



Recommendation for standardization of haematology reporting units used in the extended blood count

M. BRERETON*, R. MCCAFFERTY[†], K. MARSDEN[‡], Y. KAWAI^{§,¶}, J. ETZELL^{**}, A. ERMENS^{††} FOR THE INTERNATIONAL COUNCIL FOR STANDARDIZATION IN HAEMATOLOGY

*Central Manchester University
Hospitals NHS Foundation

Trust, Manchester, UK

[†]St James's Hospital, Dublin,
Ireland

[‡]Royal Hobart Hospital, Hobart,
Tas., Australia

[§]International University of
Health & Welfare, Sanno
Affiliate Hospital, Tokyo, Japan

[¶]Japanese Society for Laboratory
Haematology, Tokyo, Japan

^{**}Sutter Health Shared
Laboratory, Livermore, CA, USA

^{††}Amphia hospital, Breda, The
Netherlands

Correspondence:

Richard McCafferty, Haematology
Dept., St James's Hospital,
Dublin, Ireland.

Tel.: +353 1 4162067;

Fax: +353 1 4162920;

E-mails: mccafertryr@eircom.net;

Richard.McCafferty@stjames.ie

doi:10.1111/ijlh.12563

Received 10 December 2015;
accepted for publication 11 July
2016

Keywords

ICSH, recommendation,
standardization, reporting units,
blood count

SUMMARY

Introduction: It is desirable in the interest of patient safety that the reporting of laboratory results should be standardized where no valid reason for diversity exists. This study considers the reporting units used for the extended blood cell count and makes a new ICSH recommendation to encourage standardization worldwide.

Methods: This work is based on a literature review that included the original ICSH recommendations and on data gathered from an international survey of current practice completed by 18 countries worldwide.

Results: The survey results show that significant diversity in the use of reporting units for the blood count exists worldwide. The use of either non-SI or other units not recommended by the ICSH in the early 1980s has persisted despite the guidance from that time.

Conclusion: The diversity in use of reporting units occurs in three areas: the persistence in use of non-SI units for RBC, WBC and platelet counts, the use of three different units for haemoglobin concentration and the manual reporting of WBC differential, reticulocytes and nucleated RBCs when the latter are available from automated analysis or can be expressed as absolute numbers by calculation. A new recommendation with a rationale for each parameter is made for standardization of the reporting units used for the extended blood count.

AIMS OF THIS PAPER

The aim of this study was to consider the opportunities and challenges surrounding the standardization of reporting units used for the complete blood cell count, to review the progress made in this area since the 1982 publications from the ICSH committee and to formulate a new recommendation to encourage standardization worldwide. This work is based on a literature review and on an ICSH survey completed by 13 nations. It also acknowledges work published from the Scandinavian Nordic Reference Interval Project (NORIP), giving data from 18 countries worldwide in total.

INTRODUCTION

Individual patient pathology services may be sought from a variety of laboratories; this may be due to the clinical needs of the patient, the requirement for specific expertise, transport availability, geographical or financial considerations or the movement of the individual. The electronic transfer of information and data is becoming increasingly common and may occur on an international basis [1]. It is therefore essential that laboratories are clear about the services they offer and the format in which the tests' results are presented to users. ISO states that units of measurement and appropriate reference ranges must be reported alongside any result but when users receive data with different units for the same test from different providers, the risk of confusion is raised [2]. Some nations are already moving towards single electronic data resources for patients so that a patient's health record is available to them when they travel. The need for consistency of reporting standards is therefore essential.

The cost of pathology in health care is a major consideration, with mergers and multilaboratory partnerships formed across healthcare services; thus, providers of large-scale pathology require high levels of standardization. Furthermore, the last 10 years have witnessed a blossoming of point-of-care testing (near-patient testing) technology, enabling patients to have routine blood tests in less regulated locations (nonhealthcare environments), some with limited clinical infrastructure or on-site expertise but seeking guidance from laboratory professionals [3–5]. Considering patient safety, it is the duty of the pathologist to remove confusion

over laboratory reporting and eliminate differences where no valid clinical reason for the difference exists. By providing professional guidance to users of our services, we can send a clear clinical message that is transferable between pathology providers.

