Assessment of Accuracy of Continuous Noninvasive versus Invasive Method of Hemoglobin Estimation in Patients Undergoing Pituitary Surgery

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Abstract

Aim Determination of hemoglobin (Hb) concentration by standard methods is time consuming, invasive, and intermittent. Noninvasive (NI) methods of Hb estimation are less time consuming, and reduce the risk of infection, number of required working personnel, and long-term costs. In this study, we aimed to find the accuracy of Hb values at various time points using noninvasive (NI) Hb monitoring and standard invasive techniques such as laboratory (LabHb) and arterial blood gas (ABG).

Methods All American Society of Anesthesiologists (ASA) physical grade I and II adult patients between 18 and 65 years of either gender undergoing pituitary surgery under general anesthesia were included over a period of 1 year. Samples were collected for Hb estimation from the arterial line (aHb) using ABG analyzer machine and LabHb using automated Hb analyzer. Simultaneously, Hb reading from the NI Hb monitor was recorded using Masimo Spot Hemoglobin Check Device. Bland–Altman plot was used to find out agreement between Hb values drawn from three different techniques. A p-value < 0.05 was considered significant.

Results A total of 30 patients participated in the study. The male to female ratio was 13:17. Statistical analysis showed poor correlation between the invasive and NI methods of Hb estimation.

Conclusion NI method of Hb estimation may be successfully used in clinical practice, replacing estimation from ABG analysis or laboratory tests. However, NI method cannot replace the invasive methods of Hb estimation.

Keywords
- noninvasive hemoglobin monitor
- invasive hemoglobin monitor
- blood loss
- arterial blood gas
- laboratory test

Introduction

Neurosurgical procedures may involve massive and rapid blood loss. Decision to measure the hemoglobin (Hb) level and when to transfuse blood is important and crucial. In operating room, Hb estimation is largely relied on values obtained from arterial blood gas (ABG) analysis. Until recently, only invasive monitoring techniques were available for the estimation of Hb. Noninvasive (NI) Hb monitoring is found to be more efficient, less expensive, and preferred by patients compared with invasive Hb monitoring.[1] A new NI device, Masimo Spot Hemoglobin Check Device, received the Food and Drug Administration (FDA) clearance that allows for quick and noninvasive (NI) checking of total Hb, oxygen saturation (SpO_2), pulse rate, and perfusion index (PI). Continuous, NI Hb monitoring provides clinicians with the trending changes in Hb, and has the potential to alter red blood cell transfusion decision making. Awada et al's suggestion to add NI monitor to standard monitoring resulted in decreased utilization of blood products during intraoperative period specifically in neurosurgical procedures where excessive blood loss is anticipated while facilitating earlier transfusions.[2] However, it has been observed that the NI Hb monitoring may not have sufficient accuracy to minimize the

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need for invasive Hb monitoring, but it may allow continuous monitoring of Hb and could guide clinicians as to the need for invasive monitoring.[3] In our study, we aimed to find out the accuracy of NI Hb monitor for estimating Hb values by comparing it with invasive methods such as arterial and laboratory samples.

Methods

This study was conducted after taking approval from institute ethics committee (Ref: IEC/NP-315/07.08.2015, RP-13/2015). After taking consent, all American Society of Anesthesiologists (ASA) physical grade I and II adult patients between 18 and 65 years of either gender undergoing pituitary surgery (transnasal and trans-sphenoidal) were included. Patients who refused consent, those with a history of peripheral vascular disease, hemoglobinopathy, and sickle cell disease and patients whose PI on Masimo mo nitor was < 1.4 were excluded. A day before surgery, pre-anesthetic checkup was done. Patients were fasted for 8 hours before the scheduled surgery and received pre-medication with glycopyrrolate 0.2 mg via intramuscular route, 1 hour prior to surgery. Anesthesia was induced with fentanyl 2 µg/kg and propofol 1.5 to 2 mg/kg. Tracheal intubation was facilitated with rocuronium 1 mg/kg. Sevoflurane (0.8–1.2 minimum alveolar concentrations) in a mixture of O_2 and N_2O (1:2) was used for the maintenance of anesthesia, together with fentanyl 1 µg/kg, as an intermittent bolus to maintain analgesia. Rocuronium 0.2 mg/kg every 30 minutes was used intermittently to provide neuromuscular blockade. A blood sample of 1 mL was obtained using a radial artery catheter immediately after induction of anesthesia, but before the start of surgery and approximately every hour thereafter till we removed the arterial line at the end of surgery. Samples were collected for Hb estimation from the arterial sample (aHb) using ABG analyzer machine (Eschweiler GmbH & Co. KG) and laboratory (LabHb) using automated hemoglobin analyzer. Simultaneously, the Hb reading from the NI Hb monitoring was recorded using Masimo Spot Hemoglobin Check Device, Masimo Spot Hemoglobin Check Device (Pronto; Irvine, California, United States). Other values displayed on the monitor, such as the PI was also recorded. Hb values at a PI < 1.4 are not considered reliable as these are not recommended by the manufacturer, hence not included for analysis. The blood oxygen saturation values from the standard pulse oximeter (SpO_2), NI (SpO_2), and ABG were noted. Also, the core body temperature was noted each time the values were recorded.

