Original Article

Measurement of non-invasive blood pressure in lateral decubitus position under general anaesthesia – Which arm gives more accurate BP in relation to invasive BP - dependent or non-dependent arm?

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Submitted: 01-Mar-2020
Revised: 03-May-2020
Accepted: 14-May-2020
Published: 01-Jul-2020

Access this article online

Website: www.ijaweb.org

DOI: 10.4103/ija.IJA_125_20

Quick response code

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ABSTRACT

Background and Aims: Non-invasive blood pressure (NiBP) varies with the arm and body position. In the lateral decubitus position (LDP), the non-dependent arm reads lower, and the dependent arm reads higher pressure. We aimed to study the correlation between the NiBP and invasive arterial blood pressure (ABP) as anaesthesia progressed and its correlation in different BP ranges. **Methods:** American Society of Anesthesiologists (ASA I–III) patients, between 18–70 years undergoing neurosurgical procedures in the LDP were studied. All were anaesthetised using a standard protocol, positioned in the LDP. NiBP was measured every 15 min in both dependent and non-dependent arms and correlated with the ABP. **Results:** Intra-class correlation (ICC) done between the dependent arm NiBP and ABP showed good correlation for mean and systolic BP and moderate correlation for diastolic BP. ICC was 0.800, 0.846 and 0.818 for mean and 0.771, 0.782, 0.792 for systolic BP at 15 min, 1 h, and 2 h, respectively. The ICC between the non-dependent arm NiBP and the invasive ABP showed poor correlation for all BP (systolic, diastolic and mean). As anaesthesia progressed, the mean difference between the NiBP and the ABP decreased in the dependent arm and increased in the non-dependent arm. The strength of agreement between the NiBP and the ABP in various BP ranges showed moderate correlation for the dependent arm NiBP (0.45–0.54) and poor correlation (0.21–0.38) for the non-dependent arm. **Conclusion:** The NiBP of the dependent arm correlated well with ABP in LDP under general anaesthesia (GA). It is better to defer measuring NiBP in the non-dependent arm as the correlation with ABP is poor.

Key words: Dependent arm, general anaesthesia, invasive arterial blood pressure, non-invasive blood pressure, supine position

INTRODUCTION

The safe conduct of anaesthesia requires careful monitoring of vital signs. It is recommended that in patients undergoing surgery under general and regional anaesthesia or sedation, vital signs need to be monitored every 3–5 min.[1] The most commonly used non-invasive blood pressure (NiBP) measurement method in anaesthesia is the automated oscillometric device method.[2] As major decisions regarding haemodynamic management are based on intra-operative BP measurements, it is essential to determine accurate BP readings under anaesthesia.[3] It is of further significance in surgeries with major fluid shifts, blood loss and in patients with multiple

How to cite this article: Thomas AS, Moorthy RK, Raju K, Lakshmanan J, Joy M, Mariappan R. Measurement of non-invasive blood pressure in lateral decubitus position under general anaesthesia — Which arm gives more accurate BP in relation to invasive BP - dependent or non-dependent arm? Indian J Anaesth 2020;64:631-6.

co-morbidities where strict control of BP is needed.[4] In some instances, kinking or damping of the arterial line results in an inaccurate measurement of invasive BP, particularly in patients undergoing surgery in a lateral or prone position. It is not possible to have an invasive BP in every setting, especially in low-income countries. Hence, an accurate NiBP measurement is crucial to prevent peri-operative morbidity in patients undergoing surgery in lateral decubitus position (LDP).