The blood count (complete blood count CBC/full blood count FBC) is one of the most frequently requested tests in laboratory haematology worldwide. It has evolved from the earliest days of laboratory medicine when methods included cell counts achieved by manual microscopy and haemoglobin estimation by comparison of a solution of the patient's blood to a depth of colour index, through revolutionary automated cell counts using electrical impedance and spectrophotometry in the 1950s, to latest generation analysers using multiple technologies including flow cytometry to produce a full 'extended' blood count that encompasses a full white cell differential, fluorescent or immunofluorescent platelet counts, automated reticulocyte and nucleated red blood cell counts [6–8].

The ICSH has given much consideration, since its inception in the era of automated cell counters, to all aspects of the blood count, including methodologies, quality control, standardization, reference ranges and of course reporting units [9–12]. Recommendations and guidelines on these topics have been issued from the 1960s to the 1990s; nevertheless, variations in practice exist around the world. The last 20 years have seen much development in cell counter technology, information technology in the healthcare setting, point-of-care testing and in delivery of pathology service. It is therefore appropriate that the reporting units used for the extended full blood count, which now include complete white cell differential counts, reticulocyte and nucleated red blood cell counts, be revisited in the interests of standardization and patient safety [13].

In 2013, to assess the extent of variation in reporting units for the extended blood count, the ICSH issued an international survey among nine participating countries. Subsequently, four other interested countries also submitted data in 2014 and information concerning the reporting units used by the five countries of the Scandinavian Nordic Reference Interval Project (NORIP) group was made available to the authors, giving data from eighteen countries in total. The results of the survey and the additional data are discussed below. However, it is useful to first consider the original ICSH recommendations, which are set out below.

Original ICSH recommendations

Cell counting technology has developed considerably since the early ICSH deliberations on the issue of reporting units and methods of measurement. In the 1982 publication 'Advances in Haematological methods: The Blood Count' [12], the ICSH summarized its position as previously agreed at its general assemblies and external meetings as follows:

'The International Committee for Standardization in Haematology (ICSH), the International Federation of Clinical Chemistry (IFCC) and the World Association of (Anatomic and Clinical) Pathology Societies (WAPS) agreed to recommend to medical practitioners and all others concerned with health services the following principles with regard to units of measurement for medical laboratory results:

- The International System of Units (SI) is accepted in its broad application
- In accordance with chemical usage, the preferred unit of volume is litre symbolized 'l'
- For multiples and submultiples of units, including derived units, only one prefix should be used. For preference, this should be confined to the numerator; exception is made in the case of the kilogram. Thus, units of concentration should use the litre as the denominator.
- For quantities concerning a component with sufficiently well-known chemical structure, 'molecular kinds of quantities' based on amount of substance (using the unit mole) are recommended.*

'The position taken by ICSH was confirmed at the 8th General Assembly (Jerusalem, 1974) and reconfirmed at the 9th General Assembly (Kyoto, 1976). At that time, however, it was agreed that, when mass concentration was used, gram per litre should be the accepted unit for expressing results of haemoglobin in blood. At the 11th General Assembly (Montreal, 1980), there was again unanimous and strong endorsement of the decision, taken at previous assemblies, that in the context of haematology, haemoglobin should be expressed in g/L until convincing argument can be presented on the advantages of expression as substance concentration'.

In the same publication [12], ICSH set out its recommendation for the SI units to be used for haematological results, which are reproduced showing the components that are part of the blood count, in Table 1 below. This shows the SI unit along with the alternative 'conventional' unit, indicating that ICSH recommended that the former be used.

In 1978, the ICSH recognized that the typewritten lower case l (litre) may be confused with the number 1 and so the upper case L was also accepted.

It is important to note that, in addition to clearly stipulating the units to be used for each component of the blood count, ICSH also recommended at this time that haemoglobin concentration (and by extension MCHC) be expressed as g/L rather than as substance concentration (mmol/L) (11th General Assembly, 1980). The use of g/dL was considered a 'conventional unit' rather than a true SI unit [11, 12]. A review of the subsequent ICSH literature showed that, despite the clear decisions made in 1980 and 1982, both g/L and g/dL continued to be used to express mass concentration, and less frequently, mmol/L was used to express haemoglobin concentration.