Statistical analysis was performed using Stata 12.0 (StataCorp LP, College Station, Texas, United States). Data were presented as number (percentage) or mean ± standard deviation (SD) as appropriate. Bland–Altman plot was added to find out the agreement between Hb values drawn from three different techniques. The *p*-value < 0.05 was considered statistically significant.

Results

A total of 30 patients participated in the study, which was conducted over a period of 1 year. None of the patient was excluded from the study. The male to female ratio was 13:17. The other demographic characteristics including mean age of 40.83 (17.03) and mean weight of 66.5 (12.31). Hb could be measured up to two time points (Hb1 and Hb2) in 30 patients, up to three time points (Hb1, Hb2, and Hb3) in 27 patients, and up to four time points (Hb1, Hb2, Hb3, and Hb4) in only 18 patients. This was due to the difference in duration of surgery (►**Fig. 1**). At different time points, there was a trend, which showed NI Hb monitor with the highest Hb values followed by Hb values obtained from arterial sample and the laboratory test (►**Fig. 2**).

►**Table 1** shows the correlation between different techniques of Hb estimation. (►**Fig. 3**) displays the Bland–Altman plot of the relationship between the observed differences between Hb values of Laboratory and NI Hb monitor and the mean of the two measures. Limits of agreement (horizontal lines) indicate that 28 of the 30 estimates of NI Hb values were within the limits. The limits of agreement are defined as the mean difference ± 2 SD, and the calculated lower and upper limits for Laboratory and NI were between–4.5 and +2.7. (►**Fig. 4**) displays the Bland–Altman plot of the relationship between the observed differences between Hb values of arterial and NI Hb monitor and the mean of the two measures. Limits of agreement (horizontal lines) indicate that 28 of the 30 estimates of NI Hb values were within the limits. The limits of agreement are defined as the mean difference ± 2 SD, and the calculated lower and upper limits for Laboratory and NI are between–4.6 and +3.6. (►**Fig. 5**) displays the Bland–Altman plot of the relationship between the observed differences between Hb values of laboratory and arterial and the mean of the two measures. Limits of agreement (horizontal lines) indicate that 29 of the

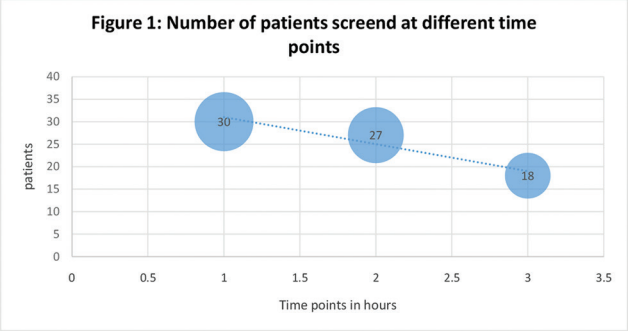

Fig. 1 Number of patients screened at different time points.

