International Journal of Innovative Research in Medical Science (IJIRMS)
Volume 08, Issue 09, September 2023,
https://doi.org/10.23958/ijirms/vol08-i09/1729

Original article

Comparison Between Noninvasive and Invasive Blood Pressure Monitoring in Post Percutaneous Coronary Intervention Patients Admitted to Cardiac Intensive Care Unit

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Received 23 July 2023; Accepted 20 August 2023; Published 01 September 2023

Abstract

Background: Percutaneous coronary intervention (PCI) remains one of the most important treatment modality for all the spectrum of artherosclerotic coronary artery disease. Post PCI patients are routinely admitted into the cardiac intensive care unit (ICCU) for observation and further management during which blood pressure (BP) and other hemodynamic parameters are monitored. Blood pressure (BP) monitoring is vital for the management of hemodynamically unstable patients in the cardiac intensive care Unit (ICCU). Despite errors from inaccurate calibration, movement artifacts and over or underdamping, invasive arterial blood pressure (IABP) monitoring remains the preferred method of monitoring BP in hemodynamically unstable patients. Nonetheless, automated noninvasive BP (NIBP) monitoring is commonly used in critically ill patients in cardiac ICU. ***Aim of study:*** To compare IABP using radial and femoral arterial line with NIBP monitoring, and to determine if radial and femoral arterial lines can be used interchangeably in patients undergoing PCI. ***Methodology:*** A total of eighty post PCI patients who had arterial line cannulation during PCI and admitted into ICCU were enrolled. Study participants were divided into two groups of Fourty (40) patients each. One group had IABP monitoring via right femoral artery line while the second group had IABP monitoring via right radial artery cannular. A cuff was placed on the left arm for concurrent noninvasive BP monitoring in all 80 patients. Data were obtained by performing noninvasive blood pressure (NIBP) t and concurrent IABP four times at one hourly intervals with first reading taken at time of admission to cardiac intensive care unit labelled (T1). NIBP values were compared with IABP values as the reference standard. ***Results:*** There were significant differences between systolic IABP as well as mean arterial invasive blood pressure measurements obtained through both radial and femoral routes compared with noninvasive blood pressure measurements (NIBP). No statistically significant differences in invasive blood pressure measurements between the radial and femoral catheter routes was detected. ***Conclusion:*** Noninvasive blood pressure measurement alone is insufficient for monitoring of post PCI patients admitted to cardiac intensive care unit after coronary angioplasty. The femoral and radial arterial lines can be used interchangeably for blood pressure monitoring in cardiac intensive care unit.

Keywords: ***Blood pressure Monitoring, Invasive, Noninvasive, percutaneous coronary intervention, cardiac care unit***

Introduction

Percutaneous coronary intervention (PCI) remains one of the most important treatment modalities for all the spectrum of artherosclerotic coronary artery disease for many years now, due to its high efficacy and minimally invasive nature [1]. Post-PCI patients are routinely admitted into the cardiac intensive care unit (ICCU) for observation during which blood pressure (BP) and other hemodynamic parameters are monitored [2]. Hypotension following PCI can cause significant myocardial ischemia due to insufficient cardiac perfusion. To prevent this, continuous monitoring of BP is imperative [3,4]. On the other hand, significant rise in blood pressure post PCI predisposes the patient to stroke [5].

Arterial cannulation using the radial or femoral route is routinely done in patients undergoing PCI, allowing for uninterrupted display of pulse contour and continuous real time heart rate and blood pressure measurement. However, arterial cannular insertion can be associated with significant risks and clinician must weigh the risk to benefit ratio [6]. Specifically, post PCI, invasive intra-arterial blood pressure monitoring helps prevent stent thrombosis and maintain adequate myocardial blood supply to promote the recovery of damaged myocardium through capturing the instantaneous changes in the patient's arterial pressure to help maintain an appropriate blood pressure constantly [7]. However, previous data have reported the complications induced by IABP including thromboembolism, blood flow blockage, bleeding and hematoma [8]. And inadequate management of the indwelling needle and intra-arterial cannula is an important risk factor for adverse reactions in patients undergoing IABP [9]. Consequently, the application of IABP in management of post PCI patients remains controversial even-though it has been shown to be superior to non-invasive blood pressure monitoring (NIBP) [10].

Non-invasive blood pressure monitoring is the most widely used method for BP measurement in clinical practice has the advantage of being simple and easy to use simple, as well as few complications. Consequently, automated oscillometric NIBP monitoring is commonly employed in ICCU where frequent monitoring of BP among critically ill patients is required [11]. However, NIBP does not accurately reflect the hemodynamic alterations occurring in real-time, and information on BP is not captured in-between the measurements, making it less reliable than IABP monitoring [12,13].

In this study, we compared radial and femoral IABP monitoring with automated oscillometric NIBP monitoring in post-PCI patients admitted into ICCU. We also compared IABP measured in radial and femoral arteries to determine if the sites can used interchangeably for hemodynamic monitoring following PCI.

Methodology

This was a prospective observational study carried out at the cardiology unit of Meditrina specialty hospital, Kollam south India. Eighty patients >18 years admitted into the unit following PCI between August 2021 and September 2022 were studied. The following exclusion criteria were applied: cardiogenic shock, renal failure, patients requiring mechanical ventilatory support and unconscious patients.

To be eligible, the patients must have an intra-arterial line inserted on clinical indications as part standard care for PCI. Arterial catheterization (IPEX Invasive pressure monitoring system) was performed by the interventional cardiology team during PCI adhering to standard guidelines. No arterial catheter was placed for the sole purpose of this study. Forty (40) had IABP monitoring through right femoral artery cannular and the remaining 40 (forty patients) had IABP through right radial cannulation. All patients had periodic measurements of their non-invasive blood pressure (NIBP) measurements recorded.