Dr Mitchell Lewis commented in 2009 in a review paper 'International Council for Standardization in Haematology – the first 40 years' [14] that the ICSH was represented at a meeting in Munich in 1972 with the IFCC and the World Association of Pathology societies (WAPS) when it was agreed to recommend the use of SI 'to the medical practitioners and all others concerned with health services throughout the world'. He described that 'whilst this would create no difficulty in reporting blood cell counts, the ICSH was able to persuade the other parties that haemoglobin in molar concentration would be likely to confuse health workers in many countries for whom haemoglobin measurement was the fundamental screening test'. The recommendation to adopt SI was supported shortly thereafter by the World Health Assembly [15]. Dr Mitchell also stated that 'to avoid confusion, the ICSH recommended that for both clinical interpretation of data and publication purposes, the differential leucocyte count should always be expressed as the absolute numbers of each cell type per unit volume of blood'.

*Because of uncertainty concerning the elementary entity of haemoglobin to be used in calculation, ICSH recommends that for the time being, haemoglobin concentration in blood be expressed as mass concentration,

either in g/L (g/L) or in g/dL (g/dL). It is, however, permitted to use substance concentration (e.g. in mmol/L); in this case, the elementary entity (monomer or tetramer) should be specified'.

Table 1. ICSH recommendation for reporting units used in the blood count, 1982

Component	Conventional	SI	Conversion factor conventional to SI unit
Erythrocytes	$10^6/\mu\text{L}$	$10^{12}/\text{L}$	10^6
Haematocrit (PCV)	%	Fraction	0.01
Haemoglobin (in blood)	g/dL	g/L (Note a)	10
	g/dL	mmol/L (Fe) (Note b)	0.621
Leucocytes	$10^3/\mu\text{L}$	$10^9/\text{L}$	10^6
Leucocytes, differential count	%	Fraction	0.01
Mean corpuscular haemoglobin (MCH)	$\mu\mu\text{g}$	pg	1
	pg	fmol(Fe) (Note b)	0.621
Mean corpuscular haemoglobin concentration (MCHC)	g/dL	g/L (Note a)	10
	g/dL	mmol/L (Fe) (Note b)	0.621
Mean corpuscular volume (MCV)	μ^3	fL	1
Thrombocytes	$10^3/\mu\text{L}$	$10^9/\text{L}$	10^6
Reticulocytes			
Relative	%	Fraction	0.001
Absolute	$10^3/\mu\text{L}$	$10^9/\text{L}$	10^6

Note a: ICSH recommendation 1976.

Note b: Although ICSH recommends g/L, mmol/L is acceptable as long as the elementary entity (monomer, tetramer) is clearly specified, for example Fe or 4 Fe.

Adapted from Table 9, *Advances in Hematological methods: The Blood Count (12)* 'some haematological laboratory results expressed in "conventional" and in SI units', showing only those components that are part of the extended CBC/FBC.

RESULTS OF ICSH INTERNATIONAL SURVEY OF COMMITTEE MEMBERS 2013 AND SUBSEQUENT DATA GATHER 2014

The results of the ICSH international survey and subsequent data gathered are discussed below. Each co-ordinating national body was asked a series of questions, to which the replies are summarized. They were also asked to report on which reporting units, or combination of units, are used in their country to report all the parameters of the extended blood count. These results are provided as Additional Supporting Information (ASI) available for download with the online version of this study.

Comments on survey results

A review of submitted data shows several areas for consideration.

Few countries appeared to have a unified system of reporting, or national recommendations, for units of measurement for the blood count. In addition, there is a very wide variation in the use of reporting units

worldwide. Guidance would appear to be needed for all parameters including the following:

- Reporting of cell counts.
- Reporting of white cell differentials, consideration of absolute values versus percentages.
- Reporting of haemoglobin, where several different options are available.
- Reporting of reticulocytes and nucleated red blood cells.

The survey results concerning individual parameters or components of the blood count are considered below.

White cell and platelet counts

The majority of countries report using the ICSH-recommended SI unit ($10^9/\text{L}$); however, there is persistence of the use of the non-SI units (Giga/L, number per mm^3 , number per μL , number $\times 10^3/\mu\text{L}$) in various parts of the world, particularly in Korea and Japan. In addition, there is variation in units used within France, the USA and particularly in Germany.

The white cell differential count is still reported as a percentage in many countries, although usually also in absolute numbers in the same countries.

Nucleated red blood cell counts

The majority of countries report as absolute number ($10^9/L$) but also per 100 WBCs.

France and Japan report as per 100 WBCs, whilst Korea uses the non-SI unit $\times 10^3/\mu L$.

