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Original Article

Measures of Blood Hemoglobin and Hematocrit During Cardiac Surgery: Comparison of Three Point-of-Care Devices

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Objective: The primary objective was to compare I-Stat, HemoCue, and RapidLab in measurements of the hemoglobin concentration during cardiac surgeries using cardiopulmonary bypass.
Design: Prospective analysis.
Setting: Single-center, academic, tertiary care cardiovascular center.
Participants: Thirty-four consecutive patients undergoing cardiac surgery requiring cardiopulmonary bypass.
Interventions: Blood samples have been collected intraoperatively, and the hemoglobin concentration in each sample was measured, or calculated, simultaneously by the 3 point-of-care devices, HemoCue, RapidLab, and I-Stat.
Measurements and Main Results: Correlation coefficients from the regression analysis for HemoCue versus I-Stat, RapidLab versus HemoCue, and RapidLab versus I-Stat were 0.89, 0.96, and 0.88, respectively. Results of the Bland–Altman analysis of the hemoglobin concentration measurements for each device against one another (Fig 1) were as follows: RapidLab versus I-Stat (bias 0.42; 95% confidence interval [CI], –1.05 to 1.89), I-Stat versus HemoCue (bias 0.23; 95% CI, –1.14 to 1.59), and RapidLab versus HemoCue (bias 0.65; 95% CI, –0.17 to 1.47). It appears that I-Stat slightly underestimated the concentration of hemoglobin when compared with both RapidLab and HemoCue. The results of Bland–Altman analysis of each device to a mean Z value (Fig 2) were as follows: RapidLab versus Z (bias 0.36; 95% CI, –0.29 to 1.01), I-Stat versus Z (bias –0.07; CI –0.97 to 0.84), and HemoCue versus Z (bias –0.29; 95% CI, –0.86 to 0.28). Based on the 174 paired samples used for the Pearson moment analysis, the R^2 values for I-Stat versus HemoCue, I-Stat versus RapidLab, and RapidLab versus HemoCue were 0.79, 0.80, and 0.87, respectively
Conclusions: These data support the interchangeability of these 3 devices for the intermittent intraoperative point-of-care assessment of hemoglobin concentrations in cardiac surgery patients. It is important, however, to consider the possible pitfalls associated with each device when making a clinical decision to transfuse

Key Words: point-of-care testing; hemoglobin concentration; cardiac surgery; I-Stat; HemoCue; RapidLab

POINT-OF-CARE testing (PoCT) is a fast-growing technology that has revolutionized laboratory monitoring in acute care settings, such as the operating room and intensive care units. With PoCT devices readily available near patients, laboratory results can be obtained quickly and efficiently. As a result, PoCT device testing now is used commonly during major surgeries. Early detection of occult bleeding by the rapid and repetitive measurement of hemoglobin during cardiac surgery allows for proactive resuscitation efforts. Currently, there are several point-of-care devices used to measure hematocrit and hemoglobin concentration intraoperatively,

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employing either a conductivity or a co-oximetry method. Co-oximetry, used by HemoCue (Hemocue, Brea, CA) and RapidLab (Siemens, Malvern, PA) devices, ues spectrophotometric analysis of the substance light absorbencies to measure hemoglobin concentration directly.[1–3] Conductivity methods, such as I-Stat (Abbott Inc, Princeton, NJ), measure electrical conductance of the plasma sample, which then is converted to hematocrit after a few corrections are applied by the device, such as temperature and size of the sample.[2,4] The measured conductivity is inversely related to the blood hematocrit. Hemoglobin concentration then is calculated based on the assumption that hemoglobin is approximately one-third of the hematocrit.[3]

There is concern that the conductivity method may lead to an underestimation of the actual hemoglobin and hematocrit values, which could lead to unnecessary transfusions.[4,5] Several commonly occurring processes may cause such underestimations. Abnormal total protein levels, amplified with the use of crystalloid solution administration during cardiopulmonary bypass (CPB), elevated white blood cell counts, abnormal lipid levels, and electrolyte abnormalities all can affect the I-Stat hematocrit measurement.[4,6–8] However, in addition to performing hematocrit measurements, I-Stat offers the ability to measure a series of other biomarkers, making this device an attractive option for intraoperative use.

