Comparison between Invasive and Non-Invasive Blood Pressure Monitoring in High-Risk Prolonged Surgeries in a Medical College of Assam

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ABSTRACT

BACKGROUND
Blood pressure monitoring in intraoperative period is one of the basic parameters in haemodynamic monitoring. This guides an anaesthesiologist to maintain an optimal condition between the patient's stress condition and the depth of anaesthesia. Blood pressure can be measured either invasively or non-invasively in patients undergoing surgery. Invasive measurement from an arterial line is the preferred method even though there may be calibration errors, movement artefacts and over or under damping. The gold standard in cases of high-risk prolonged surgery is continuous monitoring of blood pressure by means of invasive blood pressure (IBP) measurement. The purpose of this study was to compare the non-invasive and invasive blood pressure monitoring in patients undergoing high risk surgeries

METHODS
After getting institutional ethical committee (H) clearance, study was conducted on 40 patients undergoing high-risk prolonged surgeries. Non-invasive blood pressures (NIBP) were recorded by oscillometric method before intubation, after intubation, half an hour after intubation and one hour after intubation. Simultaneously invasive blood pressure monitoring was done by establishing radial artery line. Bland-Altman plot was used to compare the blood pressure measurement by the non-invasive and invasive method.

RESULTS
Systolic blood pressure readings using non-invasive blood pressure monitoring was overestimated, diastolic and mean arterial pressure (MAP) readings using non-invasive blood pressure monitoring was underestimated in all instances. In all time points non-invasive blood pressure showed a good correlation with invasive blood pressure.

CONCLUSIONS
The study revealed that there is statistically significant difference between non-invasive and invasive blood pressure readings. We recommend invasive blood pressure monitoring in high-risk surgeries and critically ill patients, although a large-scale study is required to arrive at a conclusion.

KEYWORDS
Non-invasive Blood Pressure, Invasive Blood Pressure, Bland-Altman Analysis, High Risk Surgery

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BACKGROUND

Intraoperative blood pressure monitoring is one of the vital signs in monitoring. It is a key dynamic parameter in maintaining an optimal balance between patient's stress condition and depth of anaesthesia. Blood pressure monitoring is a standard recommendation for patients undergoing and recovering from general anaesthesia, regional anaesthesia and sedation as recommended by Association of Anaesthetists of Great Britain and Ireland.[1] Blood pressure can be measured by invasive or non-invasive methods in patients undergoing surgery under general anaesthesia. Radial, femoral or dorsalis pedis are the common sites used for cannulation for invasive arterial blood pressure measurement. Non-invasive blood pressure monitoring is extensively used because of its simplicity and safety.

Traditional non-invasive blood pressure monitoring by an upper arm cuff device is a standard practice in all patients undergoing anaesthesia, and is endorsed by American Society of Anaesthesiologists (ASA).[2] Accuracy of the non-invasive blood pressure measurement is problematic in hemodynamically unstable patients and blood pressure monitoring in these patients often require direct intra-arterial pressure recordings.

Non-invasive blood pressure measurement is not continuous and may show incorrect readings compared to invasive blood pressure in case of severe hypotension, hemodynamic instability, arterial stiffness, or obesity.[3-8] In patients with ASA status of greater than or equal to III or critically ill or in those undergoing high-risk surgeries, blood pressure measurement using intra-arterial catheter is considered as gold standard.[4-6,9-11] However, due to the invasive nature, use of peripheral arterial catheter may cause complications such as haemorrhage, limb ischemia, infection, thrombosis, embolism, formation of pseudo aneurysm, difficulty of insertion and non-availability of arteries.[12-14] It also requires technical expertise. Invasive blood pressure may give inaccurate readings due to calibration errors, artefacts due to underdamping, overdamping or air bubbles in the circuit.[15,16] Non-invasive blood pressure monitoring is done routinely in our hospital. Because of unavailability of equipment and cost restraints, invasive blood pressure is not routinely done. Invasive blood pressure monitoring is done in very selective cases of cardiothoracic and neurosurgery operation. No study has been done in the north-eastern part of our country to compare these two methods.

Therefore, this study was done for comparison between non-invasive and invasive methods of blood pressure monitoring.