It was reported that in China, this parameter is only available in some hospitals.

Red cell counts

There is reasonable consensus as the majority of countries report red cell counts using the ICSH-recommended units ($10^{12}/L$). However, Japan and Korea use non-SI units ($10^6/\mu L$) as do some laboratories in the USA. France and Germany also use Tera/L and $\#/mm^3$.

Haemoglobin

Haemoglobin concentration is reported variously as g/L, g/dL, g/100 mL or mmol/L. It could be said that there is almost an even split among the majority between the use of g/L and g/dL, whilst mmol/L is the third most frequent unit used, followed by g/100 mL. Only the Netherlands and Denmark report exclusively as mmol/L. However, the use of mmol/L still persists in Spain and France along with the use of other units, as it does in Germany where it was used in the former East Germany; however, since unification, the advice is to follow ICSH guidance for SI and g/L. National guidance is in place only in the Netherlands and the UK, although the Scandinavian countries including Iceland, Finland, Norway and Sweden have an agreement on reporting units through the NORIP group [16, 17] where haemoglobin is reported in g/L except in Denmark where it is reported as mmol/L.

Red cell/Platelet distribution width

These parameters are not routinely reported to the clinician in some countries. They are reported variously as fL or as a percentage.

Other parameters (MCV, MPV, MCH)

MCV: There is excellent consensus here already, as all respondents reported the use of the ICSH-recommended unit (fL) and only France reported that some laboratories use μm^3 .

MCH: There is also excellent consensus for this parameter, as all respondents reported use of the ICSH-recommended SI unit pg, except Denmark and the Netherlands which use fmol, which is consistent with use as mmol/L to report haemoglobin concentration in those countries.

MPV: This parameter is not routinely reported; however when it is, the widely used unit is the fL. France reported that there is no consensus.

Reticulocytes

There is good agreement as the majority of countries report reticulocytes as the recommended absolute number ($10^9/L$); however, many also report as a percentage, which introduces variation but of course can be quite easily converted to absolute number. Only India and Korea stated that they only report as a percentage, whilst France reported that whilst $10^9/L$ is used, Giga/L (G/L) and number per mm^3 are also used.

Haematocrit

Haematocrit (Hct) (PCV) appears to be reported variously as either percentage or by volume (e.g. L/L) or without units. The ICSH recommended use of the 'fraction' or by volume as being compatible with SI and that the use of percentage should be discontinued.

DISCUSSION

There are many legitimate reasons why laboratories have developed different ways of reporting the basic blood count profile. However, the growth of electronic reporting systems and the increase in global healthcare providers are driving the need for harmonization and standardization where clinically appropriate. If results are reported in different formats, there is both a clinical risk that they will be misinterpreted and a danger that abnormal results may be simply missed.

Quite clear guidance as to which units to use for the blood count is available from the early deliberations of the ICSH outlined above, in which SI units were recommended. Nevertheless, our survey of a total of eighteen countries has clearly shown that significant diversity in practice exists worldwide. The authors regret that further countries were not included in the limited survey completed; in that, the Middle East, Africa and South America are not represented. However, we feel that the survey we did carry out revealed that significant diversity without good reason exists and that therefore this point has been made.

If one takes an overall view of this diversity as regards the reporting of white cells, red cells and platelets, it appears that the use of non-SI (or not recommended) units of the type that the ICSH called 'conventional units' in the early 1980s (Giga/L, number per mm³, number per μL , number $\times 10^3/\mu\text{L}$, $10^6/\mu\text{L}$) has persisted despite the ICSH guidance from that time. An argument can be made on this basis alone, for the use of these reporting units to be discontinued in favour of the SI units ($10^9/\text{L}$ and $10^{12}/\text{L}$) already used by many. Such a change alone would greatly improve standardization worldwide.

The reporting of white cell differentials in percentages should be discouraged as this only has meaning when compared to the total white cell count. A clear recommendation to this effect has already been made by the ICSH. Although the majority of reports expressed in absolute units are derived from equipment with automated differential technology, the reports from laboratories which still report percentages no doubt derive from the production of differential manual counts by microscopy. It is of course possible to convert the percentage result to absolute numbers using the total white cell count, but this does depend on the IT system available. The authors recommend that when the IT infrastructure is robust, differentials should be reported in absolute values as a preference.