Although the accuracy of I-Stat and the other devices have been studied previously, many of them have not been directly compared with each other during cardiac surgery when potential changes in blood rheology and conductivity may vary.[1,4–10] Thus, to assess the interchangeability of I-Stat relative to the 2 other commonly used devices that measure hemoglobin, the HemoCue and the RapidLab, the authors performed this quality improvement study in patients during cardiac surgeries utilizing CPB.

Methods

Institutional review board approval was waived by the University of California, San Diego Human Research Protections Program. As part of a hospital quality improvement project, intraoperative hemoglobin and hematocrit data from 34 patients who underwent open heart surgery were analyzed. From this cohort, 208 consecutive paired blood samples were collected and simultaneously measured hemoglobin concentration and hematocrit during cardiac surgery on the 3 point-of care devices: HemoCue, I-Stat, and RapidLab, the latter being the hospital reference standard. Sample collection was carried out per routine practice by the perfusionist. The number of measurements was not equal between patients, as the need for hemoglobin and hematocrit values varied with the complexity and length of each surgery. HemoCue and RapidLab devices measure hemoglobin concentration directly, whereas the I-Stat device measures hematocrit and calculates hemoglobin from the hematocrit value.

Data were collected over a 3-month period. Paired data were analyzed via regression analysis, Bland–Altman, and Pearson sequential moment analyses. Because none of the devices is considered a gold standard, in addition to Bland–Altman analysis comparing the devices to one another, a mean hemoglobin value of all 3 devices for each time point, defined as Z (where Z = [RapidLab + HemoCue + I-Stat]/3) was used, as previously done for similar multiple device comparisons.[11]

Results

Hemoglobin values measured in this study ranged from a high of 16.0 to a low of 5.4 (mean 9.9, median 9.9). Correlation coefficients (R) from the regression analysis for HemoCue versus I-Stat, RapidLab versus HemoCue, and RapidLab versus I-Stat were 0.89, 0.96, and 0.88, respectively. The results of the Bland–Altman analysis of the hemoglobin concentration measurement for each device against one another (Fig 1) were as follows: RapidLab versus I-Stat (bias 0.42; 95% confidence interval [CI], −1.05 to 1.89), I-Stat versus HemoCue (bias 0.23; 95% CI, −1.14 to 1.59), and RapidLab versus HemoCue (bias 0.65; 95% CI, –0.17 to 1.47). It appears that I-Stat slightly underestimated the concentration of hemoglobin when compared with both RapidLab and HemoCue. The slight systematic bias seen when comparing each device to another was lost when the authors analyzed each device to their mean common hemoglobin value (Z). The results of the Bland–Altman analysis of each device to a mean Z value (Fig 2) were as follows: RapidLab versus Z (bias 0.36;

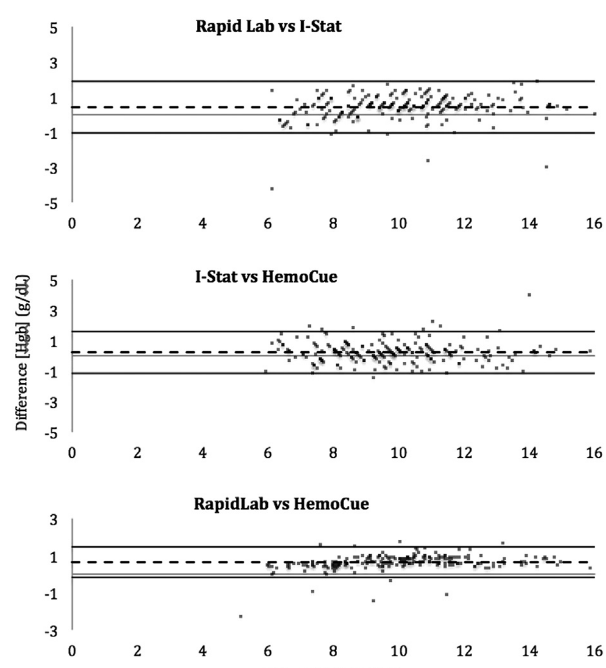

Fig 1. Bland–Altman analysis comparing paired simultaneously measured hemoglobin values between each of the 3 devices separately. The x axis represents the average [Hgb] for each sample analyzed by the 2 devices being compared. The y axis represents the difference between the [Hgb] measured by both devices in each sample (eg, for a RapidLab versus I-Stat graph: the x axis = [RapidLab – I-Stat]/2, while the y axis = RapidLab - I-Stat).

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