Patients are operated in the LDP during lung and hip surgeries and in several neurosurgical procedures. It is well established that the BP varies with the arm and body position because of hydrostatic forces.[5] The non-dependent (upper) arm NiBP reads a lower pressure and the dependent (lower) arm NiBP tends to overestimate the BP because of the hydrostatic effect.[6] The LDP, and its impact on the BP have been studied extensively in pregnant women with gestational hypertension and in stroke patients in whom strict control of BP is needed.[7-9] To our knowledge, till date, no studies compared the correlation of NiBP in the dependent and non-dependent arm with the gold standard arterial BP (ABP)[2] under general anaesthesia (GA). We had done a survey regarding the measurement of NiBP in patients undergoing surgery in LDP among the 300 practicing anaesthesiologists in India and overseas (unpublished data). There was a difference in opinion regarding the site of NiBP measurement in lateral position. There are no guidelines or recommendation available regarding the same under anaesthesia. So, we aimed to study the correlation between the NiBP and ABP in LDP under general anaesthesia. The primary objective of our study was to examine the correlation between the dependent and non-dependent arm NiBP with the ABP (transduced at mid sternal level) in LDP at the start of anaesthesia and as anaesthesia progressed. The secondary objective was to study the correlation between dependent and non-dependent arms NiBP with ABP in low, normal and high ranges of blood pressure.

METHODS

This prospective observational cohort study was conducted between the period of September 2016 and February 2017, after getting approval from the Institutional Review Board and the Ethics Committee. Informed consent was obtained from all the patients recruited into the study. All ASA I–III patients aged between 18 and70 years, undergoing neurosurgical procedures in the lateral decubitus position during the study period were included. Patients with morbid obesity, atrial fibrillation, peripheral vascular disease, coarctation of the aorta and vascular lesion/vascular malformation or arteriovenous fistula involving the upper limbs were excluded. Patients in whom there was a difference of >20 mmHg in systolic BP or >10 mmHg in diastolic BP between the two upper arms were also excluded.

Arm circumference was measured proximal to the antecubital fossa on both arms on the day prior to surgery, and the appropriate BP cuff size was selected for intra-operative use as per the American Heart Association (AHA) recommendations.[10] On the day of surgery, prior to induction, NiBP was measured simultaneously in both the arms in a supine position using an appropriate cuff size with an automated oscillometer (Philips IntelliVue MP20, Philips Medical System, Eindhoven, North Brabant, The Netherlands) to obtain the baseline BP. These monitors are calibrated once in two years as per the manufacturer's recommendation. No further calibration was done prior to the start of the study.

In the operating room, after placing the standard anaesthesia monitors-electrocardiogram (ECG), NiBP, Peripheral oxygen saturation (SpO2) and end tidal carbon dioxide (ETCO2), patients were induced with Inj. Fentanyl 2 mcg/kg, Inj. Propofol 2–3 mg/kg and paralysed using Inj. Vecuronium 0.1 mg/kg. Phenylephrine (50 μg) or ephedrine (6 mg) was given to combat the anaesthetic induced hypotension if needed. Propofol 0.5 mg/kg and Fentanyl 0.5 μg/kg was given at the time of intubation. Patients were intubated with an appropriate size endotracheal tube (ETT). Maintenance of anaesthesia was carried out with air, oxygen and 0.8 to 1 minimum alveolar concentration (MAC) Isoflurane. Vecuronium infusion was titrated to keep 1 to 2 twitches in a train of four (TOF) neuromuscular monitor.

Radial artery cannulation was done after induction with either a 20 or 22 gauge intravenous cannula in the right or left arm and was transduced at the level of the heart in the mid-axillary line. NiBP was measured in both arms and was correlated with the ABP at 5 and 15 min after placing the arterial line in the supine position. The patient was then turned to the LDP, and appropriate measures were taken to transduce the arterial line at the mid-sternal level (aortic arch). NiBP was measured every 15 min in both the dependent and the non-dependent arm simultaneously. Since the

measurement of NiBP in both arms can increase the ABP because of pain, the ABP was recorded at the start of measurement of simultaneous recordings of NiBP readings not at the end of NiBP reading. Correlation between the NiBP and the invasive arterial BP recordings for systolic, diastolic and mean BP was done at 15 min, 1 h and 2 h.

The sample size was calculated keeping the expected difference in the mean for all systolic and diastolic and the mean BP as 10 with the standard deviation of 5; the effect size was taken as 2. Using the values, the minimum required sample size was 42.