METHODS

The present hospital based observational study was carried out in the Cardiothoracic, Neurosurgery and General surgery operation theatre of Assam Medical College and Hospital, Dibrugarh, from July 2019 to June 2020, after getting approval from institutional ethics committee (H). The study was conducted to compare non-invasive and invasive blood pressure monitoring in patients undergoing high-risk prolonged surgeries. 40 patients (age 18 to 65 years) admitted in our hospital, undergoing high-risk prolonged surgeries satisfying the inclusion criteria were selected. Written informed consent was obtained from them before the study. After shifting the patient to operation theatre, standard hemodynamic parameters are recorded and monitored.

Non-invasive blood pressure using oscillometric method was measured in one arm and invasive blood pressure using radial artery catheter was measured in the other arm. Simultaneous IBP and NIBP measurement were performed before intubation, after intubation, half an hour after intubation and one hour after intubation. IBP was recorded at the same time the oscillometric blood pressure measurement gets completed and result is displayed on the monitor. A total of 320 blood pressure readings were obtained. Bland-Altman plot was incorporated to test discrepancy between IBP and NIBP; intraclass correlation coefficient to investigate relationship between IBP and NIBP.

Inclusion Criteria

Patients who had given written informed consent, age between 18 to 65 years, undergoing high-risk prolonged surgeries expected to cause major fluid shift or major blood loss, radial pulse palpable in both limbs.

Exclusion Criteria

Patients not willing to give written informed consent, presence of arteriovenous shunts in the study limbs, congenital or acquired anatomical difference between upper limbs, difference of blood pressure more than 10 mm of Hg between upper limbs as measured by brachial cuff BP technique, history of vascular surgeries in the study limbs, known or clinically suspected peripheral arterial disease.

Preoperatively, relevant history, physical examination and laboratory investigations were checked and recorded. The procedure was explained to the patient on the day of surgery. An intravenous line was secured with 18 G cannula and patient was preloaded with crystalloid. Standard monitors were connected and baseline parameters of SpO_2, electrocardiogram (ECG) and pulse rate were monitored.

Blood pressures were checked in both arms before the procedure to confirm there was no difference of more than 10 mm of Hg in both arms. Simultaneous IBP and NIBP measurements were performed before intubation, after intubation, half an hour after intubation and one hour after intubation. The IBP were recorded and at the same time the oscillometric blood pressure measurement gets completed and resulted on the monitor.

For non-invasive blood pressure measurements, oscillometric blood pressure cuffs, meeting AAMISP10: 2002 requirements[17] were used. Cuff size was be selected based on patient's limb circumference measured at the midpoint of arm. The cuff was placed on the arm opposite to arterial catheter for all study measurements. For invasive blood pressure measurement, a radial arterial catheter (Leader Cath Arterial polyethylene catheter - 20-gauge, 8 cm length, 0.6 mm internal diameter, 0.9 mm external diameter; Vygon, Ecouen, France) was placed in the radial artery using Seldinger technique.

The transducer system (Medtronic's) was connected to the arterial catheter through a three way stop cock 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 right atrium (phlebostasis axis) and zero-calibrated to atmospheric pressure[18] The arterial waveform was observed to verify normal wave pattern and a rapid saline flush was performed to rule out damping.

Sample Size Calculation

The sample size for estimating correlation between BP measurement by invasive and non-invasive methods was calculated according to the formula given by Hulley et al. (2013).[19]

Sample Size

$N = [(Z_\alpha + Z_\beta)/C]^2 + 3$

Where C = 0.5 * ln [(1 + r) / (1 - r)], r being the observed correlation in previous studies.

The sample size for the study was based on a study by Riley et al. (2017),[20] who reported the correlation between MAP by IBP and NIBP to be 0.74.

Observed correlation (r) = 0.74
Type I error (α) = 5 %
Z_α = 1.96
Type II error (β) = 5 %
Power of the Study (1 – β) = 95 %
Z_β = 1.65
C = 0.5* [ln ((1 + 0.74) / (1 - 0.74))] = 0.950

Based on the formula given above, using the mentioned values, required sample size

$[(1.96 + 1.65) / 0.950]^2 + 3 = 17.43 \approx 20$

Thus 20 patients are required for our study. For optimum power of study, we took 40 patients.

Statistical Analysis

Statistical significance was achieved with a P value of < 0.05. Analysis was presented as mean ± SD. Comparison between the two measures was done by paired t – test. Paired t - test is used to find out the difference between two variables in the same subject. 40 numbers of data in each group were entered to calculate paired t - test value. The difference for each comparison was calculated as IBP minus NIBP. Consequently, a positive difference indicated that the non-invasive BP recordings were underestimated in comparison with IBP measurements, whereas a negative difference showed that the NIBP readings where overestimated when compared with IBP recordings. The relationship between IBP and NIBP was investigated using interclass correlation coefficient. Discrepancy between IBP and NIBP were also tested using Bland-Altman plots.

