UNIVERSITY OF NAIROBI

HAEMOGLOBIN LEVELS MEASURED BY THE ARTERIAL BLOOD GAS ANALYSER VERSUS THE AUTOMATED HAEMOGLOBIN ANALYSER IN CRITICALLY ILL PATIENTS

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H58/34266/2019

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF MEDICINE IN ANAESTHESIOLOGY, UNIVERSITY OF NAIROBI

STUDENT'S DECLARATION

This dissertation is my original work and has not been presented for an award or similar purpose. The resources and materials used have been indicated and acknowledged by referencing.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABG	Arterial Blood Gas Analyser
ABG	Arterial Blood Gas
AHA	Automated Haemoglobin Analyser
BGA	Blood Gas Analysis
CBC	Complete Blood Count
CCU	Critical Care Unit
CI	Confidence Interval
Cl^-	Chloride
CLA	Central Lab Auto-Analyzer
CLIA88	Clinical Laboratory Improvement Amendments Of 1988
CM	Haemoglobin Cyanide Method
CST	Copper Sulphate Test
EDTA	Ethylenediaminetetraacetic Acid
EPOC	Handheld Wireless Blood Gas Testing at The Point of Care
Hb	Haemoglobin
$HCO3^-$	Bicarbonate
Hct	Haematocrit
HiCN	Haemoglobin Cyanide
ICU	Intensive Care Unit
IFCC	International Federation of Clinical Chemistry
K+	Potassium
KNH	Kenyatta National Hospital
Lab	Laboratory
LOA	Limit of Agreement
MetHb	Methaemoglobin
Na+	Sodium
Oxy-Hb	Oxyhaemoglobin
PaCO2	Partial Pressure of Carbon Dioxide
PaO2	Partial Pressure of Oxygen
POCD	Point of Care Device
POCT	Point of Care Testing
p-value	Probability Value

r	Correlation Coefficient
RBC	Red Blood Cell
SLS	Sodium Lauryl Sulphate
TRCCT	Transfusion Requirement in Critical Care Trial
UON	University of Nairobi
USA	United States of America
USCLIA	United States Clinical Laboratory Improvement Amendments
VS	Versus
WBC	White Blood Cell
WHO	World Health Organization

OPERATIONAL DEFINITIONS

The Dead Space Volume of the Syringe: The liquid remains in the syringe's hub and the needle after completely emptying the syringe.

Arterial Blood Gas Analyser: A machine that measures the concentration of blood gasses, pH and bicarbonate iron concentration in the blood to evaluate a person's lung function and acid-base balance. It may also have additional menus to measure blood glucose, haemoglobin and electrolyte levels.

Automated Haemoglobin Analyzer: A machine that has an in-built cell counter. It assesses the various components of blood: the red and white blood cell parameters and platelets.

ABSTRACT

Background: Haemoglobin (Hb) is the iron-rich protein component of red blood cells (RBC) that is responsible for at least 98% of systemic oxygen delivery (DO2). Haemoglobin measurements are often performed in the Intensive Care Unit ICU as a surrogate of DO2. Various methods of measuring haemoglobin by spectrophotometry, namely, the arterial blood gas analyser (ABG- A) and automated haemoglobin analyser (AHA), have been used with unknown levels of agreement in our setup. This study intended to establish the agreement between the two methods and their interchangeability.

Objective: To assess the interchangeability of the haemoglobin results as measured by the arterial blood gas analyser versus the automated haemoglobin analyser at the Kenyatta National Hospital (KNH)Main ICU.

Methods: This was a cross-sectional method-comparison study. Suitable patients had paired sampling for the two forms of haemoglobin estimation. The data was collected using a pretested data collection tool and stored in a password-protected Excel database. Continuous variables were tested for normality using the Shapiro-Wilk test and summarised into means, median, standard deviation, and interquartile ranges. Paired samples t-tests were used to compare means of parametric variables. Categorical variables were presented in tables or percentages. Bias and limits of the agreement were established using the Bland-Altman test. A mean difference of 0 indicated a lack of a fixed bias. A mean difference within 1.96 standard deviations (limits of agreement) indicated how far apart the measurements were in at least 95% of the samples analysed.

Results: 132 paired samples from 73 patients were analysed, 62.8% of whom were male. The patients were between 18-77 years, with a mean age of 43.3.The mean Hb levels mean for ABGA was 11.35(+/-2.41SD, 95%CI of 10.93-11.76) whereas that of AHA was 10.88(+/-2.20SD, 95%CI of 10.50-11.25). The mean difference was 0.47. The Bland Altman analysis indicated a strong agreement with the bias of 0.47 being close to zero and most data points falling within the 95% LOA. The correlation coefficient r=0.83(p-value 0.000) showed a strong association. The total allowable error for Hb was 4.7%

Conclusion: There was a strong association and level of agreement between haemoglobin levels measured by the two methods, with the total allowable error falling within the United States Clinical Laboratory Improvement standards margins of +/-7%. Therefore, the two methods were interchangeable at the KNH Main ICU.

1.0 CHAPTER ONE: INTRODUCTION

1.1 Background Information

Critical care management of patients requires prompt decision-making and interventions. Point of care testing (POCT) has increasingly become popular in modern critical care units (CCUs). The benefits of POCT include convenient bedside sampling, timely results generation and subsequent facilitation of instant medical diagnosis and management of patients. [1]

Haemoglobin (Hb) testing in ICUs has been made possible by POCT methods such as the arterial blood gas analyser (ABGA). Hb levels are measured alongside the partial pressures of carbon dioxide and oxygen (PaCO2 and PaO2, respectively), pH, and bicarbonate ion concentration (HCO3). Some ABG-As can also measure electrolytes such as sodium, potassium, chloride, lactate, serum urea and creatinine. [2] ABG-A's average turnaround time is about 2 minutes [3]

The standard, reliable haemoglobin testing method is the automated haemoglobin auto-analyser (AHA) at the central laboratory of most facilities. It measures the Hb level as an isolated parameter or as part of the complete blood count (CBC) with or without differentials. It is similar in precision to the gold standard haemoglobin cyanide method (CM). [4–6] The average turnaround time for a CBC is 36 minutes. [7]

Conventionally, the AHA process involves collecting blood samples and sending them to a central lab. They are separated, diluted and tested before results are transmitted electronically or manually back to the ICU. This is often a source of delay in patient management.

Few studies have compared the Hb levels by the ABG-A versus the AHA in the acute care setting, with only one done in Africa - none in Kenya. Most of these studies were conducted in the emergency care departments; some were retrospective and with conflicting conclusions on the interchangeability of the two methods. There were preanalytical and analytical discrepancies in some of these studies. Preanalytical errors occurred when paired samples were collected by two pricks from the artery and vein within the acceptable time limit of 1 hour. However, an intervention could have occurred within such an interval in the Emergency Care setting. [8–15]

This study aimed to determine whether the ABG-A Hb levels at Kenyatta National Hospital (KNH) CCU were believable or whether clinicians should wait for confirmation from the central lab results. The study also intended to establish whether the agreement between the two methods is acceptable by the recommended United States Clinical Laboratory Improvement Amendments (USCLIA) of 1988 guidelines, which recommend a Hb accuracy of +/-7%. [16]

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 Background of the Methods of Haemoglobin Estimation

Measurement of haemoglobin has undergone evolutionary changes from the old qualitative methods like the copper sulphate technique (CST) to newer quantitative methods that utilise the principle of spectrophotometry. The CST method is currently more of a screening tool for blood donors in resource-poor settings, whereas the Haldane method is no longer in use. [4,5]

Modern methods of haemoglobin estimation are categorised into invasive and non-invasive quantitative methods. The invasive techniques include the gold standard haemoglobin cyanide (HiCN) method (CM), the Vanzetti-Azide methaemoglobin (MetHB) method, the AHA method and the POCT method. [5]

The POCT methods comprise the manual Sahli's method, the WHO Haemoglobin colour scale and portable electronic hemoglobinometers like the hemoCue, and CO-oximeters like the ABG machine that measure both COHb and MetHb. [17]

Modern non-invasive methods use occlusion spectroscopy and CO- oximeters like the Masimo^{TM}, whose technology is incorporated into pulse oximeters that measure Hb in capillaries with oxygen saturation, pulse rate, and perfusion index well as oxygen and carbon dioxide concentration. [4,17,18] This progress has sired more accurate, rapid, and user-friendly methods with improved portability.