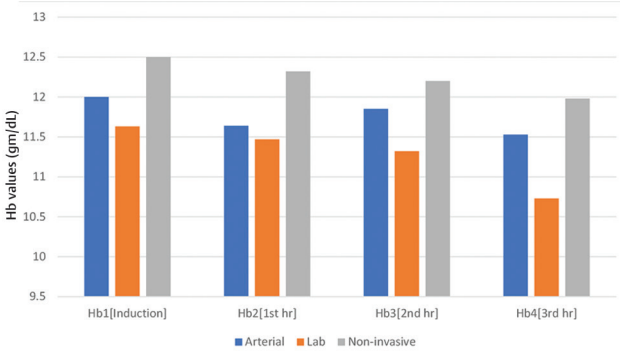

Fig. 2 Hemoglobin estimation at different time points. Hb, hemoglobin; hr, hour.

Table 1 Correlation between different methods of hemoglobin estimation

	Total patients	Correlation	Significance
Arterial and laboratory	30	0.7040	0.0000
Laboratory and noninvasive	30	0.2355	0.2103
Arterial and noninvasive	30	0.1059	0.5775

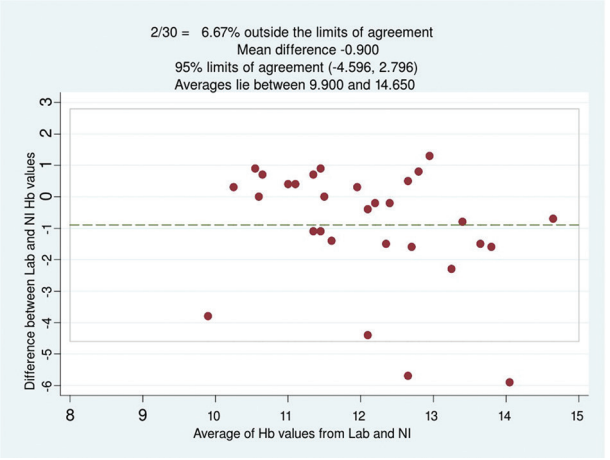

Fig. 3 Bland–Altman plot of correlation between observed differences between laboratory and NI. Hb, hemoglobin; NI, noninvasive.

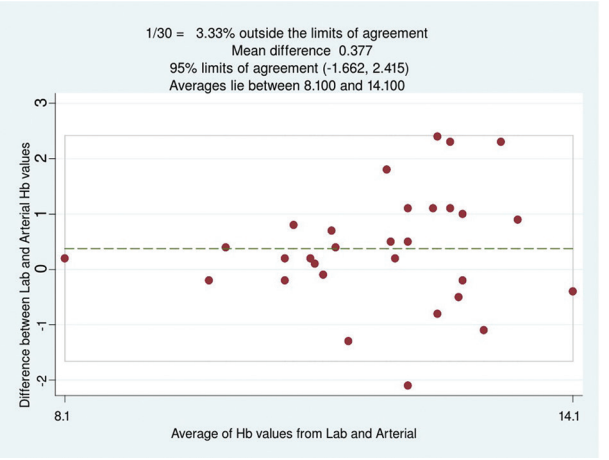

Fig. 5 Bland–Altman plot of correlation between observed differences between arterial and laboratory. Hb, hemoglobin.

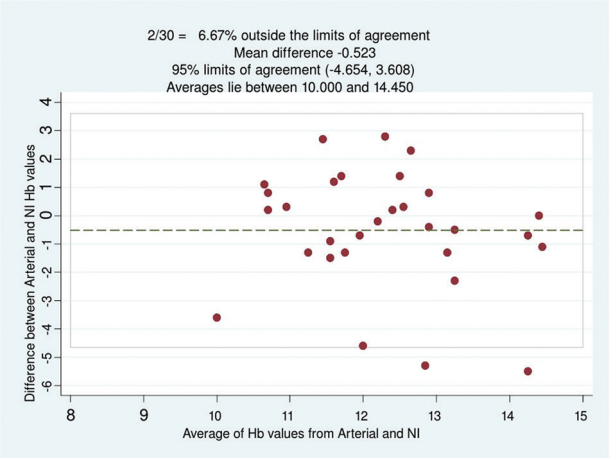

Fig. 4 Bland–Altman plot of correlation between observed differences between arterial and NI. Hb, hemoglobin; NI, noninvasive.