RESULTS

Age in Years	Number	Percentage
18 - 28	3	7.5 %
29 - 39	17	42.5 %
40 - 50	11	27.5 %
51 - 61	7	17.5 %
62 - 65	2	5 %
Mean ± SD	41.12 ± 11.76	
Range	20 - 64	

Table 1. Distribution of the Participants in Terms of Age (Years)

	Mean ± SD (mmHg)		P - Value
	IBP	NIBP	
SBP	133.00 ± 12.32	136.22 ± 12.44	< 0.001
DBP	83.50 ± 11.91	81.10 ± 11.87	< 0.001
MAP	100.03 ± 11.53	99.45 ± 11.59	< 0.001

Table 2. Summary of BP Measurement before Intubation

	Mean ± SD (mmHg)		P - Value
	IBP	NIBP	
SBP	137.93 ± 10.99	141.22 ± 11.26	< 0.001
DBP	86.72 ± 10.47	84.17 ± 10.57	< 0.001
MAP	103.75 ± 10.34	103.15 ± 10.41	< 0.001

Table 3. Summary of BP Measurement after Intubation

	Mean ± SD (mm Hg)		P - Value
	IBP	NIBP	
SBP	133.10 ± 9.87	137.28 ± 11.58	< 0.009
DBP	82.90 ± 9.53	80.28 ± 9.23	< 0.001
MAP	99.53 ± 9.07	98.75 ± 9.10	< 0.001

Table 4. Summary of BP Measurement Half an Hour after Intubation

	Mean ± SD (mm Hg)		P - Value
	IBP	NIBP	
SBP	131.20 ± 10.49	133.18 ± 11.11	< 0.001
DBP	81.20 ± 9.51	79.03 ± 9.34	< 0.001
MAP	97.83 ± 9.22	97.05 ± 9.18	< 0.001

Table 5. Summary of BP Measurement One Hour after Intubation

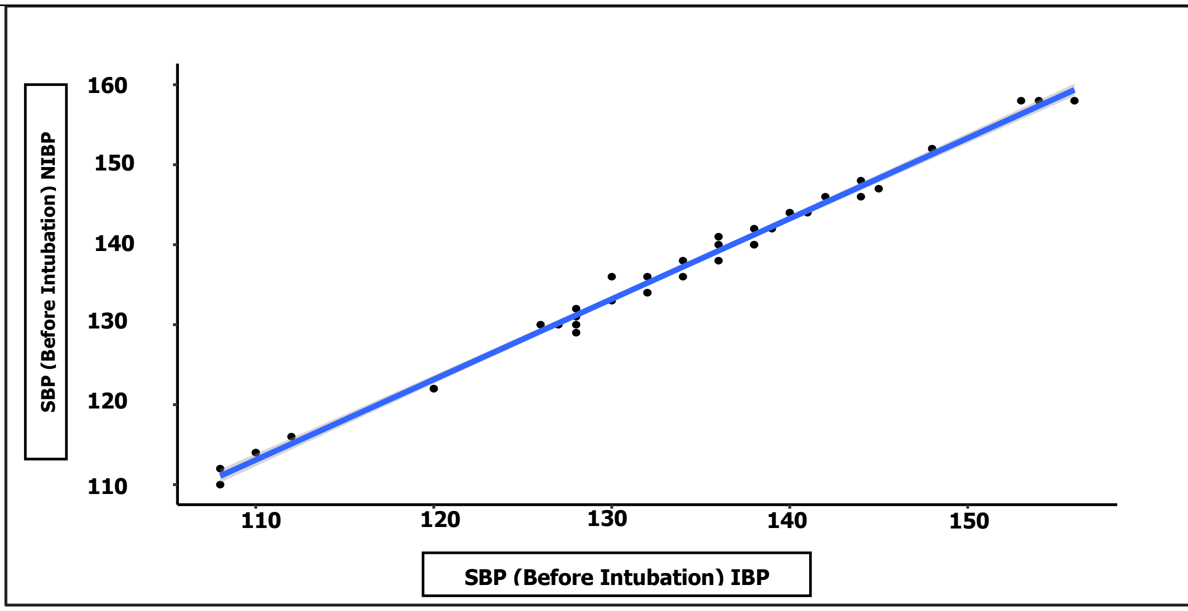

Figure 1.1. Scatter Plot Depicting Correlation between SBP (before Intubation) (IBP) and SBP (before Intubation) (NIBP)

In fig 1.1, individual points represent individual cases. The blue trend line represents the general trend of correlation between the two variables. The shaded grey area represents the 95 % confidence interval of this trend line. This correlation was statistically significant (Interclass Correlation Coefficient = 1.00, P = < 0.001).