Data were entered into a spreadsheet and analysed using R and SPSS 16.0 statistical software. (SPSS for Windows, Version 16.0. Chicago, SPSS Inc.) A paired *t*-test was used to show that there was no significant difference in the NiBP between the two arms before and after anaesthetising the patient in the supine position. The scatter plots between the two methods (non-invasive Vs. invasive) was done. Reliability was measured by intra-class correlation coefficients (ICC) using random effect models. In order to study the randomness of the difference between methods, Bland–Altman plots were done. To study the strength of agreement between the two methods in all BP ranges (low, normal and high ranges), weighted kappa with squared weights was performed. The low, normal and high BP ranges are summarised in Table 1.

RESULTS

Of the 45 patients who underwent neurosurgical procedures in the LDP during the study period and met the inclusion criteria, 42 were recruited. Three patients were excluded because one patient had the systolic BP difference of >20 mm Hg and two patients had a diastolic difference of >10 mmHg between the two arms on the day of surgery. The mean age of the study population was 42 years, ranging between 19 and 67 years. The mean body mass index (BMI) was 23.63 ± 4.61. The 42 study patients comprised 22 males and 20 females. Twenty-three patients underwent the procedure in the right lateral position while the other 19 patients underwent surgery in the left lateral position. Of the 42 patients, 28 were ASA grade I and 14 were ASA grade II (7-hypertension, 3-diabetes, 1-hypothyroid, 3-obesity). The NiBP was measured in the right and the left arms before induction simultaneously. There was no significant difference in NiBP between the right and the left arm both, clinically and statistically. The difference in NiBP between the right and left arm for the systolic, diastolic and the mean with the *P* values were 0.33 ± 8.29 ($P = 0.796$), -0.8 3 ± 5.45 ($P = 0.328$) and -0.24 ± 4.73 ($P = 0.746$), respectively.

The mean differences between the NiBP and the ABP for the systolic, diastolic and mean after induction were 0.125, 9.25 and 3.6 5 mm Hg in the right arm and 1.475, 7.24 and 1.925 mm Hg in the left arm. The differences were very minimal for the systolic and mean BP, but it was larger and more significant for the diastolic BP [Table 2]. There was no significant clinical or statistical difference between the two arms after induction in a supine position [Table 2].

The non-invasive systolic, diastolic and mean BP in the dependent arm was slightly higher than the corresponding invasive BP. The scatter plots between the two methods (dependent NiBP vs invasive arterial BP) were done. Table 3 shows the intra-class correlation (ICC) between the dependent arm NiBP and invasive arterial BP. There was a good correlation between the dependent arm NiBP and the invasive arterial BP for both mean (ICC = 0.826) and systolic BP (ICC = 0.787). There was only a moderate correlation for diastolic BP. The Bland–Altman plots suggest that as anaesthesia progressed, the mean difference between the non-invasive and invasive BP decreased for both mean [Figure 1] and systolic BP [Figure 2] when NiBP was measured in the dependent arm.

Table 1: Blood pressure ranges

Blood Pressure	Range	Values (mm Hg)
Systolic blood pressure	High	>121
	Normal	91-120
	Low	<90
Diastolic blood pressure	High	>81
	Normal	50-80
	Low	<49
Mean blood pressure	High	>81
	Normal	65-80
	Low	<65

Table 2: Difference between non-invasive and invasive BP in the supine position after induction

Difference in BP (mm Hg) (mean±SD)	Right arm (NiBP-ABP) (mean±SD	Left-arm (NiBP-ABP) (mean±SD)	*P*
Systolic	0.12±12.45	-1.47±10.17	0.523
Diastolic	9.25±10.51	7.47±8.14	0.372
Mean	3.65±10.60	1.95±9.68	0.445

The systolic, diastolic and mean BP in the non-dependent arm was lower than the corresponding invasive BP. The scatter plots between the two methods (non-dependent NiBP vs invasive BP) were done. Table 3 shows the intra-class correlation (ICC) between the non-dependent arm NiBP and invasive arterial BP. There was a moderate to poor correlation between the non-dependent NiBP and the invasive arterial BP for all three BPs (systolic, diastolic and the mean BP) at the start of anaesthesia. As anaesthesia progressed, the ICC correlation became poor [Table 3] for all three BPs. The Bland–Altman plots [Figure 3] suggest that as anaesthesia progressed, the difference between non-invasive and invasive BP for mean BP increased when the NiBP was measured in the non-dependent arm.