For the NIBP measurements, oscillometric blood pressure measurements were performed by cardiac critical care nurses with training in standardized blood pressure recording methods. Standard oscillometric blood pressures cuffs, meeting ISH SP10:2020 requirements [14], models 30503-13LA, 30503-12A, and 30503-14LA (Index Line Health, Mumbai India), were used. Adult Cuff sizes (Bladder sizes ranging from 13.1X 23.5cm to 16 X 36cm) for patients mid arm circumferences ranging from 25-45cm were used for measurements. The cuff was placed on the arm opposite the arterial catheter for all study measurements. The cuff was situated according to the manufacturer's recommendations in the middle of the arm with the dedicated arterial indicator band placed at the level of the brachial artery. Standard oscillometric module M3000A (Hygeia, EVA-N model) Monitor was connected to the cuff with manufacturer-approved tubing, and automatically inflated and deflated the cuff for the NIBP measurement [15]. For the IABP measurements, a 20-G or a 16G (Art-can manufacturers) arterial catheter was present in the radial artery or the femoral artery respectively. The transducer system (PX278, IPEX; Merilyl Life partners, New Delhi, India) was connected to the arterial catheter through a three-way stopcock and high pressure tubing. The tubing was flushed to ensure all air was removed from the system. Tubing was inspected to ensure no kinking. The pressure transducer was placed at the level of the right atrium (Phlebostatic axis) and zero-calibrated to atmospheric pressure [16]. The critical care nurse and study personnel observed the arterial waveform to verify normalcy, and a rapid saline flush was performed to verify a square wave test and rule out damping [17]. Blood pressures were taken with the patient in the semi-recumbent position with the arms resting at the patient's side. Simultaneous IABP and NIBP measurements were performed at I hour intervals for four cycles. First measurements were done at the time of transfer from cathlab to ICCU and recorded as T1. Subsequent measurements were T2- T4 respectively. Values for Mean arterial blood pressure, systolic and diastolic blood pressures for both NIBP and IABP. Four pairs of measurements were collected in total to follow the guidelines set forth by the European Society of Hypertension (ESH) 2016 protocol and the British Hypertension Society 2020 protocol [18]. Each IABP measurement was recorded concurrently with the oscillometric blood pressure measurement (NIBP) and the result displayed on the space lab Monitor (MP50; Spacelabs cardiovascular ltd, Mumbai India). The correlations between invasive and non-invasive systolic (SAP), diastolic (DAP), and mean arterial pressure (MAP) values were assessed using Bland-Altman analysis [19,20].

Statistical analysis: Data management and analysis were performed using SPSS version 19.0. Continuous variables were presented as means (+ SD) while categorical variables were presented as proportions. Student's t-test was used to compare means between two groups. P Value < 0.05 was considered statistically significant. Bland-Altman plots [20] were constructed to assess the accuracy of NIBP against the gold standard of IABP. Bland-Altman plots easily allows assessment of the extent of agreement between two modes of measurement, its particularly useful in a scenario where the true values remain unknown and plots the difference of the two measured values against the mean of the values. Plots are presented with 95% limits of agreement (precision; ± 2 SD) and bias (the mean difference). This provides a visual guide to judge how well the two methods of measurement agree. The smaller the range between the two limits the better the level of correlation or agreement [20].

Ethical clearance was obtained from the hospital research committee in addition to the informed consent obtained from each patient.

Results

A total of 80 (52 males and 28 females) participants aged 64.85 ± 12.13 years (range 33 - 88) were involved in this study. Further descriptive statistics for weight, height, BMI and physiological parameters for the combined population are shown in **Table 1**. The mean weight and height revealed that males are significantly taller and heavier than their female counterparts. There was no significant difference in age, BMI and physiological variables between male and female participants.

Results of paired sample t-test comparison of systolic BP, diastolic BP and mean arterial pressure measured using invasive and non-invasive methods are summarized in **Table 2**. Systolic blood pressure (t = 16.27, P <0.001) and mean arterial pressure (t = 9.35, P <0.001) measured using the invasive technique are significantly higher than those measured non-invasively. The higher mean systolic BP and mean arterial pressure measured using invasive technique implies that the invasive technique is disproportionately more sensitive than the non-invasive technique. Although the non-invasive technique is not sensitive in measuring higher systolic and arterial pressure compared to the invasive technique, it however, was able to measure high systolic blood pressure of the scale of hypertension, suggesting that the non-invasive method is applicable for measuring relatively lower systolic BP and arterial pressure of hypertensive patients and hypotensive individuals.

In contrast, comparison of the mean diastolic BP measured using the invasive and non-invasive methods shows no statistically significant difference (t=0.68, P=0.497), suggesting that both methods can be used interchangeably.

The mean systolic BP and mean arterial pressure were not significantly different between femoral and radial arteries for measurements taken invasively (**Table 3**). These preliminary results showing low heterogeneity in SBP (3.64 mm Hg) and MAP (0.91 bpm) between the two routes implies that both routes can be used interchangeably. Mean diastolic BP taken through femoral artery is significantly higher (5.23 mm Hg, t = 2.22, P = 0.029) when measured invasively. This implies that femoral artery has higher potential to measure BP than radial arterial route.

