161/HYPERTENSIONAHA.107.089078, PMID 17485598.
28. Van Bergen FH, Weatherhead DS, Treloar AE, Dobkin AB, Buckley JJ. Comparison of indirect and direct methods of measuring arterial blood pressure. Circulation. 1954 Oct;10(4):481-90. doi: 10.1161/01.cir.10.4.481, PMID 13209734.
29. Sobana R, Parthasarathy S, Madanmohan T, Amirthaganesh B, Jaiganesh K. A cross sectional analytical study on the influence of age in the precision and accuracy of non-invasive blood pressure recording compared to invasive intra-arterial pressure recording. Natl J Physiol Pharm Pharmacol. 2017;8(3):436-40. doi: 10.5455/ijmsph.2018.1039720102017.
30. Lind L, Andersson J, Rönn M, Gustavsson T, Holdfelt P, Hulthe J et al. Brachial artery intima-media thickness and echogenicity in relation to lipids and markers of oxidative stress in elderly subjects:-the prospective investigation of the vasculature in Uppsala Seniors (PIVUS) Study. Lipids. 2008 Feb 1;43(2):133-41. doi: 10.1007/s11745-007-3125-6, PMID 18004605.
31. Kallioinen N, Hill A, Horswill MS, Ward HE, Watson MO. Sources of inaccuracy in the measurement of adult patients' resting blood pressure in clinical settings: a systematic review. J Hypertens. Mar 2017;35(3):421-41. doi: 10.1097/HJH.0000000000001197, PMID 27977471.
32. Marshall T. When measurements are misleading: modelling the effects of blood pressure misclassification in the English population. BMJ. 2004 Apr 17;328(7445):933. doi: 10.1136/bmj.328.7445.933, PMID 15087340.
33. Bilo G, Sala O, Perego C, Faini A, Gao L, Głuszewska A et al. Impact of cuff positioning on blood pressure measurement accuracy: may a specially designed cuff make a difference? Hypertens Res. 2017;40(6):573-80. doi: 10.1038/hr.2016.184, PMID 28077860.
34. Shivashankar R, et al. Validation of a Practical Approach to Blood Pressure Measurement: Secondary Analysis of Data from a Nationally Representative Survey in India. Global Heart. 2021; 16(1): 87. DOI: https://doi.org/10.5334/gh.1085