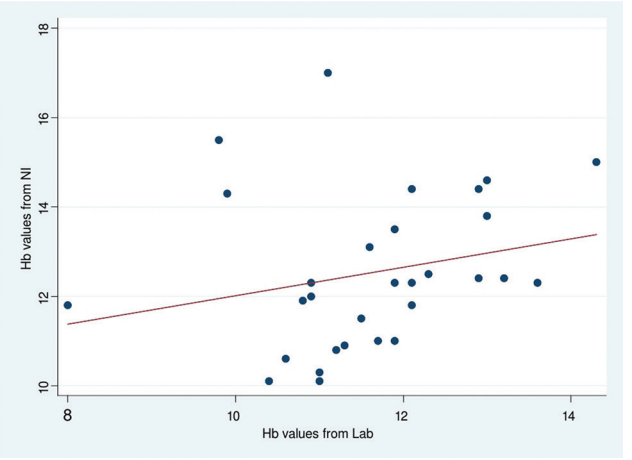

Fig. 6 Scatter diagram showing relationship between laboratory and NI Hb values trends. Hb, hemoglobin; NI, noninvasive.

30 estimates of arterial Hb values were within the limits. The limits of agreement are defined as the mean difference ± 2 SD, and the calculated lower and upper limits for laboratory and NI were between–1.6 and +2.4. In (►**Fig. 6**), the regression lines show the relation between the laboratory and NI Hb trends. (►**Fig. 7**) shows the relationship between the arterial and NI trends, and (►**Fig. 8**) shows the relationship between the arterial and laboratory trends, respectively.

Discussion

Determination of Hb concentration by standard methods is time consuming, invasive, and intermittent. NI Hb monitoring devices have the potential for detecting sudden changes in a patient's Hb concentration in blood. This NI method of Hb determination provides a comfortable environment to the patient as well as reduces the risk of infection, number of required working personnel, and long-term costs. However, the accuracy of NI method can be influenced by many clinical factors such as perfusion state, temperature, a large volume shift, type of infused fluid, and age of the patient. In our study, we aimed to assess the accuracy of NI method of Hb estimation over invasive methods. Based on the results of the Bland–Altman plots, in our study, the calculated 95% confidence interval (CI) for the difference calculated on the laboratory and NI Hb value was–4.5 and +2.7. Therefore, for an actual Hb value of 12 mg/dL, it could be reported to be either as low as 7.5 mg/dL or as high as 14.7 mg/dL. It is definitely considered to be clinically

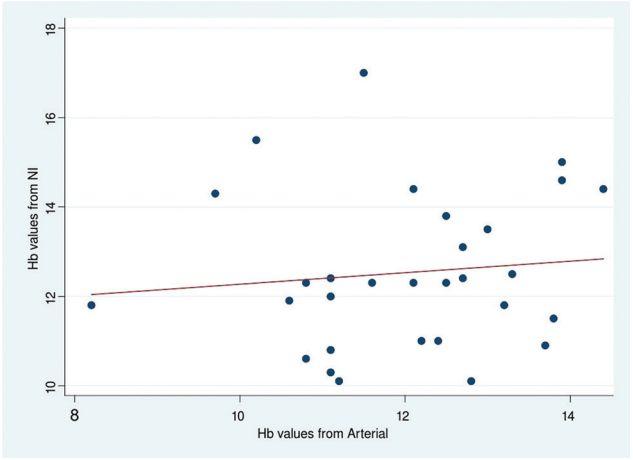

Fig. 7 Scatter diagram showing relationship between arterial and NI Hb values trends. Hb, hemoglobin; NI, noninvasive.

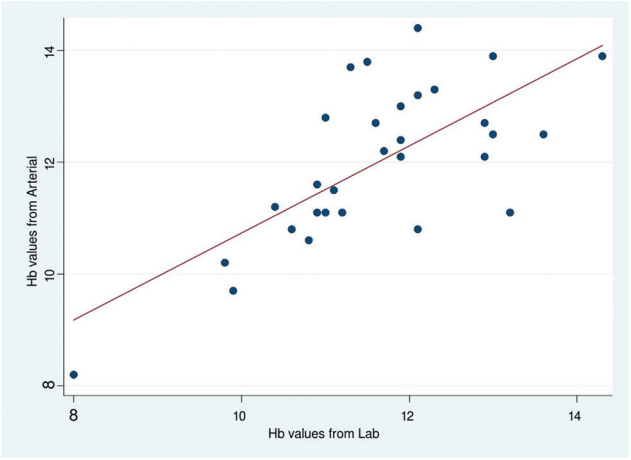

Fig. 8 Scatter diagram showing relationship between arterial and laboratory Hb values trends. Hb, hemoglobin.

