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EVALUATION OF INVASIVE AND NON-INVASIVE (POINT OF CARE TESTING DEVICES) FOR HAEMOGLOBIN IN COMPARISION WITH HAEMOTOLOGY ANALYZER

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Abstract

BACKGROUND : Anaemia is a major public health problem worldwide. Recent findings of NFHS-5 indicate an increasing trend in the overall prevalence of anaemia detected by Haemoglobin (Hb) meters at the community level. There is scepticism about the use of Point of Care Testing (POCT) devices to accurately measure the Hb level in community settings. The sensitivity and specificity of the Hb meters have to be evaluated properly before being used for the community level screening of anaemia.

OBJECTIVE : This study aims to evaluate the Sensitivity, Specificity and bias/Limits of Agreement (LOA) of the commercially available Hb meters / POCT devices, by comparing the results with Haematology Analyzer.

METHODS : A total of 416 blood samples were collected in a community setting at Kelampakkam Block, Chengelpet District and referred to State Public Health Laboratory (SPHL) for the analysis of haemoglobin. A total of 9 Hb meters were tested which included 3 non-invasive and 6 invasive devices. The Non-invasive devices were evaluated on the site of sample collection and the invasive devices were tested in SPHL and the results compared and analyzed with haematology analyser.

RESULTS : All the 9 Hb Meters failed to meet the Government of India's criteria for its sensitivity, specificity and bias/LOA, suggesting the use of Haematology Analyzer to accurately measure the Hb level.

CONCLUSION : Haematology analyser would be the method of choice for the accurate measurement of Hb in both institution and at community level screening of anaemia through an effective hub and spoke model of sample referral from community setting.

KEYWORDS : Anaemia, Haemoglobin, Hb meters

INTRODUCTION

Anaemia is a global public health problem that primarily affects young children, adolescent girls, menstruating women, pregnant and postpartum women. World Health Organisation (WHO) projects that 40% of children, 37% of pregnant women, and 30% of women are anaemic worldwide. Anaemia is characterised by reduced haemoglobin levels compared to normal.[1] A number of conditions can lead to anaemia, including poor diets, inadequate nutrient absorption, infections (such as malaria, parasitic infections, TB, HIV), inflammation, chronic illnesses, gynaecological and obstetric conditions, and hereditary red blood cell disorders. Iron deficiency is the most frequent nutritional cause of anaemia, whereas folate, vitamins B12, and A, and deficits in iron are other significant contributors.[1]

The majority of anaemia cases occur in low and lower-middle-income nations, mostly impacting populations in rural areas and lower-class households.[3] The Government of India's Ministry of Health and Family Welfare introduced the Anaemia Mukt Bharat (AMB) policy in April 2018 in an effort to address the high prevalence of anaemia in the nation.[4]

AMB has set a goal to reduce the anaemia burden by 3% per year between 2018 and 2022. Standard medical testing facilities are frequently scarce and inaccessible to the majority of patients, despite the fact that anaemia is most common in underdeveloped countries.[5] The National Family Health Survey (NFHS) has detected a substantial rise in anaemia from NFHS-4 to NFHS-5. The NFHS-6 has excluded the measurement of anaemia as the testing methods using the Hb meters are faulty.[6] Appropriate anaemia care depends on an accurate and timely diagnosis of anaemia.

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WHO recommends the Haematology Analyzers to accurately measure the Hb value and diagnose anaemia.[7,8,14,15] However, the haematology analyzers are expensive, sensitive and sophisticated equipment which cannot be taken to the field conditions and also requires a consistent supply of reagents.

In recent years, the point of care testing devices (POCT) has been used extensively for the detection of Hb value due to its portability, capillary blood, affordability, ease of use, and ability to provide immediate, digitally displayed results without the need for refrigeration or even electricity.[9-11]

One of the interventions carried out by the AMB is the use of POCTs for haemoglobin estimation and anaemia treatment.[4] These POCTs should be affordable, sensitive, specific, user-friendly, rapid and robust and deliverable.[12,13]

Government of India recommends the commercially available Hb meters to have more than 80% sensitivity and specificity and a bias of ±0.5g/dL.

There are different types of digital Hb meters available for estimating haemoglobin levels, but POCTs with inadequate diagnostic precision or difficult procedures can result in inaccurate haemoglobin level estimation and ultimately in incorrect anaemia management, which can have an impact on the patient and the healthcare system.[14]

Thus, it is imperative to verify the sensitivity, specificity, and accuracy of the Hb meters. Our study focuses on the evaluation of non-invasive and invasive digital hemogolobinometer in a community level field setting with adolescents, adults, and pregnant women.

OBJECTIVES

To evaluate the performance of commercially available Hb Meters (POCT devices) both Invasive and Non-invasive Type for Hb estimation and also to find out the Sensitivity and Specificity of Hb Meters/POCT Devices at field conditions by comparing the results with Hematology Analyzers as Gold Standard.