Bland-Altman results for percentage bias and limits of agreement (LOA) are presented in **Table 4**. Bland-Altman scatterplots (**Figures 1-6**) graphed the bias and LOA (defined as x¯ ± 1.96*SD). Negative bias indicates that values measured by one technique are not significantly different from the other whereas, positive bias indicates otherwise (that is, values measured using one technique is significantly higher). The negative bias (between IDBP vs NDBP and FISBP vs RISBP) indicates that measurement taken through NDBP method is higher than that taken through IDBP, also measurement taken through RISBP is higher when compared to FISBP. With a preset cut-off point of ≤5% (mm Hg or bpm for MAP) between any pair of methods, two methods can be used interchangeably or are considered to be in agreement if their bias do not exceed this cut-off point. Bland-Altman analysis demonstrated biases within acceptable limits (approximately ≤1.9%) for IDBP vs NDBP, FISBP vs RISBP and FIMAP vs RIMAP while the others performed worst (particularly ISBP vs NSBP with 14.5% overestimation). Similarly, the 95% LOA measures whether methods (invasive vs. non-invasive or femoral or radial arterial route) agree sufficiently for use interchangeably. For instance, in **Figure 2**, with a 95% LOA between IDBP and NDBP of (-25.60 to 22.66) indicate that for 95% of observations, diastolic BP measurement taken by one method (invasively or non-invasively) was between -25.60% Hg less and 22.66% more than a measurement taken by the reference method.

The relationship between BP measurements taken invasively and those taken non-invasively are show in **Figures 7-9**. The relationship of measurements taken invasively and non-invasively are linear. The correlation coefficient between ISBP and NSBP is highest (r = 0.66, P <0.0001) and lowest between IDBP and NDBP (r = 0.31, P <0.005). The results demonstrate that Pearson's correlation coefficient detect significant linear association in BP measured using invasive and non-invasive methods. Correlation between measurements taken through the femoral and radial route showed inverse associations (**Figures 10-12**). None of the correlation attained significant inverse association.

Table 1: Demographic characteristics of study of participants

	Mean ± SD	**Min – Max**	**Male**	**Female**	**T**	**P**
N	80	-	52	28	-	-
Age (yrs.)	64.85 ± 12.13	33 – 88	63.65 ± 13.52	67.07 ± 8.81	1.21	0.232
Height (m)	1.70 ± 0.07	1.53 – 1.82	1.74 ± 0.04	1.62 ± 0.06	10.29	<0.001
Weight (kg)	81.99 ± 10.18	60 – 102	85.35 ± 8.67	75.75 ± 9.97	4.48	<0.001
BMI (kgm-2)	28.45 ± 2.36	23.51 – 35.25	28.25 ± 2.01	28.82 ± 2.90	1.03	0.306
PR	89.20 ± 14.65	56 – 126	89.81 ± 14.58	88.07 ± 15.00	0.50	0.616
Fasting blood sugar (mg/dL)	149.75 ± 51.02	70 – 324	144.42 ± 42.53	159.64 ± 63.58	1.28	0.205
Invasive systolic BP (mm Hg)	171.31 ± 16.73	131.75 – 227.50	171.75 ± 15.74	170.51 ± 18.71	0.31	0.755
Invasive Diastolic BP (mm Hg)	84.83 ± 10.79	66.25 – 122.50	85.72 ± 10.73	83.20 ± 10.91	1.00	0.322
Invasive mean arterial pulse (bpm)	114.52 ± 10.90	93.50 – 157.75	114.93 ± 10.08	113.77 ± 12.43	0.45	0.653
Non-invasive systolic BP (mm Hg)	147.97 ± 13.15	122.33 – 180.00	147.41 ± 13.00	149.00 ± 13.60	0.51	0.609
Non-invasive diastolic BP (mm Hg)	85.64 ± 5.92	69.25 – 100.00	85.87 ± 5.87	85.22 ± 6.11	0.46	0.646
Non-invasive mean arterial pulse (bpm)	105.66 ± 7.14	86.50 – 124.50	105.65 ± 7.23	105.67 ± 7.10	0.01	0.993

Table 2: Comparison of blood pressure between invasive and non-invasive routes

	Non-invasive	**Invasive**		
	Mean ± SD	Mean ± SD	t*	*P*
N	80	80	-	-
Systolic BP	147.97 ± 13.15	171.31 ± 16.73	16.27	<0.001
Diastolic BP	85.64 ± 5.92	84.83 ± 10.79	0.68	0.497
Mean arterial BP	105.66 ± 7.14	114.52 ± 10.90	9.35	<0.001

**Paired sample t-test*

Table 3: Comparison of invasive blood pressure measured through femoral and radial arterial routes

	Femoral arterial	**Radial arterial**		
Invasive line BP	Mean ± SD	Mean ± SD	t*	*P*
N	40	40	-	-
Systolic BP	169.49 ± 14.56	173.13 ± 18.66	0.97	0.334
Diastolic BP	87.45 ± 6.30	82.22 ± 13.50	2.22	0.029
Mean arterial BP	114.98 ± 7.56	114.07 ± 13.52	0.37	0.712

**Unpaired (independent sample) t¬-test*

Table 4: Accuracy of BP measurements

	N	Bias (%)	LOA (%)
ISBP vs NSBP	80	14.5	-0.45, 29.51
IDBP vs NDBP	80	-1.5	-25.60, 22.66
IMAP vs NMAP	80	7.8	-6.14, 21.83
FISBP vs RISBP	40	-1.9	-29.10, 25.28
FIDBP vs RIDBP	40	7.1	-29.17, 43.30
FIMAP vs RIMAP	40	1.2	-26.34, 28.80

