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HAEMOGLOBIN AND PACKED CELL VOLUME MEASUREMENT : THE RELIABILITY OF SOME SIMPLE TECHNIQUES FOR USE IN SURVEYS OR RURAL HOSPITALS

by

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Summary — Two techniques for haemoglobin concentration measurement (the COMPUR 1000 mini-photometer and the AO Spencer Haemoglobinometer) and two haematocrit measurement techniques (the COMPUR 1100 mini-centrifuge and a manual handpowered microcentrifuge) were tested for intra- and inter-observer variability, accuracy and precision of results. These quality criteria were analysed in different epidemiological situations. Operational characteristics are discussed and compared in the (hypothetical) situations of the epidemiological survey and the laboratory of a rural hospital in a developing country. They are also compared with those of the Lovibond technique, using undiluted blood, a suitable instrument at the first contact level.

KEYWORDS : Haemoglobinometry; Haematocrit; Packed Cell Volume; Rural Hospitals.

Introduction

Simple methods for accurate and reproducible heamoglobin (Hb) measurements for use in a Primary Health Care (PHC) setting are available (Van Lerberghe *et al.*, 1983). The scope of this study is to test a number of techniques, suitable for use in the field, that could provide some extra information at an acceptable cost. This might be useful for research purposes or at referral level in developing countries. The techniques that were tested are two slightly more sophisticated Hb measurement techniques (the Compur 1000 mini photometer and the AO-Spencer Hb-meter) and two haematocrit measurement techniques (the Compur M 1100 minicentrifuge and a manual handpowered microcentrifuge).

Materials and Methods

The Compur 1000 miniphotometer for haemoglobin (manufactured by Compur-Electronic GmbH, Munchen) is a small portable photometer, battery or mains operated, with a direct Hb-scale in g/dl. Standardization is obtained by using precalibrated capillary tubes for the blood and single-use disposable cuvettes that contain the diluent fluid.

The AO Spencer Hb-meter (manufactured by American Optical) is a small portable comparator, battery or mains operated, with direct Hb-scale in g/dl. Undiluted blood is placed on a cell and haemolyzed by stirring it with a disposable saponin-coated stick. The comparator scale is adjusted until its green color matches that of the cell.

The Compur 1100 minicentrifuge for haematocrit (manufactured by Compur-Electronic GmbH, Munchen) is a small portable centrifuge using the micro-haematocrit technique, battery or mains operated. The capillaries are calibrated for length, the centrifugation time is fixed and the Ht can be read directly on a fixed scale.

The manual haematocrit system (manufactured by Ingeniorsfirman Instrumentjanst, Sundbyberg, Sweden) is a flat plastic disc that can be brought to rotate by pulling and releasing strings that are rigged through its centre. Pieces of flexible polyethylene capillary tubing containing the blood are fitted into grooves. The disc can take up till 8 pieces of tubing. The Ht is calculated by simple division of measured length.

Procedures were similar to earlier reproducibility tests (Van Lerberghe et *al.*, 1983), and consisted of measuring, for each technique, intra- and interobserver variability, accuracy and precision for a total of 120 measurements on 30 blood samples with a Haemoglobin content ranging between 50 and 150 g/l.

Sensitivity (or « positiveness in disease ») is defined as the proportion of true positives (TP) among the diseased (true positives + false negatives (FN)) :

$$\frac{TP}{TP + FN}$$

Specificity (or « negativeness in health ») is defined as the proportion of true negatives (TN) among the healthy (true negatives + false positives (FP)) :

$$\frac{TN}{TN + FP}$$

The predictive value of a positive result (PV +) is defined as the proportion of TP among all positive results :

$$\frac{TP}{TP + FP}$$

The predictive value of a negative result (PV −) is defined as the proportion of TN among all negative results :

$$\frac{TN}{TN + FN}$$

Results are *accurate* if they are close to or coincide with the reference values. They are *precise* if they are close to or coincide with other results when using the same method on the same sample, or, in other words, if the method has good reproducibility.

Results

Table 1 shows the equations for the regression of the measurements of these 4 techniques on the reference values. Fig. 1 shows the average expected measurements and the 95 per cent belt for different techniques (+ or − 2 Standard Errors of the Estimate (SEE)). The width of the belt is a measure of precision, and the distance between the average expected measurements and the line of perfect agreement is a measure of accuracy.

TABLE 1

Technical characteristics of techniques with regard to accuracy and precision

Technique	Regression equation $y_{techn} = ax_{ref} + b$ $y_{ref} = ax_{techn} + b$	S.E.E.	(Correl. coeff.) r
Compur 1000 Hb	$Hb_{Compur} = .995\ Hb + 33.855$ $Hb = .997\ Hb_{Compur} - 33.118$	3.575 g/l	.9965
A.O. Spencer Hb	$Hb_{Spencer} = .919\ Hb + 9.719$ $Hb = 1.067\ Hb_{Spencer} - 8.573$	5.54 g/l	.990
Compur M1100 Ht	$Ht_{Compur} = .992\ PCV - .155$ $PCV = 1.000\ Ht_{Compur} + .333$	1.024 %	.9965
Manual Ht	$Ht_{Manual} = 1.19\ PCV + .662$ $PCV = .822\ Ht_{Manual} - 0.13$	2.138 %	.989

The equations permit to calculate the proportions of false positives (FP) and false negatives (FN) in each Hb or haematocrit (= Packed Cell Volume (Ht, PCV) class below or above a given cut-off point (Van Lerberghe *et al.*, 1983). The results are given in table 2, for Hb classes of 5 g/l and (more or less corresponding) Ht classes of 1.5 per cent, and (arbitrary) cut-off points of 90 g/l and 27 per cent respectively.