A similar issue applies to the reporting of nucleated red blood cells (NRBCs) which are variously reported as an absolute number, but also as a number per hundred white cells. This parameter is an example of the impact of new cell counting technology, given that it has only been widely available on an automated basis since the late 1990s. The NRBC count derived from

manual microscopy is performed whilst carrying out a white cell differential, hence generating a result expressing NRBCs per 100 white cells. However, such a result alone means little to the clinician, as it is not an absolute number but depends entirely on the total white cell count. The UK Pathology Harmony group recommended that NRBCs be reported as an absolute SI number $\times 10^9/\text{L}$ [18]. However, when the result is derived manually, this depends on the ability of the local IT system to convert the manual result to an absolute number using the total white cell count. As the counting of these cells moves from predominately manual microscopy to automated methods, it is preferable that their numbers should be reported as an absolute value. However, the authors recognize that consideration should be given to developing countries where the automated method may not be widely available, or IT systems may not have the capability to automatically calculate the absolute number from the manual count.

The unit of measurement used to report haemoglobin concentration, and by extension MCH and MCHC, is split in the case of the majority between g/L and g/dL but mmol/L is also used. Nevertheless, the ICSH in the early 1980s recommended that g/L should be used. The use of mmol/L, whilst considered valid under the SI system, was discouraged by ICSH 'to avoid confusion of healthcare workers' as described by Lewis [14], 'until convincing argument can be presented on the advantages of expression as a substance concentration'. The ICSH survey reported in this study shows that the molar unit to report haemoglobin concentration is only used exclusively in the Netherlands and Denmark and also by a minority of laboratories in France, Germany (in the former East Germany) and Spain.

It is interesting that both g/dL and g/L are used almost equally worldwide, when the ICSH favoured g/L as being a 'true' SI unit, given that the use of g/dL breaks the rule emphasized in the joint ICSH-IFCC-WAPS paper of 1972 recommending the use of SI units, that 'only one prefix should be used, and that for preference, this should be confined to the numerator', the litre being the denominator [11]. In conclusion, the early ICSH guidance was in favour of the use of g/L and yet the other two forms have persisted, whether for historical or local reasons, or because the ICSH judgment was not clearly

interpreted. The reporting units used to express MCH and MCHC would follow logically from those used to express haemoglobin concentration.

Given that MCV is almost universally reported using the ICSH-recommended unit (fL), there should not be a significant issue as regards standardization for this parameter.

Haematocrit (Hct)(PCV) appears to be reported variously as either percentage or by volume (e.g. L/L) or without units. The ICSH recommended use of the 'fraction' or by volume as being compatible with SI and that percentage should be discontinued.

Red cell distribution width (RDW), platelet distribution width (PDW) and mean platelet volume (MPV) are not always routinely reported. There was an even split in reporting units for RDW between % for RDW-CV and fL for RDW-SD. Most countries reported PDW as fL and all reported MPV as fL, where these parameters are reported. The authors recommend using the SI unit fL as a preference, in the interest of introducing a standardized approach [16].

The problems that attach to the reporting of reticulocytes are analogous to those that apply to the white cell differential and NRBC reporting, which are that manual counting leads some laboratories to report as a percentage of total red cells rather than as an absolute number. The advent of automated reticulocyte counting in the latest generation cell counters has improved reporting as an absolute number, and here, the ICSH recommends use of $10^9/L$. The calculation required to convert a percentage result to an absolute number is straightforward.

Comments on 'newer parameters': Useful clinical information can be gleaned from newer parameters, which are often innovations of individual equipment manufacturers, such as percentage hypochromia of red cells, immature granulocytes or immature platelet fraction [16]. Reporting units for emerging tests are by their nature determined by the manufacturer as they are developed; however, if they gain more widespread use, they warrant attention as regards standardization.