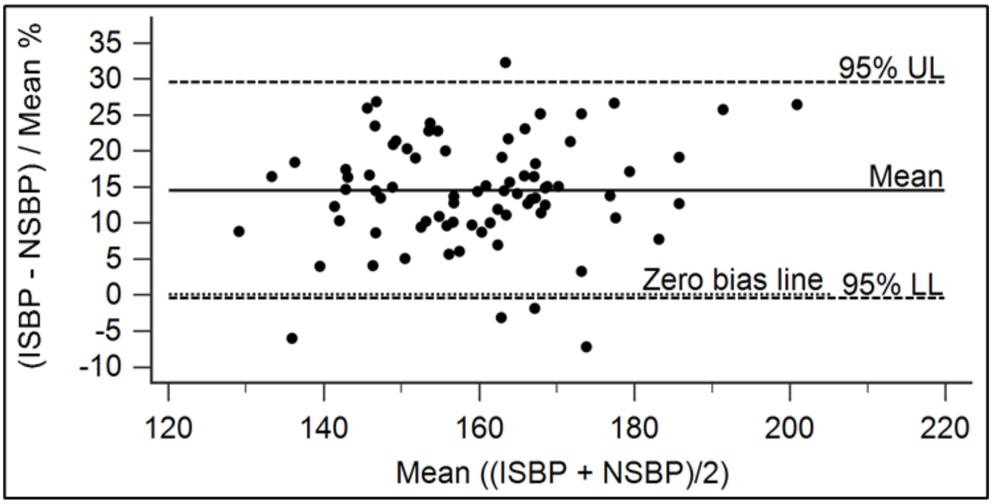

Figure 1: Bland-Altman scatterplot demonstrating comparison between invasive and non-invasive systolic BP measurements.

ISBP, invasive systolic blood pressure; NSBP, non-invasive systolic blood pressure

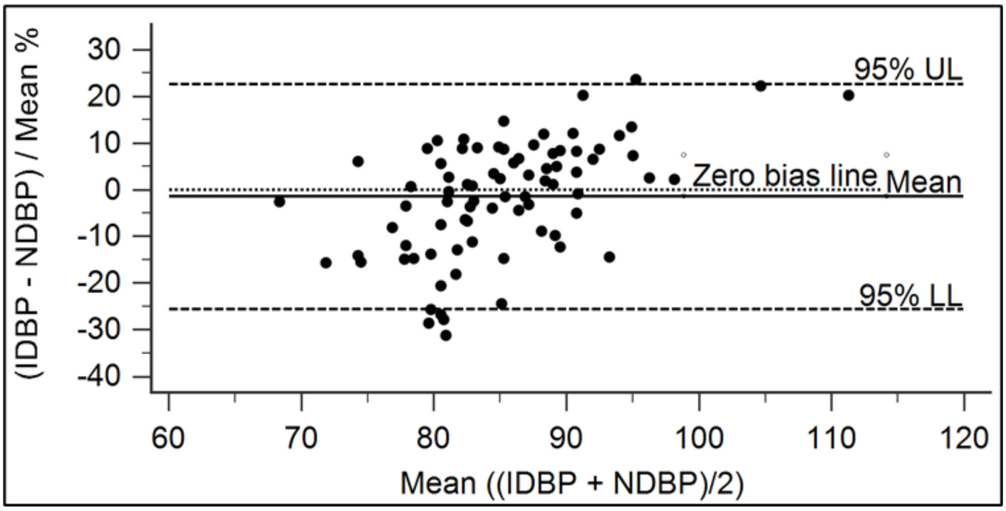

Figure 2: Bland-Altman scatterplot demonstrating comparison between invasive and non-invasive diastolic BP measurements.

IDBP, invasive diastolic blood pressure; NDBP, non-invasive diastolic blood pressure

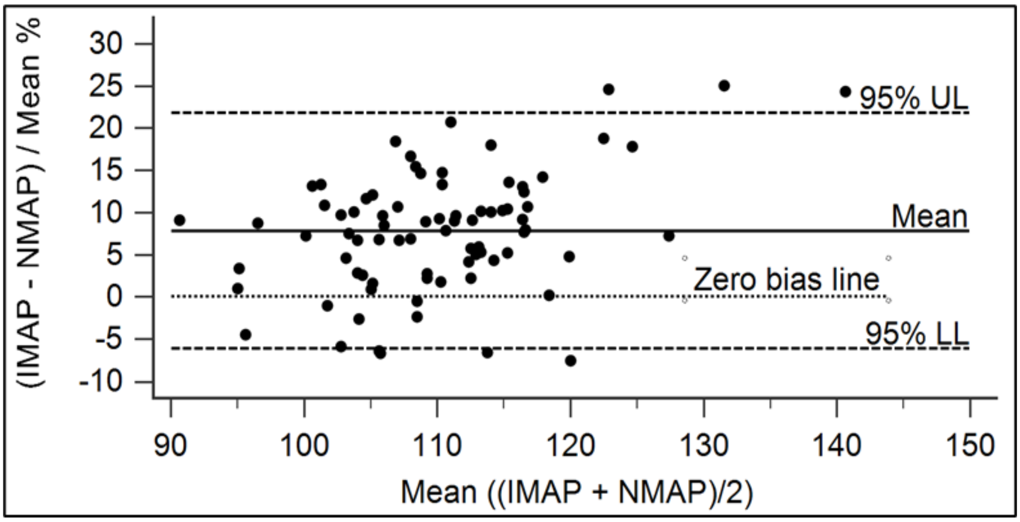

Figure 3: Bland-Altman scatterplot demonstrating comparison between invasive and non-invasive Mean arterial BP measurements.

