Primary health screening by haemoglobinometry in a tropical community

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The usefulness of a recently developed portable haemoglobinometer in primary health care was assessed in a survey of anaemia carried out in an isolated Indian community living in the jungles of northern Peru. This haemoglobinometer requires only one drop of blood to be added to a disposable cuvette without predilution; other advantages and limitations of the method are described. A high incidence of anaemia was found in men, women and children. Although intestinal parasite infections, including hookworm, were prevalent, there was no direct relationship with the anaemia. These observations indicated the need for a more extensive epidemiological study to identify the aetiological factors. Considering the importance of reliable haemoglobin measurements for providing baseline data, the study demonstrated the value of this portable, simple-to-operate haemoglobinometer for use in geographically remote areas with little or no laboratory facilities. An important advantage was that locally recruited workers were able to measure the haemoglobin easily and correctly after a brief training session.

Introduction

Measurement of haemoglobin is essential for population health surveys and epidemiological studies as well as for clinical diagnosis and management of individual patients with anaemia. These measurements are required at every level from research institutes and routine clinical laboratories to field tests in primary health care centres. Methods range from the highly accurate spectrophotometric reference method, as prescribed by the International Committee for Standardization in Haematology (ICSH) (6), to inaccurate and imprecise procedures such as the Sahli and Dacie haemoglobinometers (3, 12), and even the obsolete and totally unreliable Tållqvist blotting-paper test which is still used in some places.

WHO has recognized the need for a reliable method “to measure haemoglobin in small laboratories with limited resources such as health centres and village laboratories where there is frequently a lack of electricity and the laboratory worker is at an assistant level rather than a skilled technician”.2 In this context, “reliable” includes both accuracy and precision. Consequently, several methods have been proposed, including use of a sturdy colorimeter with a light-emitting diode (10, 11). A serious limitation of these methods has been the loss of precision when blood samples are diluted by unskilled people and, conversely, inaccuracy due to turbidity of the samples when measured in instruments which do not require dilution of the blood.

To overcome these disadvantages an alternative method has been developed in which the haemoglobin is converted to methaemoglobin azide, without dilution, in a capillary cuvette and then measured photometrically at 565 nm. This method has been incorporated in an instrument which is available commercially as the HemoCue.* The

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photometer is powered by a rechargeable 12 V battery or by mains electricity using a transformer. The disposable microcuvette is a sandwich of two thin perspex wafers containing a deposit of dry reagent. This reagent, which consists of sodium desoxycholate, sodium nitrite and sodium azide, converts the haemoglobin to metahaemoglobin azide (13). The blood sample (one drop of capillary or venous blood) is drawn by capillary action into the cuvette where the reaction results in disintegration of the red cell membranes and conversion of haemoglobin to metahaemoglobin azide. The photometer is precalibrated by means of a blood sample, the Hb of which has been measured by the ICSH method (6) with the international haemoglobin (haemoglobin cyanide) standard, and its calibration is checked before use by means of a cuvette fitted with a red filter.

Evaluation of the HemoCue in expert laboratories has demonstrated good comparability with measurements by filter photometer (7, 14). Our own evaluation of Hb readings was undertaken in the Reference Laboratory of the WHO Collaborating Centre for Quality Assessment in Haematology, in accordance with ICSH guidelines (7), with the following results:

(a) Precision: coefficient of variation, 1.2%.
(b) Linearity: linear in the range 0–170 g/l (Fig. 1).
(c) Comparability with the ICSH reference method: in range to 200 g/l, intercept 10.8, slope 0.875, r = 0.996; in range to 170 g/l, intercept 1.6, slope 0.985, r = 0.998.
(d) Paired t-test on 31 samples in the range to 170 g/l: \( \bar{x} = 0.2581, SD = 2.34, t = 0.615, P > 0.5 \).

It was concluded that the HemoCue is a reliable (i.e., accurate and precise) instrument for haemoglobinometry in expert hands in laboratories for blood samples in the anaemia range. Its usefulness was also demonstrated at the primary health care level of general practice in the United Kingdom where there was easy referral of patients to a nearby teaching hospital (9), especially for screening non-anemic persons and identifying patients who require extensive laboratory-based investigation.