The CM is the gold standard method for haemoglobin Estimation. It is recommended reference standard by the International Council for Standardization in Haematology for the calibration of haemoglobinometers. [19]The process involves the addition of potassium cyanide and ferricyanide to the blood sample, which converts all forms of Hb into HiCN, whose absorbance is measured at a wavelength of 540nm against a standard solution by a photoelectric calorimeter and the Hb level determined. It is cheap and reliable but has limitations, such as time-consuming, tedious reagents containing cyanide which is hazardous to the environment. Turbidity may affect its accuracy because it is measured at a single wavelength and by sample dilution. [4,5]

The other popular haemoglobinometer in resource-poor settings is the AHA. This quantitative method produces important information on RBC and white blood cell (WBC) parameters often found on CBCs with or without differentials such as haematocrit (Hct), RBC index, RBC size, mean corpuscular haemoglobin, WBC differential counts etc. It has an in-built automated cell counter that enables it to measure particles at the same time. As much as it produces very high

precision, its use is restricted to very stable weather conditions. It has a high initial cost with a need for regular maintenance and qualified personnel to run it. [4,5]

The AHA method has been advanced from the initial Hb estimation by HiCN and Oxyhaemoglobin(oxy-Hb) methods to non-cyanide reagents like sodium lauryl sulphate (SLS), which is non-toxic. The AHA method is similar to the CM method in terms of precision. In the oxy-Hb method, Hb is converted to oxy-Hb by adding an aqueous solution of tetrasodium salt of ethylenediaminetetraacetic acid (EDTA) and air. Absorbance is measured at 540nm with the HiCN method, and the Hb level is determined. Following the use of sodium lauryl sulphate, RBC's cell membrane lipoprotein is haemolysed, releasing Hb into the solution, which then forms Hb- SLS, whose light absorbance and compared to that of the solution before SLS was added. [2021]

The ABG-A may also estimate Hb levels alongside the pH, PaCO2, PaO2, electrolytes, blood urea, and creatinine. Older models were high-maintenance devices that relied on highly skilled medical laboratory scientists for calibration, maintenance and quality control. Significant improvements over time have converted these analysers into compact point-of-care units that have the capacity for auto-calibration and ease of use such that any trained personnel were able to operate it not only in the central lab but also in the POC areas such as critical care units and emergency departments to provide instant results for timely intervention. [2]

Newer ABG-A models have other menus from the basic PH, PaCO2 and PaO2 to incorporate HCO3, Hb, Electrolytes and metabolites such as lactate, glucose and creatinine. [22]BGA analysers measure Hb spectrophotometrically, where the blood sample transmits light corresponding to a fraction of Hb already calibrated against a known Hb standard. [23] ABGs are often done routinely in the morning for ventilated patients, those on oxygen supplementation or following ventilator setting adjustment, correction of electrolyte and glucose derangements, after administering blood and certain fluids, pre and post-intubation and extubation. ABGs are also done following a cardiac event or with decreasing level of consciousness and as a repeat follow-up for abnormal results. [24, 25]

Given the frequency with which ABGs are done in the ICU for reasons other than Hb measurement, it would be time and cost-saving if the clinician were in a confident position to use these Hb results for instant patient management without having to confirm by the AHA method.

2.2 Studies on Hb Levels as Measured by the ABG-A vs the AHA and How They Compare

In 2019 a multicentre study involving 5 ICUs in hospitals in Australia by Katherine et al. evaluated 219 paired samples for Hb and sodium (Na +) and 215 for potassium (K+), collected within one hour of each other and analysed by the ABG-A while the AHA assessed the second sample. The median Hb was 7.9 and 8.1, as assessed by the AHA and ABG-A, respectively. The study found no significant statistical difference in the Hb levels by the two methods, as the mean difference was 0.35g/L, which was within the acceptable recommended USCLIA guidelines. The Bland Altman plots showed that the mean biases were small and independent of the proportions of the measurements, but the values tended to fall within the normal ranges. They, therefore, concluded that there was no benefit in concurrent Hb testing, but instead, it was cost-saving to use one or the other. [12]

Another retrospective observational study conducted in 2015 by Prakash et al.in a tertiary facility's medical and surgical ICUs in Australia compared the concordance of the Hb, Glucose, sodium, potassium, chloride and bicarbonate levels in 9,398 paired samples from 1,765 patients. Hb had the largest bias, and its readings had a variability of 5.9 which was inconsistent with the USCLIA acceptable variability criteria. They, therefore, concluded that the two measurement methods were not interchangeable for Hb.[10]

A 3rd study conducted in Melbourne, Australia, by Gibbons et al. at the emergency department evaluated 352 paired samples to compare ABG-A Hb, Na+ and K+ levels to those analysed by the AHA. This prospective cohort study assessed for bias, 95% limits of agreement (LOA) by the Bland Altman analysis and the agreement with the USCLIA guidelines. Hb had a bias of -1.6g/dL, 95% LOA -10.2-6.9g/dL, which was within the USCLIA criteria. Both electrolytes also agreed with USCLIA limits and concluded that the ABG results could be utilised for rapid decision-making in that facility. [8]

In Europe, a study conducted in Athens, Greece, by Gavala et al. for 55 weekdays comparing 200 paired samples as assessed by the POC ABG vs the CLA concluded that the results for all measurements (Hct, Hb, Na+ and K+) were lower when evaluated by the ABG-A (p=0.0001) as compared to the AHA. The mean Hb levels were 9.05+/-1.6 and 9.34+/-1.6 from the ABG and the AHA, respectively. As much as the mean biases were within the acceptable USCLIA limits for all parameters except Hct, the mean difference for all parameters, Hb, Na+, K+, and Hct, were beyond the USCLIA cut-offs at 8%,17.5%,37.5% and 56.0% respectively. These two measurement methods were, therefore, not interchangeable. [26]

A study conducted between 2017-2018 by Marija et al. in Germany retrospectively assessed 500 paired samples for the Hb and electrolytes interchangeability and reference intervals using the ABG-A compared to the AHA. The data revealed that the levels of all analytes differed significantly when assessed by the two methods with a ($p =<0.001$) save for sodium but met their interchangeable criteria except for Hb. The reference intervals estimated by the reference limit estimator were met by potassium, sodium, glucose and haemoglobin, but lactate differed significantly at the lower reference range. The study concluded that the two systems were different for Hb.[11]

A similar study conducted in a Supra maximal hospital in Germany by Pomerich et al. at the emergency department obtained and tested paired blood samples from 2,548 patients while comparing Hb from unspecified POC testing methods and that of AHA. The mean difference between POCT and AHA Hb was 0.6g/dl (0.0-7.2g/dl). The mean difference in the measured values was -0.44g/dl. POCT values were higher. The LOA from the Bland Altman analysis was (-1.66 to 0.77g/dl). [27]

Another prospective observational European study was conducted in Marseille, France, by Allerdet et al. over one month in 2015 to compare POC vs central lab Hb, Hct, glucose bicarbonate and electrolytes. This study compared 314 paired samples from 51 patients assessed by the two measurement methods. The mean Hb range by the POC was 6.1-15.5 with a mean of 10.3 and median of 10.2, whereas that of the AHA was 5.6-14.7 with a mean of 9.5 and median of 9.4 with a bias, LOA of +/- 0.96SD and coefficient of correlation of -0.8 (-1.4 to- 0.2g/dl,) r =0.985 respectively. These Hb values yielded a mean difference of 8.2% which is above the USCLIA cut-off for Hb. The study found that all the other parameters were within acceptable USCLIA limits and were, therefore, interchangeable except for Hb. [28]

A study by Navarre et al., conducted in Chicago, Illinois, compared paired samples from spinal fusion patients.[29] The results showed that the mean Hb difference in the two samples was 0.4g/dL (95% CI 0.36-0.41g/dL) 44.5% of the paired samples had a weak agreement with the USCLIA recommended criteria hence concluding that the two systems could not be confidently interchanged.