IMAP, invasive mean arterial pressure; NMAP, non-invasive mean arterial pressure

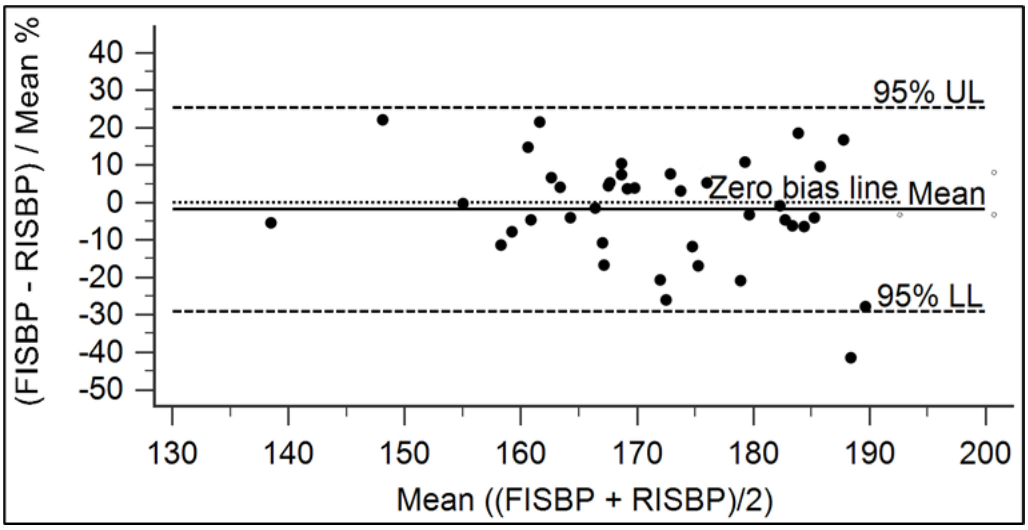

Figure 4: Bland-Altman scatterplot demonstrating comparison between femoral invasive and radial invasive systolic BP measurements.

FISBP, femoral invasive systolic blood pressure; RISBP, radial invasive systolic blood pressure

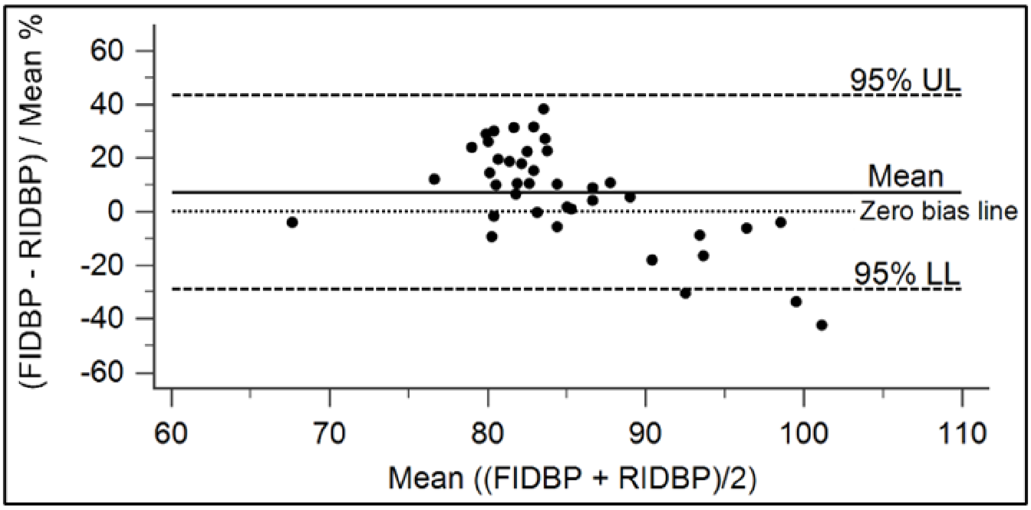

Figure 5: Bland-Altman scatterplot demonstrating comparison between femoral invasive and radial invasive diastolic BP measurements.

FIDBP, femoral invasive diastolic blood pressure; RIDBP, radial invasive diastolic blood pressure

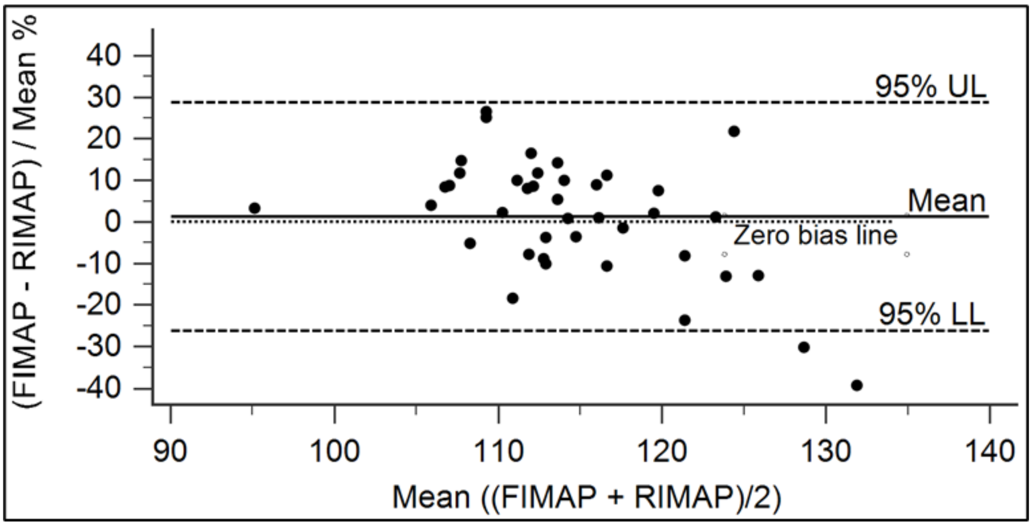

Figure 6: Bland-Altman scatterplot demonstrating comparison between femoral invasive and radial invasive mean arterial pressure measurements.