Table 3: Intraclass Correlation Coefficient (ICC) between NiBP and the arterial BP

NiBP vs Arterial BP	15 min	1 h	2 h	Overall ICC
Dependent NiBP vs Arterial BP				
Systolic Blood Pressure	0.771	0.782	0.792	0.787
Diastolic Blood Pressure	0.522	0.594	0.542	0.555
Mean Blood Pressure	0.800	0.846	0.818	0.826
Non-Dependent NiBP vs Arterial BP				
Systolic Blood Pressure	0.531	0.663	0.419	0.551
Diastolic Blood Pressure	0.667	0.651	0.401	0.594
Mean Blood Pressure	0.510	0.542	0.029	0.403

To study the strength of agreement between NiBP (dependent and the non-dependent arm) and the arterial BP in clinically normal, low and high BP ranges, weighted kappa with squared weights was performed for systolic, diastolic and mean BP. There was a moderate correlation in all ranges of BP measurement when the NiBP was measured in the dependent arm (weighted kappa -0.45–0.54). However, there was only a fair to poor correlation (weighted kappa 0.21–0.38) when the NiBP was measured in the non-dependent arm in all ranges of BP.

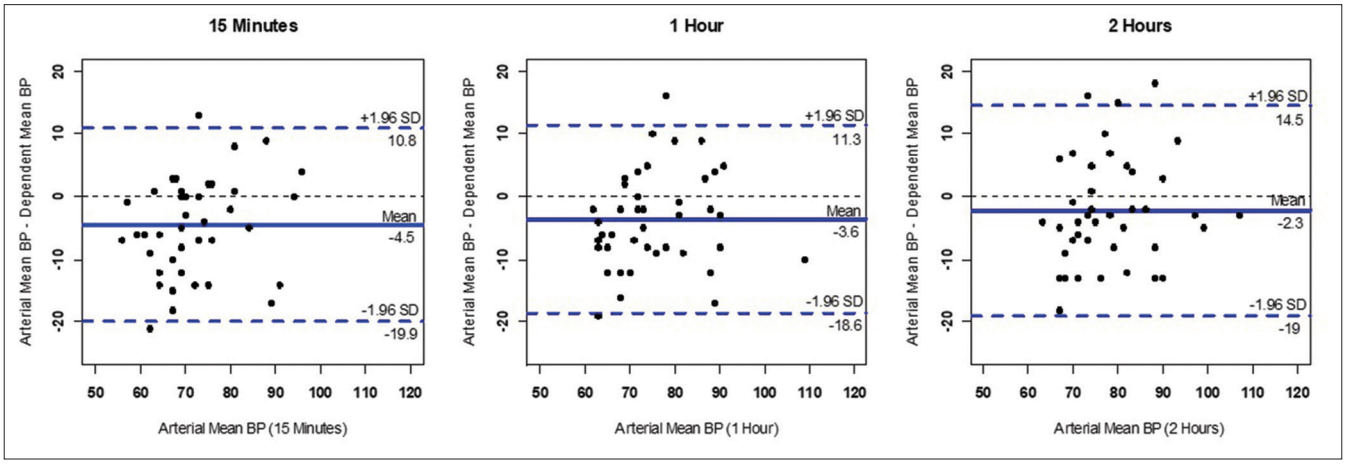

Figure 1: Bland–Altman Plot for Arterial Mean BP vs Dependent Mean BP at 15 min, 1 h and 2 h