TABLE 2a

Expected proportions of false positives (above the line) and false negatives (below the line) within each PCV-class when screening for anaemia with a cut-off point of 27 %

PCV %	Compur M1100 Ht	Manual HF
22.5-24	—	.006
24-15.5	.002	.047
25.5-27	.073	.202
27-28.5	.073	.202
28.5-30	.002	.047
30-31.5	—	.006

TABLE 2b

Expected proportions of false positives (above the line) and false negatives (below the line) within each haemoglobin class when screening for anaemia with a cut-off point of 90 g/l

Hb g/l	Compur 1000 Hb	A.O. Spencer Hb	Lovib. Und. Hb
70 - 75	—	—	.002
75 - 80	—	.006	.016
80 - 85	.003	.049	.077
85 - 90	.082	.203	.238
90 - 95	.082	.203	.238
95 - 100	.003	.049	.077
100 - 105	—	.006	.016
105 - 110	—	—	.002

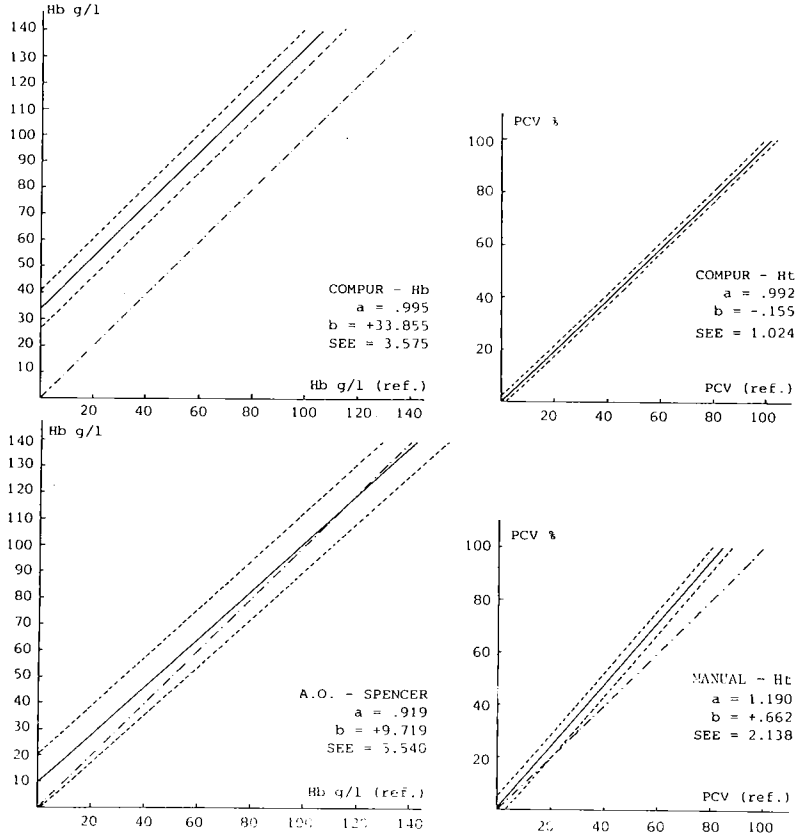

Figure 1.
Regression line (full line) and 95 % confidence belt (broken lines) of all measurements made with each of the techniques described above, on the reference value.
The diagonal (broken-dotted line) is the line of perfect agreement.
The constants a and b refer to the regression equation $y_{techn} = ax + b$ (see also table 1).

These proportions can then be applied to specific epidemiological situations.

Table 3 compares the performance of the two Hb meters in two epidemiological situations : one with high prevalence of low Hb values — pregnant women from an East African country (Cornelis, unpublished data) —, another with low prevalence of low Hb values — adult males from Central America (Viteri & Guzman, 1972). The performance of the Lovibond-undiluted technique in these same circumstances is also included in order to allow comparison with an instrument that is suitable for the first contact level.

TABLE 3

Operational characteristics of Hb measurement techniques

High prevalence of anaemia - cut-off point 90 g/l

Technique	Sensit.	Specif.	Pred. Val. +	Pred. Val. −
Lovibond und.	87.4	91.9	81.2	94.8
Compur Hb	96.6	97.9	94.9	98.7
Spencer Hb	90.0	93.7	85.1	96.0

Low prevalence of anaemia - cut-off point 90 g/l

Technique	Sensit.	Specif.	Pred. Val. +	Pred. Val. −
Lovibond und.	98.1	99.9	92.9	99.9
Compur Hb	99.9	99.9	98.3	99.9
Spencer Hb	98.9	99.9	94.8	99.9

Table 4 shows the performance of a portable battery-powered mini-centrifuge and of a hand-powered microcentrifuge for microhaematocrit measurement in the aforementioned epidemiological situations.