FIMAP, femoral invasive mean arterial pressure; RIMAP, radial invasive mean arterial pressure

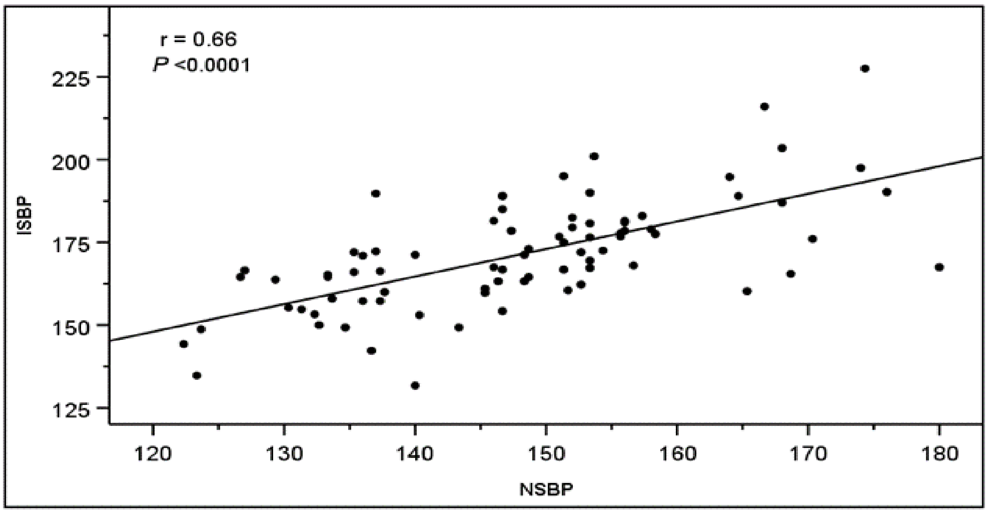

Figure 7: Scatterplots showing the correlations between invasive systolic blood pressure (ISBP) and non-invasive systolic blood pressure (NSBP).

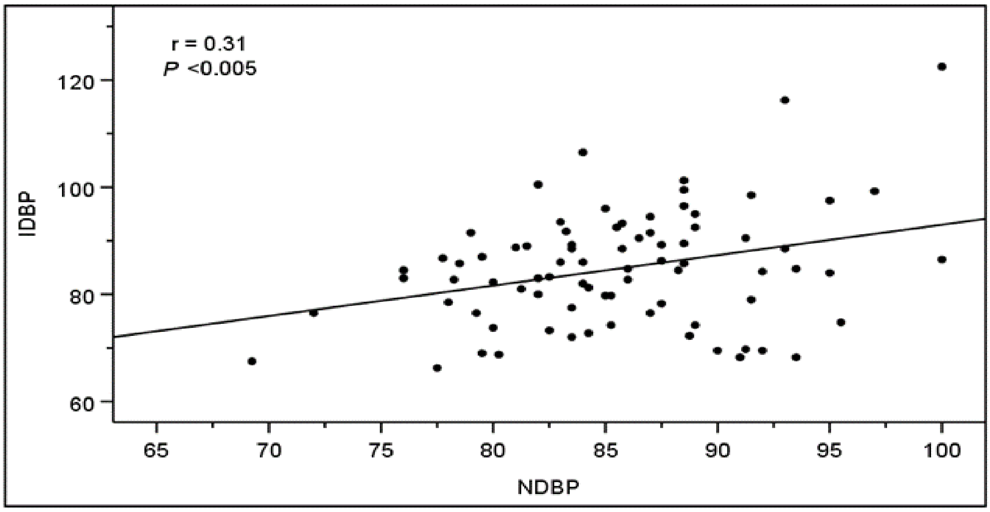

Figure 8: Scatterplots showing the correlations between invasive diastolic blood pressure (IDBP) and non-invasive diastolic blood pressure (NDBP).

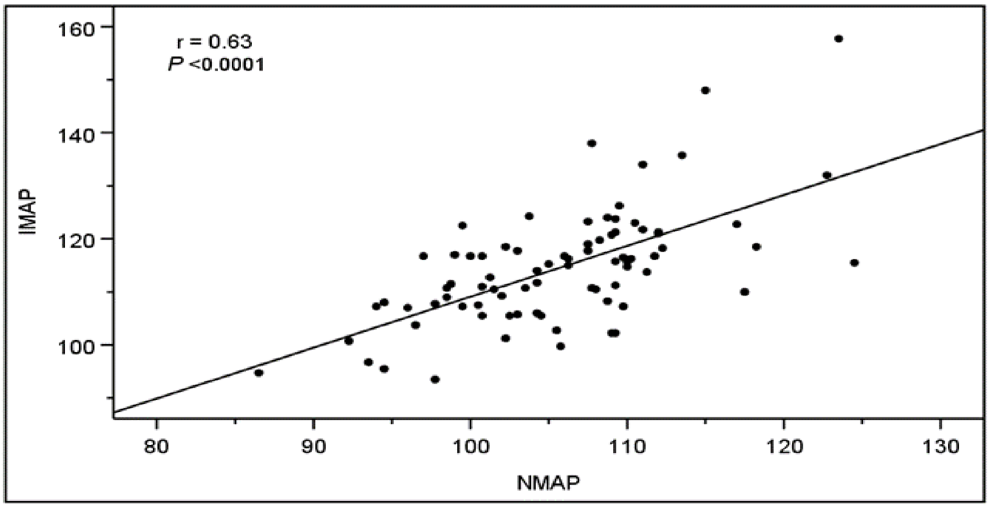

Figure 9: Scatterplots showing the correlations between invasive mean arterial pressure (IMAP) and non-invasive mean arterial pressure (NMAP).