The present study was undertaken to evaluate the instrument's performance in a tropical, primary health care situation with limited resources, and to assess the role of haemoglobinometry, especially the level of training and technical skills required to obtain reliable results, in a health programme directed to an indigenous rural population.

Study area and methods

The Aguaruna and Huambisa Indians live in the jungles of northern Peru, in communities on the banks of four rivers that flow into the Maranon river. The area has always been isolated because of impassable rapids, mountains and dense jungle, the main transport routes being the rivers. Telephone and mail communications are non-existent for most of the population. Medical and laboratory supplies are transported by bus, truck and boat—a four-day journey from Lima.

Since 1983, haemoglobinometry has been included in the laboratory services provided by the health programme of the Aguaruna and Huambisa Indian Council. But although there were laboratories near each of the five rivers, access was difficult and they were hardly ever used. In addition, the services were provided only “on demand” by the patients, which was in accord with the curative approach to medicine. In May 1987 the Council’s Health Committee therefore started a mobile laboratory service to the communities, based on the use of portable laboratory kits which included two HemoCue battery-operated haemoglobinometers. These mobile laboratories work on four levels: drinking-water monitoring, patient diagnosis, health education and survey work.

The performance of the HemoCue was tested and its value as part of the equipment of a mobile laboratory was assessed. The occurrences of anaemia and of intestinal parasitic infestations were surveyed to see what prevention and community treatment measures are needed. Families were randomly selected, an average of 25 people being tested in each of 17 communities. When the haemoglobin values were very low, the result was confirmed with a repeat test. All tests were done on fingerprick blood.

It is emphasized that this investigation was not intended to be an epidemiological study of the cause of anaemia, the prevalence of which was used as a model for assessing the use of the HemoCue in primitive conditions for determining the extent of anaemia in the population.

Use of the HemoCue

The study was carried out over a period of one year. The locally recruited staff had no previous experience in laboratory technology and were initially trained in the use of the HemoCue by one of the authors (WLJ). After the brief training session they became competent and performed satisfactorily in a trial batch of blood samples, as checked by parallel measurements on the same specimens by the supervisor. Subsequently, these workers carried out the tests on all the patients referred by the local community.
health care workers and on the population in the screening programme of the mobile laboratories.

**Ease and reliability of performance.** The HemoCue was very easy to operate and, for this reason, was popular compared with a traditional photoelectric colorimeter which requires dilution of the blood samples. Display of results in less than 60 seconds was another advantage.

Quality control consisted of duplicate tests which showed good agreement, and on each occasion checks were made with the standard which gave constant readings. It was important, however, to make sure that there were no visible air bubbles inside the microcuvettes, as this occasionally led to discrepant results. The operators were trained to be aware of this problem which is not adequately emphasized in the instruction manual.

**Environmental effects.** The high humidity caused electronic devices such as calculators, alarm clocks, conductivity meters and temperature gauges to fail. However, at no time during the course of the study did the functioning of the HemoCue fail.

In one machine the nickel-cadmium batteries failed to recharge when the transformer was plugged into a DC 220 V generator. Although the batteries were in good condition the two connecting wires had rusted through at the point of attachment to the battery clip. This was easily mended.

**Mechanical reliability.** The HemoCue, which was used during the survey work carried out on 331 people in 13 communities, has a robust plastic casing which was easily kept clean. The cuvettes were stored in their sealed containers. When a container was opened the cuvettes did not deteriorate for the four hours which were spent in each community, as shown by replicate measurements on control samples during this time period.

**Usefulness in an epidemiological study.** A major advantage of the HemoCue is the ease of transport for field studies, the results of which become available where they are needed—in the communities. In our surveys of anaemia and intestinal parasite infestations in the population, the HemoCue was found to be fast and convenient and an ideal method for community diagnostic work. A major advantage was that pipettes, test tubes and reagent solutions were not needed.