significant, and management of patients on the basis of this report could be hazardous. Again, for arterial and NI Hb values on the basis of same plot, there would be wide upper and lower Hb range difference which is not acceptable. The reason for this wide range could be smaller sample size or inaccuracy of NI Hb estimation method. The correlation coefficient between the NI and laboratory values was 0.235, and between the NI and ABG analysis values was 0.105, which showed no correlation. However, Hb values between arterial and laboratory analysis showed a good correlation (correlation coefficient of 0.707), which might serve as an explanation for inaccuracy of NI Hb estimation method thereby leading to wide variation in other two paired groups. As per the result of Scatter diagrams, invasive and NI methods of Hb estimation showed poor correlation between themselves (►**Figs. 6** and **7**). However, the scatter diagram between arterial and laboratory Hb estimation methods showed good correlation (►**Fig. 8**).

Findings from our study suggest that NI Hb monitor can neither replace ABG sampling (aHb) for Hb estimation nor Hb estimation from laboratory tests. Though both NI and aHb methods provide immediate Hb values during intraoperative period for Hb estimation, continuous real time Hb monitoring is the advantage with NI, which is not possible with aHb since it requires intermittent blood sampling. We also compared both invasive methods of Hb estimation techniques, LabHb and ABG analysis, and found a good correlation between the two (correlation coefficient of 0.7040). Hb estimation by NI monitor depends on the adequacy of blood flow to the finger, which is indirectly reflected by PI. PI is a calculated value, which is displayed on NI monitor, and Hb values displayed on monitor with PI values of < 1.4 are not considered reliable. The alteration in finger perfusion either underestimates or overestimates the true Hb values depending on the decreased or increased tissue perfusion. So, PI is an important clinical indicator of actual Hb values on NI monitor. According to Khanna et al, NI Hb monitor does not have sufficient accuracy to minimize the need for invasive Hb monitoring, which includes both ABG and laboratory sample.[4] One limitation of their study was that they could not use NI monitor properly in 8 patients out of 30 due to PI value < 1.4. Throughout surgery in our study, all patients had PI values >1.4. In contrast, Vora and Desai conducted a study that was performed in the intensive care unit and compared transcutaneously spectroscopically NI measured Hb values with venous Hb values. They concluded that there is a good relation between the two methods for measuring Hb. However, authors further concluded that larger studies are required to validate this NI method in those with conditions that affect the perfusion.[5] Joseph et al observed that the NI Hb monitoring was found to have excellent correlation with invasive Hb measurement in trauma patients, and its application allows immediate and accurate Hb measurement.[6] In our study, we found a poor correlation between Hb values by invasive and NI Hb monitoring methods; however, the main difference between ours and their study was that they compared LabHb and NI, whereas in our study, we compared two invasive methods (aHb and LabHb) of Hb estimation with NI Hb estimation method. Another difference was the patient population that in our study included non-traumatic patients. In another study by Applegate et al, they compared NI, aHb, and arterial finger stick blood with LabHb and observed that all three methods provided similar intraoperative guidance regarding increase or decrease in Hb value, whereas these cannot be used for guide transfusion decision making.[7] Butwick et al reported that despite a significant correlation between NI and laboratory Hb values, NI monitor overestimated Hb values compared with laboratory Hb values.[8] We also observed the same trend of higher Hb values with NI compared with laboratory Hb. However, NI always overestimated Hb values at different time points compared with arterial Hb values. In our study, LabHb values were the lowest when compared with NI and aHb values.

Conclusion

From our study, we conclude that NI method of Hb estimation may be successfully used in clinical practice; however, this method cannot replace the invasive Hb estimation methods such as ABG analysis and laboratory method of Hb estimation. More trials are required to find out the accuracy

between noninvasive method of Hb estimation and invasive methods of Hb estimation. Inclusion of NI method of Hb estimation in standard monitor list could be helpful in instantaneous assessment of blood loss and guiding blood transfusion therapy in patients at risk of bleeding.

Conflict of Interest
None.

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