In 2000, over 28 days, a prospective study was conducted at the General Hamilton Hospital, Toronto, by Ray et al. on the use of rapid ABG for Hb estimation. The study compared these results to the coulter counter method at the central lab. The mean Hb by the coulter counter was 107.2g/l (SD= 23.2g/l). The mean Hb difference was 4.3g/l p=0.060 with a significant

positive correlation between the two methods r^2=0.981, 95%CI 0.97-0.99 p<0.0001. The study concluded that ABG is a valuable alternative and cost-saving method of Hb estimation. [30]

A retrospective study conducted in Philadelphia between 2011-2017 by Herman et al. compared Hb measured by POC devices (EPOC machine) vs that measured by the AHA in 98 paired samples.51% of the samples had an absolute difference of <7%, which is within the USCLIA recommendations. 73% of the lab comparison points fell within +/- 1g/dl of each other. The Bland Altman mean Hb difference had a bias of -0.268g/dl. The EPOC values were slightly lower; about 30% of the EPOC vs AHA values were within the +/- 7% range. EPOC's accuracy was much lower when the patient had a lower Hb value of less than & 7g/dl. This study concluded that for anaemic patients with a Hb of less than 7g/dl, a CBC should be done within 30 minutes to corroborate the POCT results. [31]

A prospective study conducted in 2 hospitals in China by Zhang et al. to compare the analysis bias in 200 paired samples measurements of K+, Na+ and Hb as assessed by the ABG-A vs AHA for eight months in 2013 concluded that ABG results were reliable as they agreed with the central lab values. Measurements by the ABG-A vs AHA were mean Hb of 12.28+/- 2.62 and 12.35+/-2.6, respectively. There was no statistical bias for Hb as compared to the USCLIA cut-offs. Still, there were statistically significant biases for the electrolytes and all the ranges were well within the acceptable USCLIA guidelines. [32]

A similar study was conducted in 2 other hospitals in China, ZRY and QY hospitals, by Xie et al. This study retrospectively compared the agreement between Na+, K+, glucose and Hb levels assessed by the ABG analyser to the lab autoanalyser. It evaluated the correlational coefficient, 95% CI, and 95% LOA. The ABG Hb in both hospitals was highly correlated to that of the lab analyser at a Correlation coefficient of 0.98 and 0.866 at ZRY and QY hospitals, respectively. The mean difference of the Hb by the two analyser systems at ZRY hospital was -2.8g/L (95% CI -3.14 to -2.49) and a 95% LOA of -12.3 to 6.7 at ZRY with a mean derivative bias of -2.7%. At the QY hospital, mean Hb difference levels was -0.87g/L (95% CI -9.4to -8.5) with a 95%LOA of -39.4 to -21.9 and a mean derivative bias of -6.7%. Agreement of Hb for the paired samples correlated with the CLIA88 criteria in 15.7% and 58% at ZRY and QY hospitals, respectively; hence interchangeability of the two testing systems is not recommended. [13]

In Turkey, Avci et al. compared Hb Hct and electrolyte samples assessed by a venous BGA analyser and the lab autoanalyser in haemodialysis patients. Two hundred thirteen paired samples were eligible for the retrospective study that established a high correlation between Na+, K+, Cl-, Hct and Hb, with K having the highest correlation coefficient of 0.821 while that of Hb was 0.738 between the two analyser methods. The mean Hb levels were 10.8 (4.7-17.4)

for the CLA and 10.7 (2.2- 22.3) for the BGA. The study concluded that bedside BGA was useful for rapid decision-making and interventions in haemodialysis patients. [33]

Similarly, Koraci et al. conducted a study that prospectively evaluated Na+, K+, Cl-, Hb and Hct values of 100 paired venous samples as tested by the ABG analyser versus the CLA in Turkey. From the results, the mean lab Hb value was 12.22+/-2.44 vs the BGA 12.36+/-3.17. All the parameters had a significant statistical correlation with p= <0.001. For Hb, the average difference between the two methods was -0.14g/dL, r=0.751 at 95%CI, concluding that there was a significant positive correlation between the two methods for all the variables assessed[34].

In another study in Turkey, the Kecioren Hospital emergency department by Corbacioglu et al. compared ABG Hb, Hct, K+ and Na+ to those assessed by the lab autoanalyser for paired samples from 1,374 patients and found a strong correlation for K+, moderate to high for Hb and Hct and poor correlation for sodium. P=0.001 in all parameters, whereas r=0.83, 0.79, 0.78 and 0.46 for K+, Hb, Hct and sodium, respectively. The mean difference for Hb in the two samples was -0.5 +/- 1.6 hence poor agreement between the two testing methods. It was, however, noted that pH levels did not affect levels of any of the parameters field[15]

At Birat Medical and Teaching College in Nepal, Arjyal et al. conducted a study over two months that compared Hb and electrolytes (Na+, K+, CL-) levels for 124 paired samples collected within one hour of each as assessed by the ABG-A vs the AHA. The mean Hb levels were 10.47+/-2.64 and 10.31+/-2.72 as measured by the ABG -A vs the AHA, respectively. The mean difference for Hb was 0.16g/dl, which was inconsistent with the USCLIA ranges, whereas that for Na+, K+, and CL- was 0.57,0.04 and 1.17, which were all within their acceptable range USCLIA ranges. The results show that the 2 study systems were interchangeable for electrolytes but not Hb.[9]

A correlational study comparing arterial vs venous Hb levels in Saudi Arabia by Enezi et al. established that of the 123 paired samples from acute care settings, there was a positive, strong correlation r= 0.774 between the ABG Hb and the venous AHA levels with a p-value of 0.01.[35]

In Africa, a study conducted at the University of Stellenbosch, South Africa, by Johnson et al. comparing Hb values measured by POC testers vs the standard lab testing for 58 cardiac patients assessed the accuracy of 3 POC devices (2 blood gas analysers, both brand Ilex GEM premier 3500 named BG-A and BG-B and the Hemocue) against the AHA standard. The mean Hb was 11.02g/dl, 10.23g/dl, 10.21g/dl and 10.35g/dl for the CLA, Hemocue, BG-A and BG-B, respectively. The Hb assessed by all the POC were statistically significantly lower (p=0.0001), where they underestimated Hb by 0.79 (7.2%), 0.81(7.4%) and 0.67(6.0%) for the

BG-A, BG-B and the Hemocue respectively. For the two BGA analysers, the mean difference was +/-1g/dl (0.7+/- 1g/dl) with a 95% CI whereas that of the Hemocue was <1g/dl (0.7+/- 0.5g/dl). The study concluded that the POCT methods were not interchangeable with the AHA, but of the three POCDs, the Hemocue was the most accurate. [14]

There is a paucity of data from Africa and more so from Kenya. There is only one similar study in Africa conducted in South Africa.

2.3 Study Justification

The KNH ICU protocol field[36] provides for daily ABG testing among critically ill patients. The KNH Main ICU is equipped with an ABG lab and laboratory technicians who collect the ABG samples every morning for adult patients and promptly on request by the clinician. However, it has become commonplace for clinicians to order a CBC to confirm Hb levels when ABG-A Hb levels are abnormal before making a clinical decision.

The KNH CBC sampling involves the clinician drawing the sample into the purple ethylenediaminetetraacetic acid (EDTA) vacutainer and informing the day's nursing team leader, who requests the porter on duty to take the collected samples to the Renal Unit Lab. The CBC results are often obtained the following day by the records officer, but this can be expedited in urgent cases. This practice tends to delay the medical interventions that may contribute adversely to the patient's prognosis.

This study aimed to establish how closely the ABG-A Hb levels compare with the AHA ones and determine whether they were interchangeable to avoid duplication of tests and put clinicians in a confident position to make prompt interventional and diagnostic decisions once they have the ABG-A results. This was intended to minimise multiple testing and prolonged hospital stay due to delays in the care process.

Multiple blood draws in the ICU contribute to the prevalence of anaemia among critically ill patients and up to 1/3rd of ICU blood transfusions. [3 5–37] The agreement between the two methods was also intended to reduce blood draws in the ICU for confirmatory testing and, in a small way, minimise anaemia in already susceptible patients by their primary illness. [40]

This study was also expected to bridge the knowledge gap on this matter, as there is only one similar study in Africa and none in Kenya.

2.4 Research Problem

Can clinical management decisions on haemoglobin at KNH Main ICU be made using ABGs, or must clinicians wait for a correlation to be made using AHA values?

2.5 Research Question

How do the haemoglobin values compare between samples analysed using the arterial blood gas analyser versus the automated haemoglobin analyser for critically ill patients at the Kenyatta National Hospital?

2.6 Study Objectives

2.6.1 Broad Objective

To compare the haemoglobin values measured by the arterial blood gas analyser (BGA-A) versus the automated haemoglobin autoanalyser (AHA) at the Kenyatta Main ICU.

2.4.2 Specific Objectives

a) To evaluate how the arterial blood gas haemoglobin levels compared to the automated haemoglobin analyser values at the KNH Main ICU.