The HemoCue is provided with a permanently stable glass standard which was used with each batch of samples. This gave no fluctuations in the readings, thus ensuring that the instrument remained correctly calibrated in accordance with the ICSH haemoglobin-cyanide reference standard. Accordingly, data obtained in the field could be accepted as being of the same level of reliability as that obtained in laboratory-based studies in the haemoglobin range in which there was linearity of response (Fig. 1 and 2).

There are a few aspects where the problems met with in rural areas in developing countries require further consideration. The HemoCue nickel-cadmium batteries need recharging, thus requiring access to a portable generator; if the latter should be out of order or there is no petrol for it, the batteries cannot
be recharged. This problem was overcome by using a 9-watt solar panel to recharge the batteries. An external battery pack is also now available with a set of 8 ordinary type R20 batteries with which the haemoglobinometer can function for 300 hours.

Results and discussion.

The results are summarized in Table 1. Over half (55%) of the population was found to be anaemic; the incidence and severity was highest in children below the age of 6 years, 88% of them having a mean haemoglobin which was >4 SD below the normal median for western Europe (2) and lower than the WHO criteria for diagnosis of anaemia (15). In the 6-14-year age group, 50% of the subjects were affected (mean Hb, >3 SD below the normal median), whilst in adults (men and women) the anaemia was milder (mean level, 2-3 SD below the normal median) and also less frequent (incidence, 35-40%).

There was a high incidence of intestinal parasitic infections, including hookworms affecting 29% of the population (Table 2), which were not significantly related to the anaemia (Tables 3 and 4). A limitation of the study from an etiological viewpoint is lack of data on the parasite load in individual cases.

The haemoglobin values were lower than those obtained for similar ages and sex in surveys in several other tropical countries, and this was especially marked in the under-five-year-old group. Results were, however, similar to those found in one study of children in Papua New Guinea (5).

Anaemia in tropical countries is generally due to interaction of genetic blood disease, nutritional status, parasite infections, and chronic systemic infections. In these multifactorial situations it is not easy to identify the main cause of anaemia. In the present study there was no significant difference in haemoglobin levels between subjects with and without intestinal parasitic infections. Hookworm infection did not appear to be responsible for any greater intensity of anaemia; this was a surprising finding, which contrasts with observations made previously (4, 8). Although the present study did not include a formal

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Table 1: Incidence of anaemia by age group and sex

<table>
<thead>
<tr>
<th>Age group</th>
<th>&lt;1–5 years</th>
<th>6–14 years</th>
<th>&gt;15 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Hb (g/l)</td>
<td>Lower normal reference limit*</td>
<td>No. with anaemia</td>
</tr>
<tr>
<td>No. tested</td>
<td>93</td>
<td>96</td>
<td>115</td>
</tr>
<tr>
<td>Mean Hb (g/l)</td>
<td>79</td>
<td>105</td>
<td>107</td>
</tr>
<tr>
<td>Lower normal reference limit*</td>
<td>67</td>
<td>122</td>
<td>117</td>
</tr>
<tr>
<td>No. with anaemia</td>
<td>82</td>
<td>(88.2)%</td>
<td>(50.6)</td>
</tr>
<tr>
<td>(88.2)%</td>
<td>23</td>
<td>36</td>
<td>182</td>
</tr>
<tr>
<td>(50.6)</td>
<td>(34.3)</td>
<td>(39.1)</td>
<td>(55.0)</td>
</tr>
</tbody>
</table>

* At 3 SD according to Dacie & Lewis (2). The equivalent WHO criteria for diagnosis of anaemia in these four groups are Hb levels below 110, 120, 130 and 120 g/l, respectively (15).

Table 2: Incidence of intestinal parasites

<table>
<thead>
<tr>
<th>Hookworm (Necator americanus)</th>
<th>Ascaris</th>
<th>Trichuris trichiura</th>
<th>Entamoeba histolytica</th>
<th>Oxysoma</th>
<th>Strongyloides</th>
<th>Non-pathogenic*</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>97 (29.3)%</td>
<td>83 (25.1)</td>
<td>42 (12.7)</td>
<td>26 (7.8)</td>
<td>5 (1.5)</td>
<td>2 (0.6)</td>
<td>10 (3.0)</td>
<td>157 (47.4)</td>
</tr>
</tbody>
</table>

* Figures in parentheses are percentages.