CONCLUSIONS AND RECOMMENDATION

The objective to introduce standardization in reporting units used worldwide for the extended blood count, in the interest of patient safety, may seem like an

intractable problem given the diversity of reporting units currently in use as revealed by the recent ICSH survey. Nevertheless, the arguments in favour of attempting greater harmonization are well made as outlined in the introduction. Given the continuing advances in the capabilities of cell counting technology, as well as in near-patient testing, along with information technology for handling patient data advance, this is an appropriate time to reassess this area. As discussed above, the early ICSH deliberations on the topic of reporting units resulted in clear recommendations for the blood count; however, despite this, the use of nonrecommended units has persisted. The current diversity in reporting units in use could be considered in three main areas: (i) the persistence in use of non-SI or non-ICSH-recommended units for RBC, WBC and platelet counts in some countries, (ii) the use of three different units for haemoglobin concentration and related parameters, with mmol/L used by a minority and a conversion factor of 10 difference between the other two and finally (iii), the persistence of manual reporting of blood film-derived results for white cell differential, reticulocytes and nucleated red cells, when these are increasingly available from automated analysis and can be expressed as absolute numbers by calculation even when manually derived. If a consensus could be achieved in even some of these areas, standardization of approach worldwide would greatly improve. Indeed, the diversity in reporting units that exists for some parameters is simply a question of nomenclature, where the actual numeric value in a given blood sample would be the same even when expressed in different reporting units. For example, a leucocyte count of $5.0 \times 10^9/L$ would have the same numeric value when expressed as giga/L or as $10^3/\mu L$, although it would differ by a factor of 1000 when expressed as number per μL or number per mm^3 .

International Considerations

The desirability of standardization has been recognized internationally, as shown by the fact that five countries in the Scandinavian region came together as the NORIP group [17, 19] to harmonize not only reporting units but also reference ranges for the blood count; the United Kingdom implemented a Pathology Harmony initiative to standardize within the UK [18];

and that the need to have one approach between the former East and West Germany has been recognized. The Netherlands and more recently the United Kingdom have nationally agreed guidelines for units of measurement with the UK reporting haemoglobin in g/L and the Netherlands using mmol/L. Most countries have professional bodies that provide guidance, with some reaching consensus in practice (e.g. Australia); however, very little guidance is enforced and little is published as national recommendations. The Royal College of Pathologists of Australasia has very recently endorsed a set of guidelines [20, 21]. In China, the pathology services are growing at an exponential rate with small and larger laboratories acquiring new equipment and new laboratories being set up across China under the National Centre for Clinical Laboratories (NCCL).

Where harmonization exercises have been carried out, significant planning, communication with and education of service users and detailed co-ordination are required. These are significant projects requiring resources; however, they have been achieved successfully as discussed above and perhaps ICSH has a role in giving overall strategic guidance. However, decisions to implement change ultimately rest with national bodies and healthcare authorities. It may be encouraging to note that few clinical incidents have been reported where standardization exercises have been carried out (for example, in the UK) [18].

Consideration of cell counting technology available in developing countries

The degree of automation and capabilities available for cell counting in developing countries should be considered in any guidance or recommendation issued in regard to reporting units so that such guidance will be useful and can be applied. For example, automated flow cytometry-based methods for counting reticulocytes and nucleated red cells are now well established in the developed world and lend themselves well to reporting in absolute numbers. These methodologies may not be so widely available in developing countries and so guidance on reporting units should take account of that. It would be very useful for the ICSH to further develop its knowledge in this area and contact with laboratory professionals, and EQA providers in these regions could be developed further to facilitate that.

Opportunities for standardization and rationale for current recommendations

The ICSH is in a good position to lead an international initiative aimed at improving standardization of reporting units for the blood count, or at least to provide a consensus recommendation. There are currently calls in many countries to harmonize reporting in pathology to the level of establishing common reference ranges (NORIP and UK Pathology Harmony); clearly, standardization of reporting units is a minimal prerequisite towards achieving this. The international survey reported in this study has shown that very significant diversity in the use of reporting units for the blood count exists worldwide, whilst a review of the original literature on this topic shows that the ICSH and other professional bodies made quite clear recommendations for standardization based on expert consideration and acceptance that SI units should be used over 30 years ago. This paper makes a recommendation for standardization based primarily on consensus on the units in majority use derived from the international survey, provided such are true SI units [22] and on expert opinion including that of the original ICSH recommendations described above, where there is no clear majority use of a single unit worldwide, such as in the case of haemoglobin concentration. The authors also considered practical considerations such as the clinical utility of reporting units and the practicality of calculating them where applicable, as treated in the discussion. A rationale for the recommendation of units to be used for each parameter is given in Table 2.

Table 2 below summarizes the current proposed recommended reporting units for each parameter of the extended blood count. The table lists the diverse reporting units used currently for each parameter, makes a recommendation for use of a single parameter where possible and includes a summary of the rationale for each recommendation.