3.0 CHAPTER THREE: STUDY METHODOLOGY

3.1 Study Design

This was a cross-sectional method-comparison study. Paired blood samples were drawn from patients admitted to the KNH Main ICU per the KNH ICU protocol or upon request by a clinician. The ABG-A assessed these samples against the standard test, AHA. The accuracy of the POCT method was determined by its ability to measure the Hb level close to its actual measurement value as determined by the AHA.

3.3 Study Area

The study was conducted at the Kenyatta National Hospital Main ICU on critically ill patients admitted to the unit. KNH consists of 6 critical care units, namely the Main ICU, Medical ICU, Paediatric ICU, Paediatric surgical ICU, Obstetrics and gynaecology ICU, Neurosurgical ICU, Cardiothoracic ICU and the Private wing CCU. The Main ICU is the largest, with a 21-bed capacity that mainly operates as a surgical ICU. It also admits any other critical patients from the other essential care units when their capacity is exhausted. The Main ICU is the only ICU with an incorporated ABG analysis lab offering services to all the other CCUs and the hospital. Haematological samples from the Main ICU are all taken to the Renal Unit Lab and assessed by the same AHA machine. Samples collected from all the other CCUs are analysed at the central haematology lab, which utilises three different AHAs.

3.4 Study Population

The study population consisted of critically ill adult patients over 18 years of age admitted at the central critical care unit at the Kenyatta National Hospital, comprising both surgical and medical patients.

3.5 Eligibility

All critically ill adult patients are admitted to the KNH Main ICU.

3.5.1 Inclusion Criteria

- Patients above 18 years admitted to the KNH Main ICU.
- Patients who consented to be included in the study or who's next of kin consented on their behalf.
- Samples were obtained as part of the ICU protocol for routine labs or as ordered by the physician when needed. This was done to minimise unnecessary blood draws.

3.5.2 Exclusion Criteria

- Patients with primary haematological disorders, e.g., polycythaemia vera, haemophilia, hereditary spherocytosis, sickle and aplastic cell anaemia etc., because some of them may have cell structural abnormalities that would result in errors in the validity of the AHA results.
- Pregnant patients because their Hb levels vary throughout the pregnancy due to a disproportionate increase in plasma volume vs the RBC mass and may not reflect the mean Hb level for female patients admitted to the ICU.
- Paediatric patients because there are strict restrictions to allowable blood draw volume per 24 hours, which varies significantly for every age group to about 1-5% of the total blood volume, which may not be easy to standardise or obtain adequate sample size for every age group to be able to draw meaningful conclusions from it. [41]

3.6 Sample Size Determination and Formula

Sample size calculation was done using the Altman Nomogram formula [42]

$$n = \left[\frac{2}{d^2} \right] \text{ x Cp, power}$$

n= Desired sample size

d= Standardized difference = $\frac{\text{mean difference}}{\text{SD}}$

Cp, power= constant defined by values chosen for the p-value and power

Substitution:

- Assumed p-value of 0.05
- Assumed power of 0.9, i.e., 90%
- Required difference of 7% (total allowable error for Hb)[16]
- Mean Hb difference and SD from a previous study done at Hospital European Marseille, France, by Allardet compared POC vs central lab Hb in 314 paired samples from 51 patients and found the mean Hb difference to be 0.29g/dl while the SD was ± 1.6.[28]
- The calculated standardised difference c = 0.40
- Cp, power – (with a p-value of 0.05 and power of 90%) = 10.5
- Therefore, n= 131 samples

From the above calculations, a convenient sample size of 131 paired samples was targeted for this study.

3.7 Sampling Technique

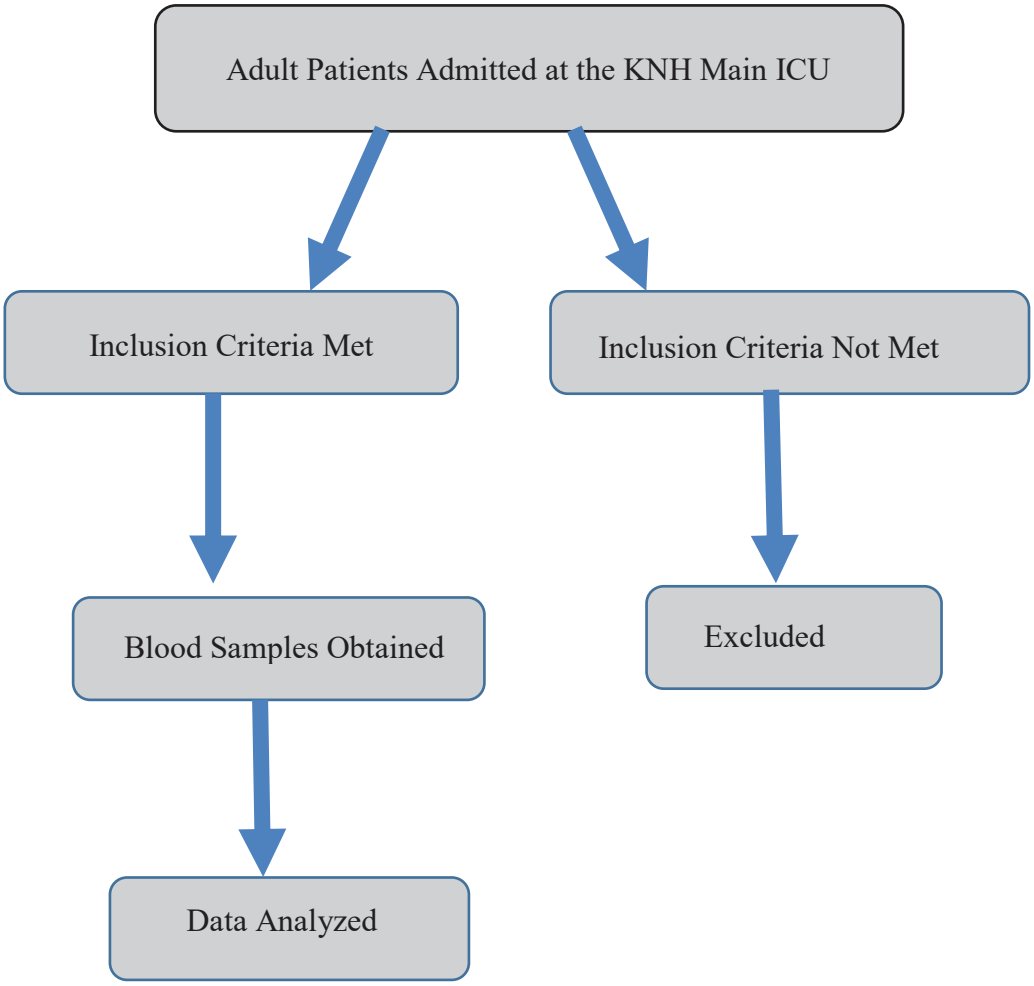
Sampling was done by consecutive/enumerative sampling method. Patients admitted at the KNH Main ICU provided the sampling frame, and consecutive sampling was made until the desired sample size was achieved. To minimise unnecessary blood draws, sampling was scheduled to coincide with the routine sampling schedule per the KNH ICU protocol [36], which provides for bi-weekly ABG and CBC sampling for all critically ill patients at admission into the unit. Samples were also included in the study if ordered by the clinicians on duty outside of the routine protocol when there were specific indications. A patient was to be sampled multiple times on different days only if the requests were made by the clinician as provided for by the KNH ICU protocol guidelines mentioned above to a maximum of four times over a period of two weeks with a maximum limit of two times every week.

3.8 Study Variables

3.8.1 Dependent Variables

The primary outcome was the Hb concentration measured by the ABG-A and the AHA

3.9 Study Flow Chart



3.10 Research Tools

Data obtained from the printed lab results were entered into an online observation tool and uploaded onto an Excel spreadsheet. The data were stored in a hard drive and backed up on iCloud in a password-protected computer only accessible to the research assistant and the principal investigator.

3.11 Blood Sampling Procedure

The paired blood samples were collected by qualified laboratory technicians licensed to perform the procedure. They were trained on the sample collection procedure according to this study's blood sample collection training manual. A blood sample of about 4mls was collected using a regular syringe by direct puncture of an artery, namely the radial artery, after performing a modified Allen test, brachial or femoral arteries. The blood sample was then

divided into two portions, 2mls was instilled into a heparinised syringe and the other 2mls into the EDTA vacutainer. The blood sample was also collected from an indwelling arterial catheter following a discard sample.