A further investigation of nutritional status, the standard of nutrition was generally poor; in one community 15% of under-one-year-old children were malnourished, as determined by lower than normal weight-height percentiles. In another community 10% of the 1–5-year-old children were considered to be malnourished by midarm circumference measurement. It would, however, be necessary to carry out more objective epidemiological anthropometry and a collaborative laboratory and clinical study to characterize the cause of anaemia. What this present study has shown is the value of haemoglobinometry for establishing the need for such a study and for providing baseline data. The study indicated the advantages and disadvantages of one commercially available haemoglobinometer for this purpose in a geographically remote area with minimal laboratory facilities.

Convenience and cost

The instrument used (HemoCue) was found to be a convenient and satisfactory method for obtaining

Table 3: Haemoglobin levels in the population studied

<table>
<thead>
<tr>
<th>Age group</th>
<th>Intestinal parasites</th>
<th>No. tested</th>
<th>Mean (g/l)</th>
<th>Median (g/l)</th>
<th>Range of central 50%</th>
<th>F-test*</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1–5 years</td>
<td>Positive</td>
<td>48</td>
<td>96.5 (± 16.6)%</td>
<td>95</td>
<td>87–107</td>
<td>1.54 (ns)</td>
</tr>
<tr>
<td>Negative</td>
<td>45</td>
<td>97.1 (± 13.4)</td>
<td>98</td>
<td>90–105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–14 years</td>
<td>Positive</td>
<td>53</td>
<td>103.6 (± 13.3)</td>
<td>105</td>
<td>94–113</td>
<td>1.05 (ns)</td>
</tr>
<tr>
<td>Negative</td>
<td>26</td>
<td>109.6 (± 13.0)</td>
<td>112</td>
<td>102–116</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;15 years: Males</td>
<td>Positive</td>
<td>31</td>
<td>119.5 (± 21.8)</td>
<td>121</td>
<td>106–139</td>
<td>1.46 (ns)</td>
</tr>
<tr>
<td>Negative</td>
<td>36</td>
<td>125.1 (± 18.1)</td>
<td>126</td>
<td>118–135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>Positive</td>
<td>46</td>
<td>107.3 (± 18.9)</td>
<td>109</td>
<td>99–120</td>
<td>1.45 (ns)</td>
</tr>
<tr>
<td>Negative</td>
<td>44</td>
<td>108.9 (± 15.8)</td>
<td>111</td>
<td>98–120</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* F-tests comparing differences in Hb levels in individuals with and without intestinal parasites; ns = not significant at 99% levels of probability.

| Figures in parentheses are the standard deviations (SD). |

Table 4: Effect of intestinal parasites on mean haemoglobin levels and analysis of these differences by the F-test

<table>
<thead>
<tr>
<th>Age group</th>
<th>Set A (hookworm)</th>
<th>Set B (other parasites)*</th>
<th>Set C (no parasites)</th>
<th>F-test analysis of differences between setsa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Mean Hb (g/l)</td>
<td>No. Mean Hb (g/l)</td>
<td>No. Mean Hb (g/l)</td>
<td>A versus C</td>
</tr>
<tr>
<td>&lt;1–5 years</td>
<td>19 94.9 (±15.2)*</td>
<td>29 96.0 (±16.6)*</td>
<td>45 97.1 (±13.4)*</td>
<td>1.28</td>
</tr>
<tr>
<td>5–14 years</td>
<td>31 99.5 (±14.1)</td>
<td>22 103.6 (±13.3)</td>
<td>26 109.0 (±13.0)</td>
<td>1.18</td>
</tr>
<tr>
<td>&gt;15 years:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>21 118.3 (±22.7)</td>
<td>10 119.5 (±21.8)</td>
<td>36 125.1 (±18.1)</td>
<td>1.57</td>
</tr>
<tr>
<td>Females</td>
<td>26 107.2 (±18.2)</td>
<td>22 107.3 (±18.9)</td>
<td>44 108.9 (±15.6)</td>
<td>1.36</td>
</tr>
</tbody>
</table>

* Excluding cases also affected with hookworm (*Necator*).
* All the results given are not significant at the 95% level of probability.
* Figures in parentheses are the standard deviations (SD).