It is unavoidable that implementation of standardization internationally would require agreement on adoption of common units and implementation of change in some countries. There is a need for input from clinicians, the cell counting and point-of-care industry, and national professional and EQA bodies in haematology in such change projects. Changes require agreement among national bodies, significant advance planning and communication, and of course the

Table 2. ICSH recommendation for standardization of reporting units used in the blood count, 2016

Blood count parameter	Reporting Units currently used worldwide	Recommended reporting unit	Reason(s) for recommendation
WBC and platelet counts	$\times 10^9/L$ Giga/L $\times 10^3/\mu L$ Number per μL Number per mm^3	$\times 10^9/L$	SI unit; previously recommended by ICSH; current majority use worldwide
WBC differential count	$\times 10^9/L$ Percentage (%) $\times 10^3/\mu L$ Number per μL Number per mm^3	$\times 10^9/L$ <i>(rather than % where technology and/or IT capability allows)</i>	SI unit; previously recommended by ICSH; more clinically meaningful than %
Nucleated RBC count	$\times 10^9/L$ per 100 WBC $\times 10^3/\mu L$	$\times 10^9/L$ <i>(rather than per 100 WBC where technology and/or IT capability allow)</i>	SI unit; more clinically meaningful than per 100 WBC
RBC count	$\times 10^{12}/L$ $\times 10^6/\mu L$ Tera/L Number per mm^3	$\times 10^{12}/L$	SI unit; previously recommended by ICSH; current majority use worldwide
Haemoglobin	g/L g/dL mmol/L g/100 mL	g/L	True SI unit unlike g/dL or g/100 mL; ICSH previously did not recommend mmol/L (used in a minority of countries).
PCV/haematocrit	L/L Percentage (%)	L/L	SI unit; previously recommended by ICSH
MCV (mean cell volume)	fL μm^3	fL	SI unit; previously recommended by ICSH; current majority use worldwide
MCH (mean cell haemoglobin)	pg fmol	pg	SI unit; previously recommended by ICSH; current majority use worldwide
MCHC (mean cell haemoglobin concentration)	As per haemoglobin	As per haemoglobin	As per haemoglobin
RDW (red Cell distribution width)	%	fL as a preference	SI unit; already reported as fL in many countries
PDW (platelet distribution width) and MPV (mean platelet volume)	fL % CV	<i>(where routinely reported)</i>	
Reticulocytes	$\times 10^9/L$ Percentage (%) Giga/L Number per mm^3 $\times 10^6/\mu L$	$\times 10^9/L$ <i>(rather than % where technology and/or IT capability allows)</i>	SI unit; previously recommended by ICSH; current majority use worldwide

logistics of adapting all laboratory and point-of-care analysers, also laboratory, hospital and healthcare network or regional IT systems that receive the results. Nevertheless, such projects have been successfully

implemented in various regions and within nations, NORIP and the UK Pathology Harmony project being examples. It may well be the case that initiatives outside of the laboratory's control drive the overall need

for standardization regardless of whether or not an international initiative is undertaken. For example, the survey reported in this study has shown that standardization is already needed across borders in Europe (the survey comments indicated this), and also the Republic of Ireland has committed to implement a single national IT system for all pathology services, which will require single reporting units for all results in all disciplines. These examples illustrate quite well that the dissemination of over-arching international guidance by the ICSH, as proposed in this study, is now very opportune.

ACKNOWLEDGEMENTS

This study was financially supported by the ICSH. The ICSH is a not-for-profit organization sponsored by unrestricted educational grants from its corporate and affiliate members who are listed in the attached supplementary file Appendix S2.

The ICSH thanks all those who contributed on behalf of their nations to the international survey in 2013, both to the ICSH survey and in providing supplementary data as follows: ICSH members: Dr Katherine Marsden – Australia RCPAQAP; Dr JM Jou – Spain; Dr Jin-Yeong Han – Korea; Prof. Ming Ting Peng – China NCCL; Prof. Yohko Kawai – Japan; Prof. Keith Hyde – United Kingdom NEQAS(H), Dr C Thomas Nebe – Germany; Richard McCafferty – Republic of Ireland; Dr Jean-Francois Lesesve – France; Dr Antony AM Ermens – the Netherlands; Dr Joan Etzell – USA CAP; Dr Gini Bourner-Canada. Dr Shanaz Khodaiji – Mumbai, India. Prof. Per Simonsson and Prof. Gunnar Nordin – Equalis and the NORDIC REFERENCE INTERVAL PROJECT (NORIP) group of five Scandinavian countries Denmark, Finland, Iceland, Norway and Sweden.