The heparinised syringes were prepared per the International Federation of Clinical Chemistry (IFCC) recommendations. A small amount of heparin (0.5 mL of 5000 µ/mL heparin) is drawn into a 2ml syringe to line the inner walls of the syringe and then squirted out completely. The arterial blood drawn was instilled into the withdrawn heparinised syringe to about 2mls, capped and all the air expelled immediately. The syringe was rotated in the palms to mix with the heparin and assessed immediately or stored on slurry ice if not immediately evaluated.

The remaining 2mls was instilled into the EDTA vacutainer with the lavender cap, after which it was transported to the Renal Unit Lab at room temperature for the haemoglobin assessment by the AHA. [43]

The ABG samples were analysed by the machine model ABL 800 FLEX blood gas analyser-Radiometer at the Main ICU side lab.The AHA samples were analysed by the Sysmex XN-350 machine, which uses the fluorescent flow cytometry technology focusing on the cyanide-free SLS method of Hb determination located in the Renal Unit Lab.The KNH ICU/HDU protocol requires that the patients be sampled for a CBC and an ABG at admission and that every patient gets a daily morning ABG test and a routine twice weekly CBC. [36] Multiple sampling on the same patient was only done when the physician ordered the two tests simultaneously or per the KNH ICU/HDU protocol. [28,30]The sample size was the number of paired samples drawn.

3.12 Data Collection

The haemoglobin level of each sample collected by the sampling procedure described was obtained from printed laboratory results generated automatically or manually from the BGA-A and the AHA machines. The principal investigator and the research assistant used an electronic data entry form to collect data on the haemoglobin levels and patient demographics, which included a unique identifier, age, sex and admission diagnosis for patients included in the study. This data included the time and date of sample collection and when the results were obtained.

3.13 Quality Control and Assurance

The heparin syringes were prepared per the International Federation of Clinical Chemistry (IFCC) recommendations. A small amount of heparin (0.5 mL of 5000 µ/mL heparin) was

drawn into a 2ml syringe to line the inner walls of the syringe and then squirted out completely. The ABG sample was analysed immediately or stored on ice if not assessed immediately. [44]

The target was to collect 20 times the dead space volume of blood. The average dead space volume is usually 0.08–0.25ml depending on the syringe and needle size if the 1-10ml syringe is used, respectively. Underfilling the syringe would result in erroneous results due to dilution and chemical errors, with a fall in pCO_2 and bicarbonate concentration. Since the heparin is acidic, using concentrated heparin may result in an increase in pCO_2 and a reduction in pH. [44]

The syringes, needles and heparin were stored in the Main ICU lab, accessible only to the laboratory technicians collecting the samples.

The principal investigator or laboratory technicians prepared the heparin syringes in advance and stored them in the ICU laboratory fridge at 8°C.

The ABG analyser in the ICU side lab uses standard reagents supplied by the manufacturer. It auto-calibrates at four and 8hrs or sooner if the sensor detects the need, like obstructing clots. The reagents utilised were standardised and supplied by the manufacturer. The manufacturer trained the laboratory technicians stationed there on routine machine maintenance and how to troubleshoot minor challenges. The manufacturer also serviced the machine every two weeks or on demand. The KNH Renal Unit AHA is under scheduled preventive maintenance and calibration by the manufacturer. It was conducted every six months or whenever it malfunctioned, and the laboratory technicians needed help troubleshooting the source of the error. The laboratory technicians stationed in the unit conducted daily control checks and changed the reagents.

3.14 Data Management

Data were cleaned before entry into the Microsoft Excel Spreadsheet 2017. Continuous variables were tested for normality using the Shapiro-Wilk test; and summarised into means, median, standard deviation and interquartile ranges. Paired samples T-test was used to compare means of parametric variables while paired samples Wilcoxon test was used to compare means of non-parametric continuous variables. Categorical variables were presented in tables or percentages. The Chi-square test of independence was used to establish an association between categorical variables. Bias and limits of the agreement were established using the Bland-Altman plots. Correlation and comparison between Hb values from ABG-A and AHA were made using the Pearson correlation, where an r-value of ≥ 0.8 was considered a significant correlation. Statistical tests were considered significant, where $p<0.05$.

3.15 Ethical Considerations

Ethical approval was obtained from the KNH-UoN Ethics and Research Committee before conducting the study. This study was conducted in compliance with KNH-UoN guidelines. The study did not harm the patients as the samples collected were part of the routine standard of care. Samples were collected by qualified medical personnel, and only one vascular puncture was done to obtain both models to minimise patient discomfort.

Written informed consent was obtained from the patient or the patient's next of kin if the patient couldn't consent. The consent forms were availed in both English and Kiswahili. Enrolment in the study was voluntary, with an option to opt out or opt-in at any point during the study timeframe without penalties or incentives. There was no financial remuneration to the participants, nor did they incur any extra costs.

Serial numbers were used for patient identification to maintain anonymity. Samples were collected in adherence to the current Covid-19 protocols. Data obtained was stored safely in a password-protected computer and only accessible to the research assistant and principal investigator.

3.16 Study Timeline/Time Frame

The study was conducted over two months.

3.17 Dissemination and Utilisation of Results

The study findings were disseminated through; a presentation to members of the Department of Anaesthesia (UON/KNH), presentation at conferences organised by the Kenya Society of Anaesthesiologists (KSA), reports sent to UON/KNH ERC as well as the Board of Postgraduate Studies (UON) and via publication to provide credible global accessibility.

4.0 CHAPTER FOUR: RESULTS

4.1 Patient Descriptive Characteristics

A total of 132 paired samples were obtained from 73 study participants. Table 4.1 shows the summary of the patient demographic characteristics. The majority of these critically ill patients were male. The patients were aged between 18- 77years, with a mean age of 43.4. The mean (SD) sample analysis time for ABGA Hb was 17.84(27.18) minutes, while that of ABGA Hb was 20.76(28.72).

Table 4.1:Patient characteristics summary

Variable	Category/Description	Number of Patients	Percentage
Sex	Male	44	60.27%
	Female	29	39.73%

4.2 Analysis of AHA Hb and ABGA Hb

The mean (SD) sample analysis time for ABGA Hb was 17.84(27.18) minutes, while that of ABGA Hb was 20.76(28.72) hours.

4.2.1 Normality Tests for Hb

The Hb level ranged from 5.4 to 17.9 g/d for the ABGA and 5.2 to 17.4g/dL for the AHA. The normality tests using the Shapiro-Wilk tests showed that the Hb analysis using ABGA and AHA were normally distributed since their P-values were 0.781 and 0.184, respectively, which were greater than the statistical significance level of 0.05. [Table 4.2].

Table 4.2:Normality tests for Hb

Variable	Number of Observations	W	V	Z	P-Value
ABGA Hb	132	0.99	0.71	0.78	0.781
HA Hb	132	0.99	1.49	0.90	0.184

4.2.2 Paired Sample-t-tests

The paired sample t-tests and correlation analysis were used to show the differences in means of ABGA Hb and AHA Hb, the strength of the relationship between the two measurements, and the significance of the differences in their means. The mean (SD) for the ABGA Hb and AHA Hb was 11.35(2.41) and 10.88(2.20), respectively. The paired sample t-test showed that the mean difference between the ABGA Hb and AHA Hb was 0.47 with a p-value =0.000 (P-value <0.05). This was a statistically significant mean difference between the two methods. [Table 4.3].

Table 4.3:Paired sample-t-test results

Variable	Number of Observations	Mean	Standard deviation	95%CI
ABGA Hb	132	11.35	2.41	(10.93-11.76)
AHA Hb	132	10.88	2.20	(10.50-11.25)
Difference	0	0.47	1.34	(0.24-0 .70)
mean(diff) = mean (ABGA Hb -AHA Hb)	t = 4.0674			
HO: mean(diff) = 0	degrees of freedom = 132			
HA: mean(diff) < 0				
HA: mean(diff) != 0	HA: mean(diff) > 0			
Pr(T < t) = 1.0000				
Pr(T > t) = 0.0001	**Pr(T > t) = 0.0000**			

4.2.3 The correlation Analysis of ABGA Hb and AHA Hb

The correlation analysis revealed a correlation coefficient (r) of 0.83, with a p-value of 0.0000. This means that the ABGAHb and AHAHb had a strong correlation. Despite the strong association between the two measurements, the mean differences were statistically different. Bland-Altman's methodology was done to establish the level of agreement between the two methods.