It should be noted that these performances apply only after correction of the observed Hb and Ht values with the help of the regression equations.

TABLE 4

Operational characteristics of Packed Cell Volume measurement techniques

High prevalence of anaemia - cut-off point 27 %

Technique	Sensit.	Specif.	Pred. Val. +	Pred. Val. −
Compur Ht	97.0	98.2	95.5	98.8
Manual Ht	90.1	93.7	85.2	96.0

Low prevalence of anaemia - cut-off point 27 %

Technique	Sensit.	Specif.	Pred. Val. +	Pred. Val. −
Compur Ht	99.9	99.9	98.5	99.9
Manual Ht	98.9	99.9	94.8	99.9

Discussion

There are two types of situation for which these instruments seem to be especially useful : the epidemiological survey and the clinical referral level (e.g. a rural hospital) in developing countries.

Information on the packed cell volume (P.C.V.) is certainly useful at referral level as a complement to Hb measurement. The Compur M 1100 provides information of a quality that is quite comparable to that obtained with standard reference techniques. It has the comparative advantage of also working independently from mains electric power, and of being fairly cheap. Therefore it seems to be a suitable instrument for rural hospitals.

The two techniques for measurement of Hb which were tested, perform slightly better than the Lovibond-undiluted technique. The Compur 1000 Hb performs well, as far as precision is concerned, but makes an important systematic error of (with our instrument) 33 g/l, which could not be corrected by zeroing the gauge in the indicated manner. It is relatively expensive in its use and requires a regular supply of diluting fluid.

The A.O. Spencer Hb-meter is slightly less good, somewhat less expensive, but requires a regular supply of saponin coated sticks. If prevalence of low Hb values is low, there is no relevant difference with the performance of the Lovibond-undiluted techniques.

On the whole, both techniques (Compur 1000 Hb and A.O. Spencer Hb-meter) do not prove to be much superior to the Lovibond-undiluted, which has important operational advantages. They are nevertheless almost certainly superior to the electric photometers that require dilution of blood, with the inevitable and serious measurement errors this entails.

The Compur M 1100 appears to be an adequate instrument for surveys measuring P.C.V. It is portable, independent from mains electric power, fast, accurate and has good reproducibility.

The manual, hand-powered microcentrifuge for measurement of P.C.V. (Mahin *et al.*, 1982) is more easily transported, but somewhat cumbersome and more expensive in its use than the Compur M 1100 Ht, and has slightly inferior performances after correction with the help of the regression equation.

If cost is not a determining constraint, the Compur 1000 Hb-meter is the best instrument, provided the calibration is carefully performed to compensate for the systematic error. However, both the A.O. Spencer Hb-meter and the Lovibond-undiluted will perform suitably well in haemoglobin surveys.

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La mesure du taux d'hémoglobine et de l'hématocrite : la fiabilité de quelques techniques simples pour l'utilisation dans des enquêtes ou des hôpitaux ruraux.

Résumé — Deux techniques de mesure du taux d'hémoglobine (le mini-photomètre COMPUR 1000 et l'hémoglobinomètre A.O. Spencer) et deux techniques de mesure de l'hématocrite (le mini-centrifuge COMPUR 1100 et un appareil à rotation manuelle) ont été étudiées. Leur variabilité inter- et intra-observateur, leur exactitude et leur précision ont été comparées. Ces critères de qualité ont été analysés dans des situations épidémiologiques contrastées.

Une discussion des caractéristiques opérationnelles est fournie, et ces dernières sont comparées dans deux situations (hypothétiques), celle de l'enquête épidémiologique et celle du laboratoire d'un hôpital rural dans un pays en voie de développement. La technique du Lovibond, utilisant du sang non-dilué, et qui est une technique appropriée aux conditions d'utilisation de terrain, et incluse dans la discussion.

Hemoglobine en hematocriet bepaling : de betrouwbaarheid van enkele eenvoudige technieken voor gebruik in een survey of een plattelandshospitaal.

Samenvatting — Twee technieken voor het meten van hemoglobine-concentraties (de COMPUR 1000 mini-fotometer en de AO-Spencer hemoglobinometer) en twee technieken voor het meten van de hematocriet (de COMPUR 1000 mini centrifuge en een manueel aangedreven microcentrifuge-apparaat) werden getest op intra- en inter-waarnemer variabiliteit, akkuraatheid en precisie van de meetresultaten. Deze kwaliteitscriteria werden geanalyseerd in verschillende epidemiologische basis-situaties.

Operationele kenmerken worden besproken en met elkaar vergeleken voor de (hypothetische) situaties van de epidemiologische survey en het klinisch laboratorium van een plattelandshospitaal in ontwikkelingslanden. Zij worden ook vergeleken met de Lovibond-methode met onverdund bloed, een techniek die (ook) in de eerstelijnszorg zeer geschikt is.

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