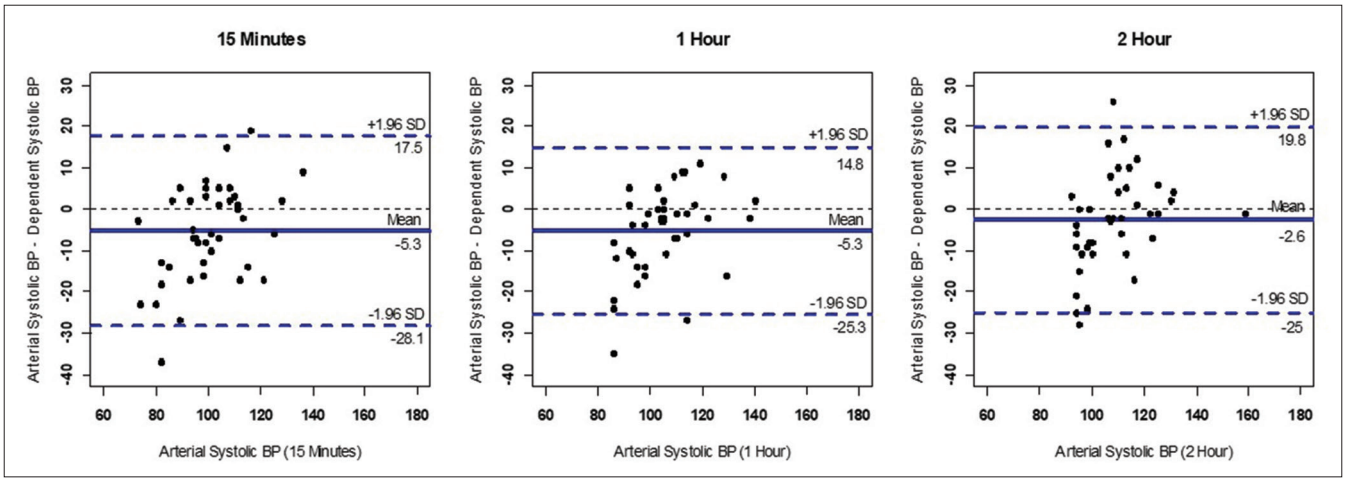

Figure 2: Bland–Altman Plot for Arterial Systolic BP vs Dependent Systolic BP at 15 min, 1 h and 2 h

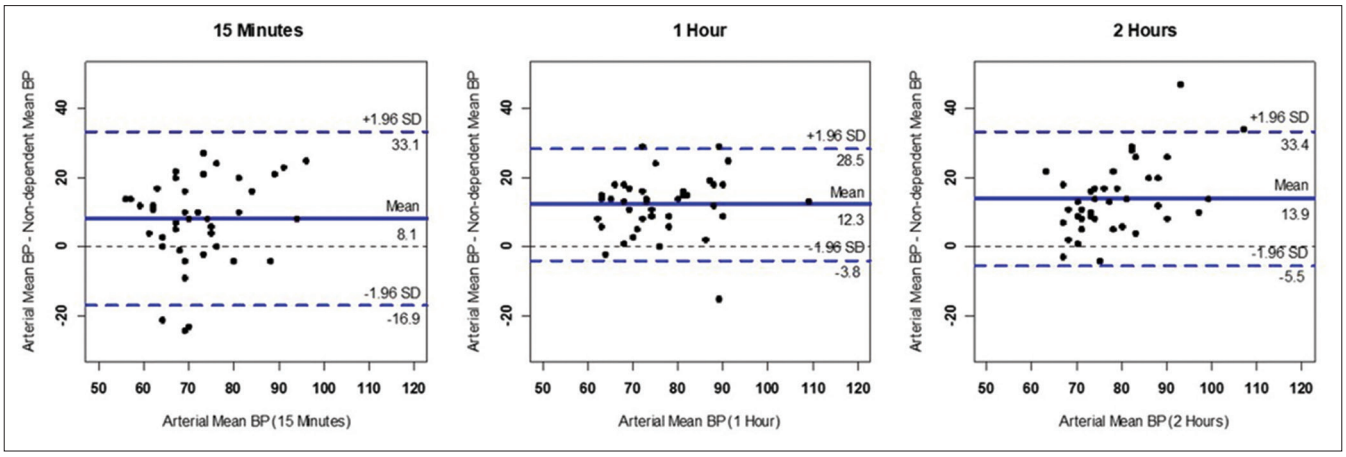

Figure 3: Bland–Altman Plot for Arterial Mean BP vs Non-dependent Mean BP at 15 min, 1 h and 2 h