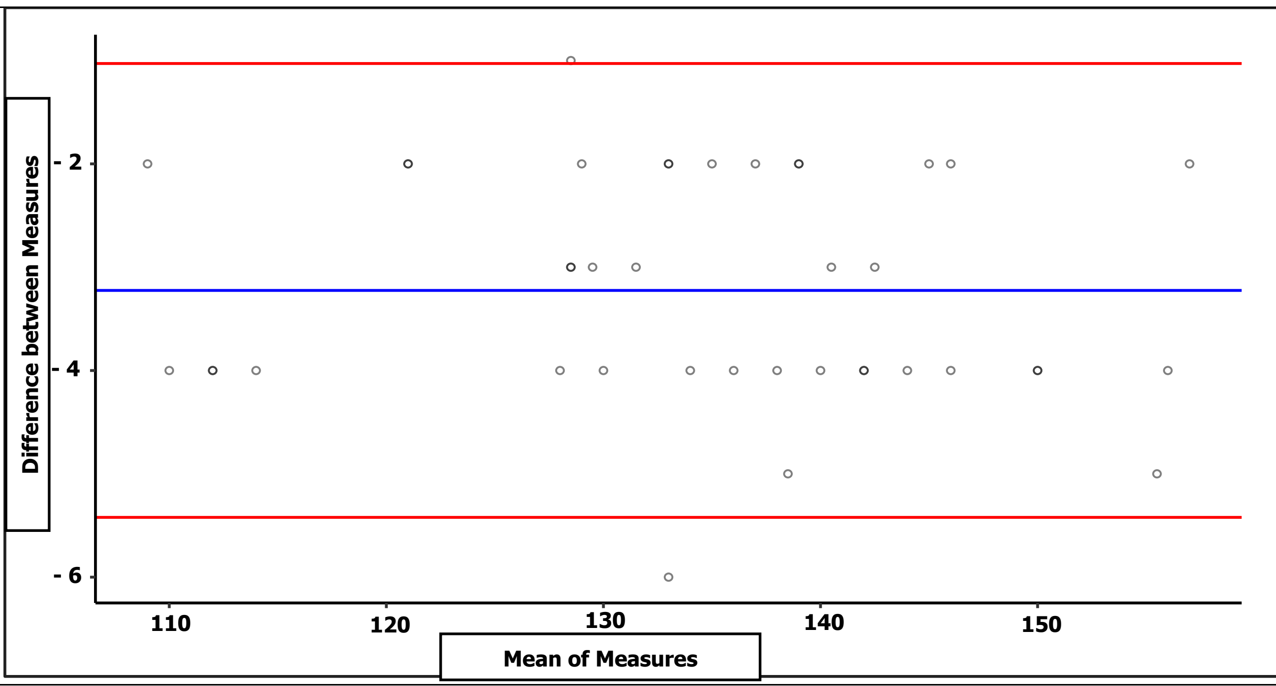

Figure 1.2. Bland-Altman Plot Mean of Two Measures (X-Axis), Difference between Two Measures (Y-Axis)

Bland-Altman Plot

The above is a Bland-Altman plot comparing the mean of two measures (x - axis) to the difference between the two measures (y - axis). The blue line represents the mean of the difference between the two measures, and the red lines represent the limits of agreement (mean ± 2SD of difference). Ideally, less than 5 % of the observations should lie outside the limits of agreement. There was 95.0 % agreement between the two measures, that is, 95.0 % of the observations had a difference which was within the limits of agreement (± 2.20).

Test for Systematic Differences

The mean invasive and non-invasive systolic blood pressure before intubation were 133 ± 12.3 and 136.22 ± 12.44 mmHg respectively. There was a strong correlation between the two, mean SD of the difference between the two was 3.2 ± 1.1, which was statistically significant (t = -18.201, P = < 0.001).