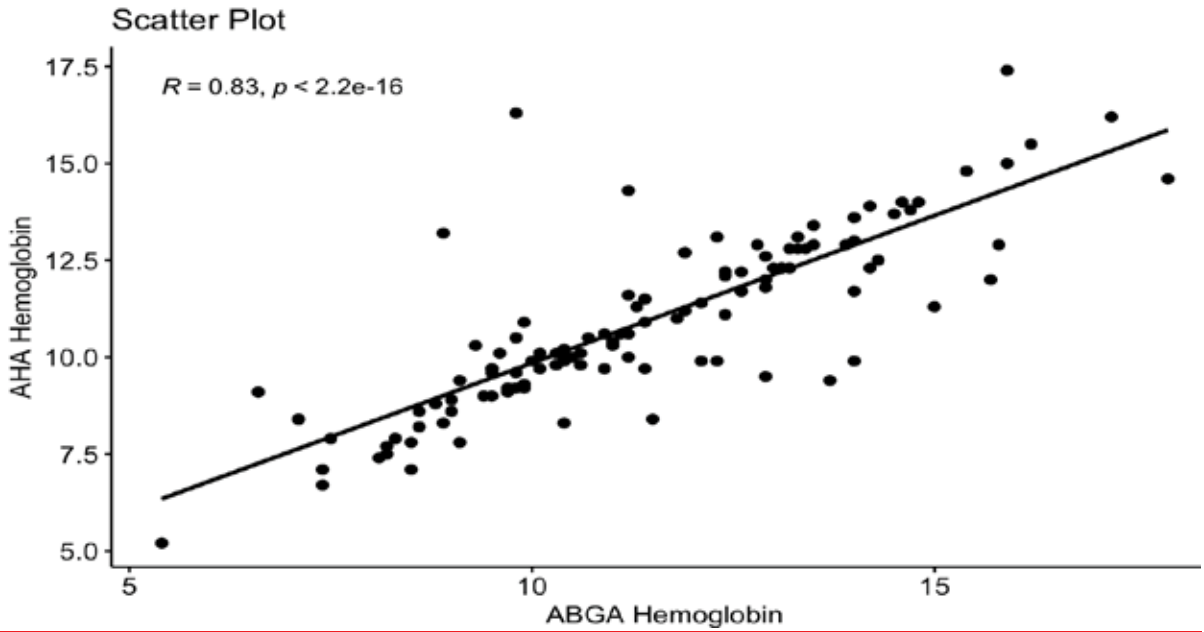


Figure 4.1:Scatter plot showing the association between AHA Hb and ABGA Hb

The scatter plot indicates the significant association between the measurements of AHA Hb and ABGA Hb.

4.2.4 Bland Altman analysis of ABGA Hb and AHA Hb

The Bland-Altman Analysis showed minor differences between Hb while using ABGA and AHA. This was expressed within the 95% (+/- 1.96 SD) confidence interval limits of agreement.

Table 4.4:Bland-Altman analysis summary

MEASUREMENT	ESTIMATE
Standard Deviation	1.33
Mean Bias	0.47
sLower 95% LOA	-2.14
Upper 95% LOA	3.09
Total Allowable Error (TEa)	7%
Proportion Beyond TEa (%)	0

As observed in Table 4.4, Haemoglobin had a mean bias of 0.47. The differences between ABGA Hb and AHA Hb were within the 95% limits of agreement (LOA)between -2.14 to 3.09. According to Ricos et al., the absolute total allowable error (TEa) for Hb is +/-7%. In this study, none of the measurements among critically ill patients was beyond the total allowable error for haemoglobin.

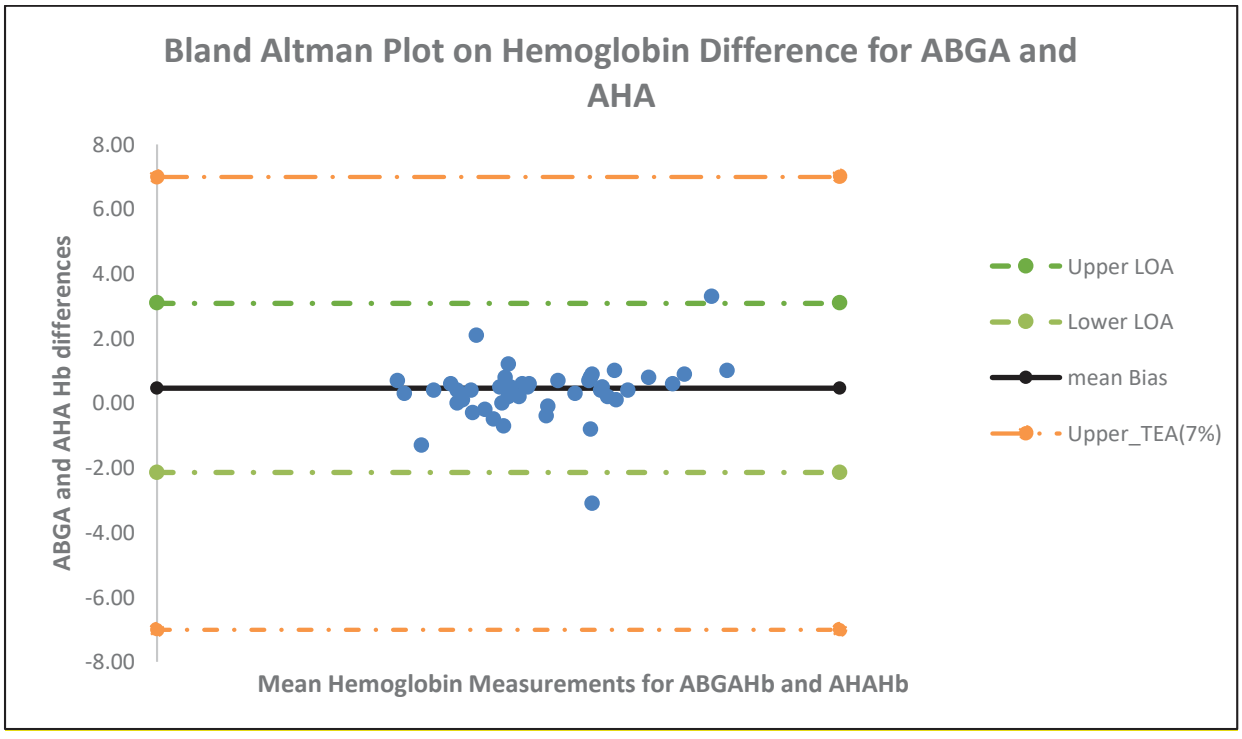


Figure 4.2:The Bland- Altman Plot for Hb difference Between ABGA and AHA

Figure 4.2 shows that all the measurements were within the set total allowable error margins.

5.0 CHAPTER FIVE: DISCUSSION AND CONCLUSION

5.1 Discussion

Patients at the KNH Main ICU undergo daily ABG analysis. Still, their haemoglobin level often needs to be correlated with AHA results before clinical decisions can be made, resulting in unnecessary delays in clinical interventions and increasing hospitalisation costs. This study investigated the differences in Hb measurements when using the arterial blood gas analyser versus the automated haemoglobin analyser among critically ill patients. The paired sample t-test revealed a statistically significant mean difference between the Hb measurements using ABGA and AHA,_implying that the two methods were not interchangeable. The mean difference is a measure of the same point in the distribution; hence further analysis was deemed necessary.

In contrast, the correlation analysis showed a strong association between the measurements in the two groups, contradicting the initial findings from the paired sample t-test analysis. For the Bland -Altman plot, the wide confidence interval of 95% used to calculate the limits of agreement ascertained that the sample mean was included. Most of the data points fell within the limits of agreement, and the mean bias was close to zero. This indicated a strong level of agreement between the two methods. The total allowable error for Hb measurements fell within the USCLIA acceptable error margins for Hb, which showed a similarity in the use of the two options without changing the clinical outcomes of the patients. Therefore, the key finding was that both ABGA and AHA could be used interchangeably since the measurements for Hb were not statistically different while using the two methods, and the measures were within the total allowable error threshold.