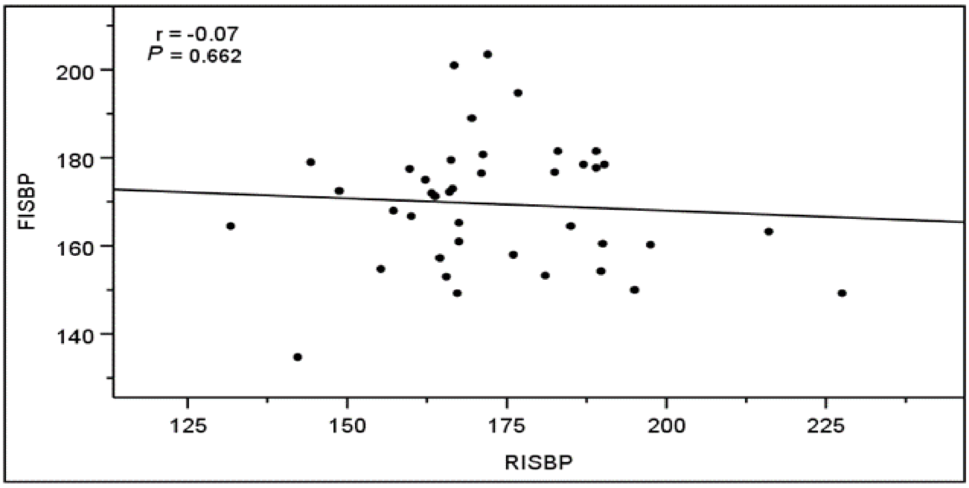

Figure 10: Scatterplots showing the correlations between femoral invasive systolic blood pressure (FISBP) and radial invasive systolic blood pressure (RISBP).

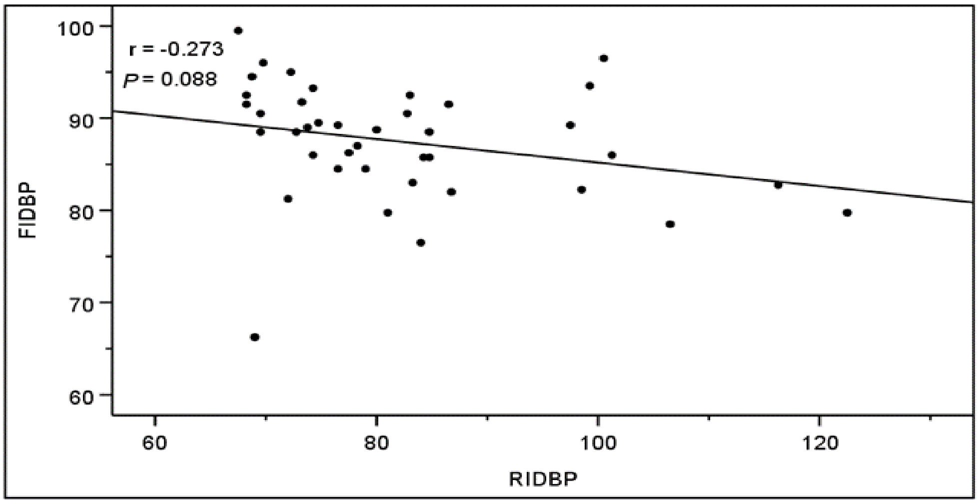

Figure 11: Scatterplots showing the correlations between femoral invasive diastolic blood pressure (FIDBP) and radial invasive diastolic blood pressure (RIDBP).

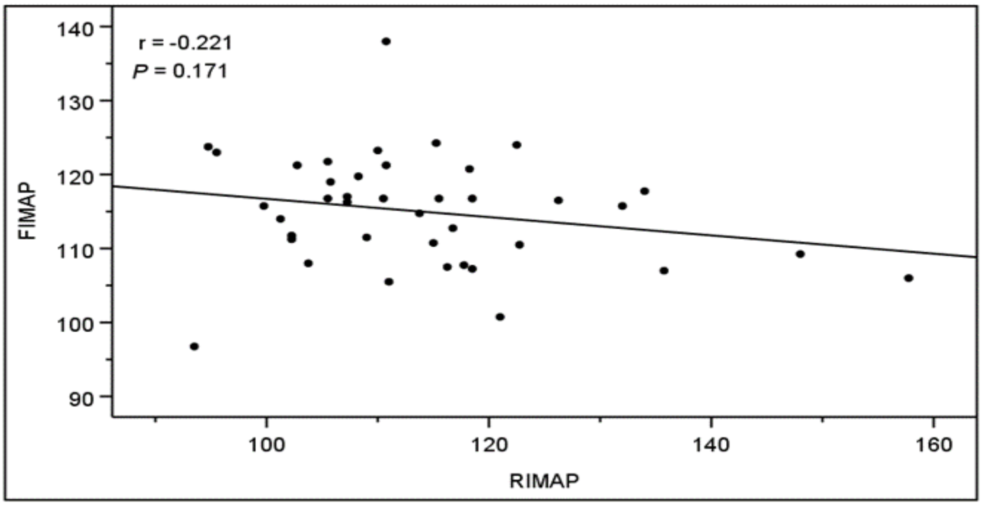

Figure 12: Scatterplots showing the correlations between femoral invasive mean arterial blood pressure (FIMAP) and radial invasive systolic blood pressure (RIMAP).