METHODOLOGY

STUDY POPULATION : A community based cross sectional study was conducted at Govt.Primary Health Centre, Kelampakkam, Chengalpattu District in which adolescent boys, girls, men, women and antenatal mothers were included in the study. Individuals with severely ill conditions (MI, Stroke etc.,) were excluded from the study. Informed written consent was obtained from the individuals.

ETHICAL APPROVAL : The study protocol was approved by the Institutional Ethics Committee of the Directorate of Public Health and Preventive Medicine (DPH&PM), Teynampet, Chennai (IEC No.DPHPM/IEC/2023/166 dated 26.08.2023)

DESCRIPTION OF THE HB METER DEVICES : DPH&PM has requested the Tamil Nadu Medical Services Corporation Limited (TNMSC) to provide the commercially available Hb meters along with consumables for this community-based evaluation study. All the 14 prospective bidders were communicated in which 9 vendors have submitted their Hb meters along with consumables for this study. As per the Non-Disclosure Agreement (NDA), the brand name of the Hb meters are not disclosed in this publication. A total of 3 Non-invasive and 6 Invasive Hb meters were included in this study and the product details are summarized in Table.1.

Table 1 : Description of the Hb Meter Devices

S.No	Device Code	Hb Meter Type	Principle
1	Hb-1	Non-Invasive	Spectrophotometry
2	Hb-2	Non-Invasive	Spectrophotometry
3	Hb-3	Non-Invasive	Spectrophotometry
4	Hb-4	Invasive-Cuvette	Photometry
5	Hb-5	Invasive-Cuvette	Photometry
6	Hb-6	Invasive-Strip	Reflectance Photometry
7	Hb-7	Invasive-Strip	Reflectance Photometry
8	Hb-8	Invasive-Strip	Reflectance Photometry
9	Hb-9	Invasive-Strip	Reflectance Photometry

HEAMOTOLOGY ANALYZER : Sysmex XP 100, an automated blood cell counter was used for the accurate measurement of Hb with quality control validation using Sysmex EightcheckTM – 3WP reference material. This value was communicated to the study participants as their Hb level.

DATA COLLECTION : Study subjects registered using a standard case sheet and necessary written consent was obtained followed by measurement of haemoglobin using 3 Non-Invasive Hb Meters. 5 ml of venous blood sample was collected in K2 EDTA Tubes from the study subjects and transported to State Public Health Laboratory (SPHL) for further analysis. EDTA samples were subjected to CBC using Sysmex X-100 Haematology Analyser to accurately measure the Hb value. Same EDTA samples were also subjected to measure Hb values using the 6 invasive Hb meters (4 strip based and 2 cuvette-based method). Hb Results were compared with the results of Haematology Analyser. Sensitivity, specificity, bias and limits of agreement were calculated by statistical methods.

RESULTS

A total of 9 Hb meters (POCT Devices) were subjected to

Hb evaluation in 416 subjects and the results were compared with the Haematology Analyzer. The prevalence of anaemia among the study participants was 44.4%. The criteria for performance evaluation were based on the Govt.of India recommendations on sensitivity, specificity, bias and limits of agreement. The results are summarized below in Table-2 & Fig-1.

Table 2 : Validity and Level of agreement of various Hb Meter Devices

Name of the Device	Principle of the Device	Sensitivity (>80%)	Specificity (>80%)	Bias (± 0.5 g/dL)	95% CI of LOA (± 1 g/dL)
Hb-1	Non-Invasive	66	67	-0.055	-2.532,2.422
Hb-2	Non-Invasive	50	57	-0.063	-5.192,5.067
Hb-3	Non-Invasive	47	73	-0.430	-4.601,3.740
Hb-4	Invasive-Cuvette	76	100	-0.398	-1.012, 0.276
Hb-5	Invasive-Cuvette	47	100	-1.052	-1.693, -0.411
Hb-6	Invasive-Strip	44	98	-1.170	-2.454,0.114
Hb-7	Invasive-Strip	96	58	0.804	-0.473,2.081
Hb-8	Invasive-Strip	95	36	0.581	-1.368,2.531
Hb-9	Invasive-Strip	96	21	2.975	-0.271,6.223

All the 9 commercially available Hb Meters evaluated for Hb measurement have failed to meet the Govt. of India requirements of achieving more than 80% sensitivity and specificity thus failing to accurately detect true anaemic and non-anaemic cases in the community.

