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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Received On 18 September 2022
Revised On 11 October 2022
Accepted On 14 October 2022
Published On 20 October 2022

Funding: This research did not receive any specific grant from any funding agencies in the public, commercial or not for profit sectors.

Citation: Dr. Sobana R. MD, Phd, Dr. Amrita Ganesh MD, DNB, Dr. Jaiganesh.K MD and Dr. Parthasarathy.S MD Phd, 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. (2022). Int. J. Life Sci. Pharma Res. 12(6), L34-40

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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. World Health Organization, Global Burden of Disease (GBD) study, and Non-Communicable Disease Risk Factor Collaboration report the prevalence of hypertension as more than 1 billion/year. KDIGO and SPRINT 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. 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. BP overestimation creates iatrogenic hypotension, additional cost, and exposure to adverse effects of unnecessary treatment. Since BP estimation remains as a crucial diagnostic parameter even a minor error can have major public health ramifications. Yet NIBP is prone for deviation from actual BP due to 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. Intra-arterial pressure estimates the actual pressure and hence considered gold standard for BP estimation. IAP estimation is invasive, and needs expertise. NIBP and IAP may differ due to various inherent physiological and technical causes. Uncertainty prevails whether NIBP reflects actual BP and true agreement between aortic and brachial arterial pressures exists. 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 categorise the ECHO derived data. Left 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.

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. 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 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-arteral 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. 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

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

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

**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:

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 30-45 years) 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.

Subjects with Left Ventricular Hypertrophy had more systolic pressure difference (+12.673 mm Hg) compared to subjects with normal LV wall thickness (+8.108 mm Hg)
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.

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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>EF</th>
<th>LVDF</th>
<th>LVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic difference</td>
<td>Pearson Correlation</td>
<td>-.014</td>
<td>-.026</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.814</td>
<td>.376</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>Pearson Correlation</td>
<td>-.090</td>
<td>.117**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.120</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>1200</td>
<td>1200</td>
</tr>
</tbody>
</table>
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. 20[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 1 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 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 with specific indications or coronary risk factors.

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.

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