DISCUSSION

This was a prospective observational study, which aimed to determine the correlation between NiBP in the dependent and non-dependent arms with ABP at the start and during the progression of anaesthesia. We found that the systolic and the mean blood pressure of the dependent arm NiBP correlated well with the corresponding pressures of ABP. The diastolic BP did not show a good correlation; this could be attributed to anaesthesia induced peripheral vasodilation, which lowered the invasive diastolic BP as compared to non-invasive diastolic BP. Our study results were similar to other studies that are reported in the literature.[8,9,11]

As the anaesthesia progressed, the difference between the NiBP and the invasive BP in the dependent arm progressively decreased, and the difference between the NiBP and the invasive BP is progressively increased in the non-dependent arm this could be due to anaesthetic induced vasodilation of both, proximal and distal arterial system along with the gravity dependent diversion of blood into the dependent arm.

Kinsella *et al*.[8] compared BP in a supine and a LDP in term and awake pregnant women and found that the dependent arm BP was closer to supine BP, which is similar to our study result. They also found that a supine BP was closer to an average BP reading of both, dependent and non-dependent arms. Since we had correlated the NiBP with a standard invasive arterial BP, we did not average the NiBP in both arms.

Aries *et al*.[9] compared the blood pressure between supine and lateral position in a stroke unit and found that the BP measured in the non-dependent arm was lower than supine and the BP measured in the dependent arm was higher as compared to supine, which was similar to our study result. Yokoyama and co-workers had compared haemodynamics such as mean arterial pressure, cardiac index, right atrial and pulmonary capillary wedge pressure between a LDP and kidney position and found that there was no significant change in a LDP, but there was a significant reduction in the above mentioned haemodynamics in a kidney position.[12] But the study did not see the correlation between the NiBP and ABP.

In our study, we also compared non-invasive and invasive BP in an awake, supine position, and there was no significant difference between the two arms. After induction of anaesthesia, the invasive arterial diastolic BP was lower in comparison to the non-invasive BP while the systolic and mean BP did not vary significantly. This reduction in diastolic BP could be due to the anaesthetic induced peripheral vasodilation at the start of general anaesthesia.

Our study result implies that, it is better to measure the NiBP in the dependent arm and to defer from measuring it in the non-dependent arm when the patient is in lateral decubitus position under general anaesthesia.

To our best knowledge, till date, no studies have compared both arm NiBP with arterial BP simultaneously and its correlation as anaesthesia progressed. Also, no studies have examined its correlation in high, low and in normal ranges. We consider these as the strengths of our study.

Limitations include, we had not done the calibration of monitors just prior to the study. But the monitors

were calibrated routinely once in two years as per the manufacturer recommendation. The second limitation is that the arterial line placement was done in either of the arms; it was not standardised. Since we had transduced the arterial line at the mid-sternal level, which is considered at the level of aortic arch, we feel the placement of arterial line in either of the arms does not alter the ABP readings. The third limitation is that we did not study the correlation between the NiBP and the ABP in the right and left lateral position and between ASA 1 and 2 patients.

CONCLUSION

The mean and systolic NiBP of the dependent arm correlated well with ABP in LDP under GA. As anaesthesia progressed, the difference between the non-invasive and the invasive BP progressively decreased when the NiBP was measured in the dependent arm, and the difference progressively increased when the NiBP was measured in the non-dependent arm. In surgeries where only NiBP is monitored, it would be advisable to rely on the dependent arm NiBP and to defer from measuring NiBP in the non-dependent arm.

Acknowledgements

The Authors would like to thank and acknowledge the work of Mrs Subbulakshmi, Anaesthesia Technician, for helping us in the conduct of the study.

Financial support and sponsorship

Internal Fluid research grant was obtained to conduct the study. (IRB minute Number - 9853).

Conflicts of interests

There are no conflicts of interest.

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