The outcome of this study is similar to a study conducted in Australia, where there were no statistical differences in Hb while using ABGA and AHA, which was also confirmed by the bland Altman plots showing that the values fell within the normal ranges. [12] The authors concluded that using one or the other method was cost-saving rather than doing Hb concurrently by the two methods. [12] A study by Ray et al. in Toronto revealed a strong significant positive correlation between the two methods, suggesting that using ABGA as an alternative to Hb assessment would be cost-saving. [30] Another study conducted in China also showed no statistically significant differences for Hb compared to USCLIA cut-offs indicating that the two methods were equally acceptable. [32]

In contrast, several studies showed that the two methods were not interchangeable such as the study by Gibbons et al. in Greece that showed that Hb results were beyond USCLIA limits. [8]

A study conducted by Johnson et al. in South Africa compared two different ABGAs and the HemoCue to the AHA with similar gender distribution to our research (more males than females). It, however, differed from our study in that findings of the two ABGAs did not concur with the AHA - HemoCue measurements were more accurate than the ABGAs. These methods were, therefore, not interchangeable for Hb. [14]

Our study showed that the ABGA and AHA were interchangeable in measuring Hb in critically ill patients. There were notable similarities and differences in comparisons with other studies. The differences may be due to the diversified nature of the research settings. For the measurements done at KNH Main ICU we found no significant differences in the measurement of the two methods. Therefore, it is justifiable to use either of the two methods to make clinical decisions. This would facilitate timely medical interventions and save on the overall cost of hospitalisation.

5.2 Conclusion

There was a strong association and level of agreement between haemoglobin levels measured by the two methods, with the total allowable error falling within the United States Clinical Laboratory Improvement standards margins of +/-7%. Therefore, the two methods were interchangeable at the KNH Main ICU.

5.3 Study Limitations

- The results are specific to the ABG and AHA platform in use at KNH and may not be generalisable to all other BGA and AHA machines.
- AHA results are subject to adherence to lab quality control measures.

5.3 Study Strengths

- It was a prospective study, thus more precise, ridding challenges of missing data commonly seen in retrospective studies.
- Single prick sampling will eliminate potential errors resulting from interventions that could occur between collecting the two samples.

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APPENDICES

Appendix I (a): Consent Information (English)

Background

I am **Dr Simaton Munke**, a postgraduate student pursuing a Master of Medicine in Anaesthesia at the University of Nairobi. I will be conducting a study comparing haemoglobin levels measured by the arterial blood gas analyser versus the automated haemoglobin in critically ill patients. I would like you to participate in my study.

Purpose

This study aims to assess the interchangeability of the arterial blood gas analyser and the automated haemoglobin analyser when measuring haemoglobin levels in critically ill patients.

Participation

Participation is voluntary, and you may withdraw from this study at any point if desired. You will not be victimised for declining to consent to the research or withdrawing consent to participate. You will not incur additional expenses for participating in the study, and there will be no financial compensation for participating in the study. If you agree to participate, a blood sample of about 4mls will be drawn from an artery on your arm or upper thigh and evaluated by two different types of machines in this hospital.

Risks

Participation in this study will not compromise patient safety.

Benefits

This study will help to minimise delays occasioned by waiting for confirmatory tests, reduce duplication of tests and ultimately save on hospital costs for critically ill patients.

Confidentiality

Participants' identifiers will not be included in any document, and all collected data will be kept confidential.

If you have any questions, you can contact:

Principal Investigator:

Dr Simaton Munke
P.O.BOX 47360 -00100, Nairobi
Tel. 0724634650

Supervisors:

Dr Julius Muriithi
P.O. BOX 19676- 00202, Nairobi
Tel. 0722850375

Dr Timothy Muriithi Mwiti
P.O.BOX 19676- 00202, Nairobi
Tel. 0721366294

Dr. Idris Chikophe
P.O.BOX 3356 -20100, Nairobi
Tel. 0721436926

Or

The Secretary,
KNH/ UON- Ethics and Research Committee
P.O.BOX 20723-00202, Nairobi
Tel. 020 2726300 Ext 44355

Appendix I (b): Consent Form (English)

I……..……. consent/consent on behalf of …… to participate in the study above, having understood the information regarding the study. My questions and concerns have been addressed, and my participation is voluntary. I have the right to withdraw from the study without fear of victimisation or compromise of the care given to my patient**.**

Signature of participant …….……. Date…….

Signature of the next of kin …… Date ……

I confirm that I have explained the research details to the participant/ their next of kin.

Signature of Investigator ……. Date …….

Appendix II (a): Consent Information (Kiswahili)

Idhini ya Kushiriki Katika Utafiti

Jina langu ni Daktari Simaton Munke, ninafanya utafiti wa shahada ya juu katika Anaesthesia katika Chuo Kikuu cha Nairobi. Ninafanya utafiti unaolinganisha kipimo cha damu cha himoglobini kikichambuliwa kwa mashine ya kuchambua gesi kwa damu ya kimbari na kipimo cha himoglobini kwa mashine ambalo limesanikishwa kupima himoglobini miongoni mwa wale wagonjwa sana. Ningependa ushiriki katika utafiti wangu.

Nia

Utafiti huu utachunguza kiasi ambacho kiwango cha himoglobini kinalingana kinapopimwa kwa mashine aina hizi mbili hivyo basi kuokoa muda kabla ya mgonjwa kupata matibabu. Hii itapunguza sababu ya kufanya vipimo viwili vinavyolingana na mwishowe kupunguza garama ya hospitalini kwa mgonjwa.

Ushiriki

Ushiriki katika utafiti huu ni wa hiari, na unaweza kujiondoa kwenye utafiti wakati wowote. Hautabaguliwa kwa kukataa kushiriki katika utafiti huu. Hakuta kuwa na malipo wala hautapata gharama za ziada kwa kushiriki katika utafiti huu. Ukikubali kushiriki katitika utafiti huu damu kiasi cha mililita nne itatolewa kwa mshipa wako ulioko mkononi au kwenye paja na kupimwa kutumia aina mbili ya mashine hapa hospitalini.

Hatari

Kushiriki katika utafiti huu hautadhuru usalama wa mgonjwa.

Faida

Utafiti huu utasaidia itapunguza sababu ya kufanya vipimo hivi viwili vinavyolingana kwa wakati mmoja, hivyo, kuokoa muda kabla ya mgonjwa kutibiwa na kupunguza garama ya hospitalini kwa mgonjwa.

Usiri

Vitambulisho vya mshiriki havitajumuishwa kwenye hati, na habari zote zilizokusanywa zitahifadhiwa kwa siri.

Ikiwa una maswali yoyote unaweza kuwasiliana na:

Mtafiti Mkuu:

Dkt. Simaton Munke
Sanduku la posta 47360 - 00100, Nairobi
Nambari ya simu 0724634650

Wasimamizi:

Dkt. Julius Muriithi
Sanduku la posta 19676- 00202, Nairobi
Nambari ya simu. 0722850375

Dkt. Timothy Muriithi Mwiti
Sanduku la posta 19676 – 00202, Nairobi
Nambari ya simu 0721366294

Dkt. Idris Chikophe
Sanduku la posta 3356 -20100, Nairobi
Nambari ya simu 0721436926

Au

Katibu,
KNH/UON – Kamati ya Maadili na Utafiti
Sanduku la posta 20723 – 00202, Nairobi
Nambari ya simu 020 2726300 ext 44355

Appendix II (b): Consent Form (Kiswahili)

Fomu Ya Idhini

Mimi…….. ninakubali/ Ninakubali kwa niaba ya ……. …… kushiriki katika utafiti huu, na nimeelewa habari kuhusu uchunguzi huu. Maswali yangu kuhusu utafiti huu yameshughulikiwa na ushiriki wangu ni wa hiari. Nina haki ya kujiondoa kwenye utafiti huu bila hofu ya kubaguliwa au kuadhiriwa kwa matibabu yatakayopewa kwa mgonjwa wangu.

Sahihi ya mshiriki……. Tarehe…….

Sahihi ya jamaa wa karibu ……. Tarehe …….

Ninathibitisha ya kwamba nimemfahamisha mshiriki maelezo ya utafiti huu

Sahihi ya mtafiti…… Tarehe……..

Appendix III: Electronic Data Entry Form

No.	Unique identifier	Age	Sex	Admission Diagnosis	Sample Collection Date &Time	Results Date &Time ABGA	Results Hb Level ABGA	Results Date &Time AHA	Results Date &Time AHA

Appendix IV: A Training Manual for Blood Sampling

TRAINING MANUAL FOR BLOOD SAMPLING

Location: Date: Time:

Technician: Staff ID number:

A. Equipment: Record form, gloves, heparin, needles,5cc and 2cc syringes, alcohol swabs, dry swabs, gauze,
strapping, marker, gauze, and ice bath.