Discussion

Data obtained from this prospective observational study of 80 post-percutaneous intervention (PCI) patients admitted to the cardiac intensive care unit (ICCU) in a south Indian hospital showed that invasive arterial blood pressure measurements (IABP) were significantly higher than those obtained from oscillometric non-invasive blood pressure measurements (NIBP). The results of this study showed a wide level of agreement and bias ranging from -25.60 to 29.61and -1.5 to 14.5 respectively for invasive versus non-invasive blood pressure measurements. This implies that there is level of agreement between IABP measurements particularly systolic blood pressure measurements and mean arterial blood pressure measurements with NIBP measurements to allow for usage of NIBP measurements for the monitoring of patients admitted in to the ICCU following PCI. Specifically, the level of agreements and bias data showed NIBP measurements to be imprecise, although the comparable diastolic NIBP measured using the invasive and IABP suggests that the two methods can be used interchangeably. Isolated diastolic NIBP for monitoring post PCI is however not practicable.

These results are similar to the data obtained by Li Wei HL et al and Kim wong Young et al in their respective studies [21,22]. It was observed that pulse pressure values were wide during IABP monitoring in this study with diastolic IABP measurements relatively low. This may account for the similarities in diastolic IABP and NIBP diastolic measurements obtained in this study and other similar studies [21,22].

Wax David et al and Avolo AP and colleagues [23,24] however obtained contrasting results in their work comparing IABP and NIBP measurements where they showed a significantly higher diastolic NIBP compared to diastolic IABP. Blood pressure monitoring in their studies were however done intra-operatively in contrast to ours where BP monitoring was post-PCI.

In the work of Wax David et al, measurements were carried out intra-operatively and they therefore postulated that higher values of circulating catecholamines during the procedures might have raised both the systolic and diastolic BP measurements. This could have resulted in the approximation of NIBP and invasive diastolic BP values [23].

Our data showed that there is no significant difference in invasive BP measurements taken via the radial and femoral routes particularly the mean systolic BP and mean arterial pressure, that both routes can be used interchangeably. Mean diastolic BP taken through femoral artery is however significantly higher (5.23 mm Hg, $t = 2.22$, $P = 0.029$) when measured invasively. This suggests that femoral artery has higher potential to measure BP than radial arterial route but isolated diastolic BP monitoring is not practicable. Results from similar studies in European population concur with these observations that femoral and radial routes can be used interchangeably for invasive blood pressure monitoring. However, because of the relative higher risks of complications and the inconvenience associated with femoral artery canulation, radial artery seem preferable but in the setting of post PCI patients, the route of canulation during procedure is practically maintained and used for monitoring post-procedure.

Data from these study showed that the correlation coefficient between ISBP and NSBP is highest ($r = 0.66$, $P < 0.0001$) followed by mean arterial BP($r=0.51$, $p<0.001$) and lowest between IDBP and NDBP ($r = 0.31$, $P < 0.005$). The results demonstrate that Pearson's correlation coefficient detect significant linear association in BP measured using invasive and non-invasive methods. This suggests that the performance of mean arterial BP monitoring is better than diastolic blood pressure values in BP monitoring for critically ill patients. Furthermore, it seems that current practice guidelines are slowly promoting MAP in vital sign monitoring. Although the society for critical care medicine utilized both systolic and MAP for defining sepsis, the American Heart Association definition of hypertension is based on systolic and diastolic blood pressure only [27,28]. These should change as more data becomes available regarding the strength of MAP.

This study is not free of limitations for example sample of eighty may be relatively small and this can limit generalizations. Additionally, inter-observer variations between the various ICCU staff involved in the measurements can be a limiting factor. However the fact well trained ICCU nurses were involved in the monitoring might have mitigated these weaknesses.

Conclusion

Given the strong correlation and agreement between measurements, Non-invasive blood pressure measurement may be insufficient for monitoring of post PCI patients admitted to cardiac intensive care unit after coronary angioplasty. The femoral and radial arterial lines can be used interchangeably for blood pressure monitoring in cardiac intensive care unit. Although IABP may carry different complications, it remains the method of choice for BP monitoring in cardiac ICU. The site of arterial cannulation should be determined by the attending cardiologist, taking into cognizance their peculiarities.

List of Abbreviations

PCI- Percutaneous coronary intervention
ICCU- Cardiac intensive care unit
BP- Blood pressure
NIBP- Non-invasive blood pressure
IABP- Invasive arterial blood pressure
BMI- Body mass index
SBP- Systolic blood pressure
DBP- Diastolic blood pressure
LOA- level of agreement
ISH- International society for hypertension
ESH- European society for hypertension
IDBP-Invasive diastolic blood pressure
NDBP- Non-invasive diastolic blood pressure
ISBP- Invasive systolic blood pressure
NSBP- Non-invasive systolic blood pressure
FIDBP- Femoral invasive diastolic blood pressure
RIDBP- Radial invasive diastolic blood pressure
FISBP- Femoral invasive systolic blood pressure
RISBP- Radial invasive systolic blood pressure
FIMAP- Femoral invasive mean arterial blood pressure
RIMAP- Radial invasive mean arterial blood pressure

Data Access

The patient data associated with this study is readily available and can be obtained from the Author on written demand and justification

Funding statement

This study was entirely funded by the Author with no additional financing from any other source

Authors contribution

This is a single Author study and all the written work was entirely done by the corresponding Author

Acknowledgement

I wish to acknowledge my mentor in interventional cardiology-Dr. Prathap Kumar N. Chairmain, Meditrina hospitals India for providing me unfettered access to the cathlab and ICCU to conduct this study. Much appreciation to my colleagues in cardiology unit, Meditrina hospital Kollam for their encouragement and assistance during the course of data collection (Drs Thanu R, Sanoop KS, Blessvin and Mathew Dale). Much appreciation also the nursing and technical staff of cathlab and ICCU Meditrina hospital, Kollam for your great assistance with data collection for this study.

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