The mean invasive and non-invasive diastolic blood pressure before intubation were 83.50 ± 11.91 and 81.1 ± 11.87 mmHg respectively. The mean invasive and non-invasive mean arterial pressure before intubation were

100.03 ± 11.53 and 99.45 ± 11.59 mmHg respectively. There was a strong correlation between systolic blood pressure measured by invasive and non-invasive methods before intubation (interclass correlation coefficient = 1), and P < 0.001 which was statistically significant. The Bland-Altman plot showed 95 % agreement between the two measures which was within the limits of agreement. The correlation between the diastolic blood pressure before intubation measured by invasive and non-invasive methods were strong (interclass correlation coefficient = 1), and P < 0.001 which was statistically significant. Bland-Altman plot showed 87.5 % agreement between the two values which are within the limits of agreement. The mean arterial pressure values before intubation shows strong correlation (interclass correlation coefficient = 1), and P < 0.001 which was statistically significant. Bland-Altman plot showed 87.5 % agreement between the values which was within the limits of agreement.

The mean invasive and non-invasive systolic blood pressure measured after intubation were 137.93 ± 10.99 and 141.22 ± 11.26 mmHg respectively. The mean invasive and non-invasive diastolic blood pressure measured after intubation were 86.72 ± 10.47 and 84.17 ± 10.57 mmHg respectively. The mean invasive and non-invasive mean arterial blood pressure measured after intubation were 103.75 ± 10.34 and 103.15 ± 10.41 mmHg respectively. There was a strong correlation between the systolic blood pressure measured after intubation by the two methods (interclass correlation coefficient = 0.99, and P < 0.001) which was statistically significant. Bland-Altman plot showed 95 % agreement between the two measures which was within the limits of agreement. There was a strong correlation between the diastolic blood pressure after intubation by the two methods (interclass correlation coefficient = 1), and P < 0.001 which was statistically significant. Bland-Altman plot showed 100 % agreement between the two measures which was within the limits of agreement. The mean arterial pressure after intubation measured by the two methods shows strong correlation (interclass correlation coefficient = 1), and P < 0.001 which was statistically significant. Bland-Altman plot showed 92.5 % agreement between the two measures which was within the limits of agreement.

The mean invasive and non-invasive systolic blood pressure measured half an hour after intubation were 133.1 ± 9.87 and 137.28 ± 11.58 mmHg respectively. The mean invasive and non-invasive diastolic blood pressure measured half an hour after intubation were 82.9 ± 9.53 and 80.28 ± 9.23 mmHg respectively. The mean invasive and non-invasive mean arterial pressure measured half an hour after intubation were 99.53 ± 9.07 and 98.75 ± 9.10 mmHg respectively. The mean systolic blood pressure measured half an hour after intubation by the two methods showed strong correlation (interclass correlation coefficient = 0.60), and P < 0.001 which was statistically significant. Bland-Altman plot showed 97.5 % agreement between the two measures which was within the limits of agreement. The diastolic blood pressure measured half an hour after intubation showed strong correlation (interclass correlation coefficient = 0.99), and P < 0.001 which was statistically significant. Bland-Altman plot showed 97.5 % agreement between the two measures which was within the limits of agreement. The mean arterial pressure measured half an hour after intubation using the two methods had a strong correlation (interclass correlation coefficient = 0.99), and P < 0.001, which was statistically significant. Bland-Altman plot showed 97.5 % agreement between the two values which was within the limits of agreement.

The mean invasive and non-invasive systolic blood pressure measured one hour after intubation were 131.20 ± 10.49 and 133.18 ± 11.11 mmHg respectively. The mean invasive and non-invasive diastolic blood pressure were 81.2 ± 9.51 and 79.03 ± 9.34 mmHg respectively. The mean invasive and non-invasive mean arterial pressure measured at the same time were 97.83 ± 9.22 and 97.05 ± 9.18 mmHg respectively. There was a strong correlation between the systolic blood pressures measured one hour after intubation between the two methods (interclass correlation coefficient = 0.98), and P < 0.001, which was statistically significant. Bland-Altman plot between the two measures showed 95 % agreement which was within the limits of agreement. The diastolic blood pressure measured one hour after intubation using the two methods had strong correlation (interclass correlation coefficient = 0.99), and P < 0.001 which was statistically significant. Bland-Altman plot showed 97.5 % agreement between the two measures which was within the limits of agreement. The mean arterial pressure measured one hour after intubation using the two methods had strong correlation (interclass correlation coefficient = 0.99), and P < 0.001 which was statistically significant. There was 90 % agreement between the two measures in Bland-Altman plot which was within the limits of agreement.