B. Procedure; steps:

1. Prepare the heparin syringes in advance just before going to the bedside by aspirating 0.5mls of 5000 μ/mL
heparin into a 2ml syringe to line the inner walls of the syringe, then squirted out completely
2. Confirm patient identification, consent then label the syringes and vacutainer
3. Explain the procedure to the patient or next of kin if present
4. While in gloves, identify the radial artery pulsation, perform the modified Allen test (elevate the arm, clench the
Fist, for one minute, apply pressure over the radial and ulna arteries; while still elevated, unclench the fists rapidly
and release the ulnar artery- the pink colour should be restored on both sides of the hand in 8-10sec for a positive
test-safe to proceed with radial artery)
5. Feel for the pulsation in preference of the radial than the brachial or femoral arteries
6. Swab the area with the pulsation using an alcohol swab
7. With the needle mounted on the 5cc syringe, advance the needle into the area of pulsation at 45 degrees while
aspirating until bright red blood is seen. Hold the syringe steadily.
8. If the continuous stream stops, adjust the needle by moving it slightly in or out to draw 4mls of blood, then
withdraw the needle and apply pressure using a dry cotton swab and strapping.
9. Push 2mls immediately through the needle into a pre-prepared withdrawn heparinised syringe, cap it and rotate it
between the palms to mix the heparin.
10. Push the other 2mls into an EDTA vacutainer (purple top vacutainer), cap it and turn it upside down severally to
mix EDTA with blood.
11. Note the time and date of sample collection
12. If not able to assess the BGA sample (in the heparinised syringe) immediately, put it in the ice bath
13. Send the EDTA vacutainer samples to the Renal Unit Lab through the Main ICU team leader who facilitates it.
14. Run the BGA samples promptly in the BGA side lab within the main ICU and put the printouts of the results

Appendix V: Supplementary Table for detailed Bland Altman analysis

ABGA Hb	AHA Hb	Difference (AHA Hb- ABGA Hb)	Mean Measurements
10.90	9.70	1.20	10.3
13.10	12.30	0.80	12.7
10.10	10.10	0.00	10.1
10.60	10.10	0.50	10.35
9.10	9.40	-0.30	9.25
13.10	12.30	0.80	12.7
9.60	10.10	-0.50	9.85
9.80	10.50	-0.70	10.15
11.20	14.30	-3.10	12.75
17.90	14.60	3.30	16.25
12.10	11.40	0.70	11.75
11.20	11.60	-0.40	11.4
9.00	8.90	0.10	8.95
10.40	8.30	2.10	9.35
13.20	12.80	0.40	13
11.20	10.60	0.60	10.9
13.00	12.30	0.70	12.65
11.00	10.40	0.60	10.7
10.30	9.80	0.50	10.05
15.90	15.00	0.90	15.45
8.90	8.30	0.60	8.6
12.40	12.10	0.30	12.25
10.70	10.50	0.20	10.6
12.30	13.10	-0.80	12.7
13.30	13.10	0.20	13.2
17.20	16.20	1.00	16.7
13.30	12.80	0.50	13.05
14.80	14.00	0.80	14.4
13.90	12.90	1.00	13.4
15.40	14.80	0.60	15.1
9.00	8.60	0.40	8.8
11.10	10.60	0.50	10.85
7.40	7.10	0.30	7.25
9.40	9.00	0.40	9.2
13.20	12.30	0.90	12.75
7.40	6.70	0.70	7.05
10.40	9.90	0.50	10.15
14.00	13.60	0.40	13.8
10.40	10.20	0.20	10.3
11.40	11.50	-0.10	11.45
9.50	9.70	-0.20	9.6
7.10	8.40	-1.30	7.75
10.60	9.80	0.80	10.2
13.50	13.40	0.10	13.45
8.80	8.80	0.00	8.8
8.30	7.90	0.40	8.1
8.60	8.60	0.00	8.6
9.90	9.30	0.60	9.6
15.00	11.30	3.70	13.15
15.70	12.00	3.70	13.85
12.30	9.90	2.40	11.1
12.40	11.10	1.30	11.75
12.90	9.50	3.40	11.2
11.40	9.70	1.70	10.55

10.00	9.90	0.10	9.95
14.00	11.70	2.30	12.85
9.10	7.80	1.30	8.45
15.80	12.90	2.90	14.35
10.40	10.00	0.40	10.2
14.00	9.90	4.10	11.95
11.30	11.30	0.00	11.3
11.50	8.40	3.10	9.95
13.50	12.90	0.60	13.2
12.10	9.90	2.20	11
8.50	7.80	0.70	8.15
14.70	13.80	0.90	14.25
12.90	12.00	0.90	12.45
15.90	17.40	-1.50	16.65
15.40	14.80	0.60	15.1
5.40	5.20	0.20	5.3
12.80	12.90	-0.10	12.85
8.50	7.10	1.40	7.8
12.60	11.70	0.90	12.15
16.20	15.50	0.70	15.85
14.60	14.00	0.60	14.3
9.70	9.20	0.50	9.45
10.30	9.80	0.50	10.05
12.40	12.20	0.20	12.3
10.30	9.80	0.50	10.05
11.90	11.20	0.70	11.55
9.90	9.20	0.70	9.55
10.40	9.90	0.50	10.15
9.70	9.10	0.60	9.4
10.30	10.10	0.20	10.2
7.50	7.90	-0.40	7.7
9.30	10.30	-1.00	9.8
8.60	8.20	0.40	8.4
11.80	11.00	0.80	11.4
11.90	12.70	-0.80	12.3
6.60	9.10	-2.50	7.85
12.40	12.20	0.20	12.3
8.90	13.20	-4.30	11.05
9.80	9.60	0.20	9.7
14.20	13.90	0.30	14.05
11.20	10.00	1.20	10.6
12.60	11.70	0.90	12.15
14.20	12.30	1.90	13.25
10.90	10.60	0.30	10.75
12.60	12.20	0.40	12.4
8.10	7.40	0.70	7.75
12.40	12.20	0.20	12.3
6.60	9.10	-2.50	7.85
11.90	12.70	-0.80	12.3
14.00	13.00	1.00	13.5
12.90	11.80	1.10	12.35
10.50	10.00	0.50	10.25
10.40	9.90	0.50	10.15
14.00	13.60	0.40	13.8
10.40	10.20	0.20	10.3
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14.30	12.50	1.80	13.4
11.90	12.70	-0.80	12.3
11.40	10.90	0.50	11.15
12.90	12.60	0.30	12.75
9.50	9.60	-0.10	9.55
8.20	7.50	0.70	7.85
9.80	9.20	0.60	9.5
13.70	9.40	4.30	11.55
11.90	11.20	0.70	11.55
9.90	10.90	-1.00	10.4
10.10	9.70	0.40	9.9
14.50	13.70	0.80	14.1
9.50	9.00	0.50	9.25
9.80	16.30	-6.50	13.05
13.40	12.80	0.60	13.1
8.20	7.70	0.50	7.95
11.00	10.30	0.70	10.65

Appendix VI: KNH/UoN-Letter of Approval

UNIVERSITY OF NAIROBI
FACULTY OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
Tel:(254-020) 2726300 Ext 44355

KNH-UON ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/69

16th February, 2023

Dr. Simaton Munke
Reg. No. H58/34266/2019
Dept. of Anaesthesia
Faculty of Health Sciences
University of Nairobi

KENYATTA NATIONAL HOSPITAL APPROVED 16 FEB 2023

Dear Dr. Munke,

RESEARCH PROPOSAL: HAEMOGLOBIN LEVELS MEASURED BY THE ARTERIAL BLOOD GAS ANALYZER VERSUS THE AUTOMATED HAEMOGLOBIN ANALYZER IN CRITICALLY ILL PATIENTS (P815/10/2022)

This is to inform you that KNH-UoN ERC has reviewed and approved your above research proposal. Your application approval number is **P815/10/2022.** The approval period is 16th February 2023 – 15th February 2024.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by KNH-UoN ERC.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to KNH-UoN ERC 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH-UoN ERC within 72 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to KNH-UoN ERC.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

DR. BEATRICE K.M. AMUGUNE
SECRETARY, KNH-UoN ERC

c.c. The Dean, Faculty of Health Sciences, UoN
The Senior Director, CS, KNH
The Assistant Director, Health Information Dept., KNH
The Chairperson, KNH- UoN ERC
The Chair, Dept. of Anaesthesia, UoN
Supervisors: Dr. Julius Mogo Muriithi, Dept. of Anaesthesia, UoN
Dr. Timothy Muriithi Mwiti, Dept. of Anaesthesia, UoN
Dr. Idris Nzao Chikophe, Consultant Anaesthesiologist and Critical Care Specialist, KNH

Appendix VIII: Certificate of Plagiarism

Haemoglobin Levels Measured By The Arterial Blood Gas Analyzer Versus The Automated Haemoglobin Analyzer In Critically Ill Patients

ORIGINALITY REPORT

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