Reliable measurements of haemoglobin in a primary health care programme. It is simple to use even by unskilled workers and a major advantage is the absence of the need to dilute blood samples. To some extent it provides the requirements set out by WHO for a “solid state battery-powered robust haemoglobinometer, resistant to hot and humid climates”.

Unfortunately it does not meet one other important requirement, that it should be inexpensive. To make such an instrument available to those working in developing countries a more realistic price would be one-tenth of the list price of £300 (US$ 520 at the March 1989 exchange rate).

In many developing countries, since laboratory supplies are extremely difficult to obtain, there would be problems in maintaining an adequate supply of the disposable microcuvettes. The needs of these countries would be better served if laboratories were not dependent on outside consumables. Manufacturers should aim to produce low-cost reusable microcuvettes and to bring the cost of the present disposable microcuvettes down to 1 or 2 p (US$ 0.03) each. Unfortunately, there is no simple solution to this problem at the present time.

Résumé

Contrôle de l’état sanitaire d’une communauté tropicale à l’aide d’un hémoglobinomètre

Il est nécessaire de disposer d’une méthode fiable pour mesurer le taux d’hémoglobine dans de petits laboratoires aux moyens limités ou dans des centres sanitaires et des dispensaires de village dont le personnel ne possède pas de qualifications techniques particulières. Un hémoglobinomètre portatif (HemoCue) répondant à ce besoin a été récemment mis au point. Cet appareil, qui a pour caractéristique originale de ne nécessiter qu’une goutte de sang qui est déposée dans une microcuvette à usage unique, sans dilution préalable, a été testé dans des laboratoires spécialisés et s’est révélé capable de mesurer le taux d’hémoglobine avec exactitude et précision dans la plage de concentrations intéressante pour le diagnostic de l’anémie.

Afin d’évaluer l’intérêt de cet instrument pour les services de soins de santé primaires, une enquête sur l’anémie a été menée dans une communauté d’Indiens vivant dans la jungle du nord du Pérou. Le présent article décrit les avantages et les limites de la méthode sur le terrain. L’instrument est très facile à utiliser et affiche les résultats en moins de 60 secondes. La qualité des mesures a été contrôlée par des essais en double, entre lesquels l’accord a été excellent, et en vérifiant régulièrement la constance des résultats avec un filtre de verre étalon. L’instrument a bien résisté au climat tropical humide.

L’enquête a révélé une forte incidence de l’anémie, que ce soit chez les hommes, chez les femmes ou chez les enfants. Les parasitoses intestinales, notamment l’ankylostomiasis, étaient fréquentes, mais ne semblaient pas avoir un lien direct avec l’anémie. Ces observations font ressortir la nécessité d’une étude épidémiologique plus poussée pour identifier les facteurs étiologiques.

L’étude a surtout démontré la nécessité d’une mesure fiable du taux d’hémoglobine pour établir des données de base et l’intérêt de disposer pour cela d’un hémoglobinomètre portatif au fonctionnement sûr, facile à utiliser dans des régions isolées où les moyens de laboratoire sont quasi inexistants. L’appareil essayé présentait l’avantage important de pouvoir être confié à un personnel recruté localement qui, après une brève période de formation, s’est révélé tout à fait
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capable de s’en servir correctement. L’HemoCue est donc un appareil pratique et fiable pour le dosage de l’hémoglobine dans ces circonstances. Malheureusement, son prix est relativement élevé (€300 ou US$ 520) et il faut pouvoir se procurer des microcuvettes à usage unique, qui coûtent également assez cher. Il s’agit là de deux obstacles sérieux à la généralisation de son emploi. Un prix plus bas et la garantie d’un approvisionnement régulier en microcuvettes en feraient cependant un instrument idéal pour les services de soins de santé primaires, notamment dans les pays en développement.

References