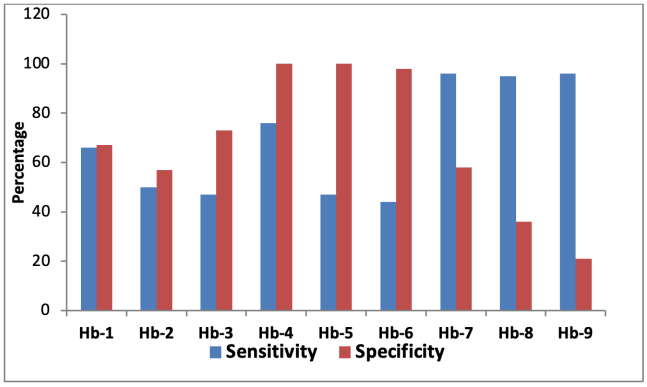

Figure 1 : Validity and Level of agreement of various Hb Meter Devices

DISCUSSION

Nine point-of-care devices—both invasive and non-invasive—have been examined in this study. The data from the present study shows that none of the Hb meter devices meets the Govt.of India's qualifying criteria for POCT, which are >80% sensitivity, >80% specificity, and 0.5% bias. The NFHS-6 has excluded the measurement of anemia stating that the ways to measure anemia is faulty. The problem with the NFHS estimation was that it used capillary samples or blood drawn from a finger prick and then measured using the Hb meters whose results could vary by almost a gram/dL of blood. [6, 20] The present study at the community level also indicated the use of inappropriate Hb meters is the cause of the faulty measurements.

Challenges with Non-Invasive Hb meters include the inability to measure Hb accurately in cases where nails are dirty, deformed, or painted. It was challenging to measure when elderly people's palms were creased and when children's fingers were too little to fit into the sensor. While using invasive hemoglobin meters, misleading results can arise from the presence of air bubbles in the microcuvette/ strip or from inadequate blood flow that prevents the microcuvettes/strip from filling entirely.[19] Although anaemia is still a concern in developing nations like India, the first line of defense against anaemia management is the use of accurate haemoglobin testing equipment. It is quite challenging to rule out the disease when there is an issue with the first step which is the measurement of blood Hb. The number of actual cases and the disease's prevalence cannot be determined until appropriate haemoglobin readings are obtained.

WHO recommends Hematology Analyzer/Cell Counters as the gold standard to accurately estimate the levels of haemoglobin in blood. In comparison to POCT devices, cell counters offer more precision and accuracy in testing. In order to ensure the accuracy of the data, cell counters frequently include integrated quality control and validation procedures.

We also recommend a solution to accurately screen anemia in the community setting using Haematolgy Analyzers by an effective Hub and Spoke model of sample referral as visualized in Fig.2.

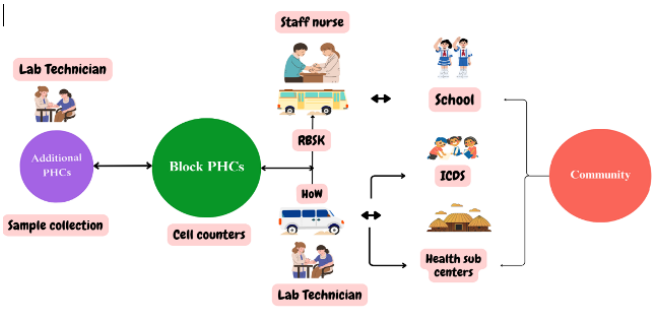

Figure 2 : Hub and Spoke model of sample referral

Haematology analyzers are available in 811 Primary Health Care Institutions in Tamil Nadu and there are qualified Laboratory Technicians in place to handle the analyzers. Integrated Essential Laboratory Services (IELS) being rolled out in Tamil Nadu provides the coverage of all the 2127 PHCs, so that EDTA Blood Samples can be collected from an Additional PHC(Spoke) and refer to the Block PHC(Hub) through an effective and efficient sample referral mechanism supported by LIMS.

Rashtriya Bal Swasthya Karyakram (RBSK) team[15] and Mobile Medical Units (MMU)[17] available in each Block

could be effectively used to cover the schools, ICDS centres and Health sub centres (HSCs) to screen the children and adults, collect blood at the community level and transport it to the Block PHC where Cell Counters are already available. Currently Adolescent Anaemia Program in Tamil Nadu has successfully adopted the same model using cell counters for the accurate measurement of Hb. Most importantly, the cost of the Cell Counter reagent fixed by TNMSC Ltd is Rs 9/ Test only which is valid up to 2027 which is comparatively at a low cost and also yielding 18 other blood parameters including cell counts and vital inflammatory status.[18]

CONCLUSION

There are several POCT devices commercially available for the estimation of Hb in blood, but the data on their validity in terms of sensitivity and specificity while testing in field conditions are limited. There is no comprehensive study undertaken on the commercially available Invasive and Non-Invasive Hb meters in the community settings to assess their usefulness for the accurate measurement of Hb. The current study suggests that the commercially available Hb Meters/ POCT devices used for Hb estimation are not reliable in terms of sensitivity and specificity as per the requirements of Govt.of India. The study also recommends the use of Hematology Analyzers for the accurate estimation of Hb by implementation of an effective Hub and Spoke sample referral which is being adopted now for the adolescent anemia screening program successfully implemented by the Directorate of Public Health and Preventive Medicine in Tamil Nadu.

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