DISCUSSION

Blood pressure measures were taken both by invasive and non-invasive method. In all the measures of the study, systolic blood pressure measures using non-invasive blood pressure monitoring were overestimated and diastolic blood pressure and mean arterial pressures measured using non-invasive blood pressure monitoring were underestimated which was calculated using paired t - test.

Liu B et al.[21] did a study to compare simultaneous invasive and non-invasive blood pressure measurements based upon MIMIC II database. The results were non-invasive systolic blood pressure is overestimated and diastolic blood pressure is under estimated as compared with the invasive method. Invasive blood pressure shows good correlation with the non-invasive blood pressure. Results were similar to what we got in our study.

Riley et al.[20] did a study to compare non-invasive blood pressure monitoring with invasive monitoring in medical intensive care unit (ICU) with septic shock. Non-invasive systolic, diastolic, and mean arterial pressures statistically correlate with the invasive blood values. Our study shows similar results.

Many researches have shown conflicting data regarding the discrepancy of invasive and non-invasive blood pressure.

Araghi et al.[22] compared invasive blood pressure monitoring with non-invasive in overweight critically ill patients and got the result that systolic, diastolic, and mean arterial pressures measured using non-invasive oscillometric method were underestimated. In our study both diastolic and mean arterial pressures were underestimated as compared with invasive blood pressures, which was similar to the study, but systolic blood pressure was overestimated. The difference may be due to the study group, which was in their case, morbidly obese patients (BMI > 30 kg/m^2). Inappropriate cuff size[23,24] for measuring blood pressure may lead to underestimation or overestimation of blood pressure readings. Because of the high body mass index of the study population, there may be inability to properly position the blood pressure cuff which might have resulted in bad signal/noise ratio,[17] which could account for these findings.

Lin et al.[25] conducted a study to compare the non-invasive blood pressure monitoring using the TL - 300 machine with standard invasive blood pressure measurement in patients undergoing elective neurosurgery. The results showed that non-invasive systolic blood pressure is over estimated when compared with the invasive blood pressure with 95 % limits of agreement. This is similar to our study. However, both diastolic and mean arterial pressures were also overestimated in this study with 95 % limits of agreement. The difference in diastolic and mean arterial pressures may be due to the difference in the type of machine they used to measure non-invasive blood pressure. Their study was meant for patients undergoing elective neurosurgery and critically ill patients were not included. This may be the reasons why we got different results.

Many of the studies[22,26,27] showed invasive systolic blood pressure is higher than non-invasive systolic blood pressure, and invasive diastolic blood pressure is same or lower than the non-invasive diastolic blood pressure. In our study, invasive systolic blood pressure was lower than non-invasive systolic blood pressures and invasive diastolic blood pressures were higher than the non-invasive diastolic blood pressures. The reasons for this difference may be because of the elastic force of the arterial wall and the two measurement methods. Non-invasive systolic blood pressure is measured by occluding the artery completely, which induces two forces towards outside, by the flowing blood and the arterial elastic force. But for measuring systolic blood pressure using invasive blood pressure, there is no need for occluding the artery. Therefore, non-invasive systolic blood pressure is slightly higher than invasive systolic blood pressure.[21] In case of diastolic blood pressure measurements, misleading factors are mainly from the measurement methods and equipment.[21]

CONCLUSIONS

From the current study of comparison of invasive and non-invasive blood pressure in high-risk prolonged surgeries, it is revealed that systolic blood pressure is overestimated by NIBP, diastolic and mean arterial pressures are underestimated by NIBP. IBP shows good correlation with NIBP. How much this difference will have on outcome of surgery has not been studied. However, we would like to recommend invasive blood pressure monitoring in prolonged high-risk surgeries and critically ill patients, although a greater number of patients are to be studied to arrive at a conclusion.

Limitations of the Study

The major limitations in the present study were that it included only 40 patients undergoing high-risk prolonged surgeries. Patients with ASA status III and IV were included and the rest were excluded. Patients with age < 18 years and > 65 years are excluded and the study population did not have any patients receiving inotropes, morbidly obese patients, critically ill children or patients undergoing elective surgeries, for that may yield different results.

Data sharing statement provided by the authors is available with the full text of this article at jebmh.com.
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