DISCLOSURE OF CONFLICT OF INTERESTS

The authors declare no conflict of interests.

REFERENCES

- Blumenthal D, Tavenner M. The “Meaningful Use” Regulation for Electronic Health Records. *N Engl J Med* 2010;363:501–4.
- ISO/TC 212 Clinical laboratory testing and in vitro diagnostic test systems. http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?comid=54916
- O’Kelly RA(1), Brady JJ, Byrne E, Hooley K, Mulligan C, Mulready K, O’Gorman P, O’Shea P, Boran G. A survey of point of care testing in Irish hospitals: room for improvement. *Ir J Med Sci* 2011;180:237–40.
- Howick J, Cals JWJ, Jones C, Price CP, Pluddermann A, Heneghan C, Berger MJ, Bunrinx F, Hickner J, Pace W, Badick T, Van den Bruel A, Laurence C, van Weert HC, van Severen E, Parrella A, Thompson M. Current and future use of point-of-care tests in primary care: an international survey in Australia, Belgium, The Netherlands, the UK and the USA. *BMJ Open* 2014;4:e005611.
- Briggs C, Carter J, Lee SH, Sandhaus L, Simon-Lopez R, VivesCorrons JL. International Council for Standardization in Haematology Guideline for worldwide point-of-care testing in haematology with special reference to the complete count. *Int J Lab Haematol* 2008;30:105–16.
- Zijlstra W.G, vans Kampen E.J. Standardization of Hemoglobinometry. *Clin Chim Acta* 1960;5:719–26.
- England JM, Rowan RM, van Assendelft OW, Coulter WH, Groner W, Jones AR, Koepke JA, Lewis SM, Shinton NK, Thom R. ICSH Protocol for evaluation of automated blood cell counters. *Clin Lab Haematol* 1984;6:69–84.
- ICSH. Implications of IUPAC-IFCC Recommendations for Haematology. Report of the ICSH Board Secretary, London 1972; Annex 2
- ICSH. Recommendation of the International Council for Standardization in Haematology on Reporting Differential Leucocyte Counts. *Clin Lab Haem* 1995;17:113.
- ICSH. Guidelines for the evaluation of blood cell analysers including those used for differential leucocyte and reticulocyte counting and cell marker applications. *Clin Lab Haematol* 1994;16:157–74.
- ICSH, IFCC, WAPS. Recommendation for use of SI in Clinical Laboratory Measurements. *Br J Haematol* 1972;23:787–8.
- Van Assendelft OW, England JM. Terms, Quantities and Units. In: *Advances in Hematological methods: The Blood Count*. Boca Raton, FL: CRC Press; 1982: (ISBN 0-8493-6596-1) 2–9
- Stamminger G, Heller S. Units in the Haematological Laboratory: a proposal for standardization. *J Lab Med* 2001;25:82–4.
- Lewis SM. International Council for Standardization in Haematology – the first 40 years. *Int J Lab Hematol* 2009;31:253–67.
- Use of SI units in medicine, WHA30.39: Prepared at the Request of the Thirtieth World Health Assembly. Geneva, Switzerland: WHO Publication; 1977. <http://www.who.int/iris/handle/10665/93202>.
- Briggs C. Quality Counts: new parameters in blood cell reporting. *Int J Lab Hematol* 2009;31:277–97.
- Nordin G, Mårtensson A, Swolin B, Sandberg S, Christensen NJ, Thorsteinsson V, Franzson L, Kairisto V, Savolainen ER. A multicentre study of reference intervals for haemoglobin, basic blood cell counts and erythrocyte indices in the adult population of the Nordic countries. *Scand J Clin Lab Invest* 2004;64:385–98.
- De La Salle B. Pathology harmony moves on: progress on implementation in haematology. *Br J Haematol* 2012;158:804–5.
- Simonsson P, Mårtensson A, Rustad P. Bättre bas för klinisk bedömning och samarbete. *Läkartidningen* 2004;101:901–5.
- Australian Pathology Units and Terminology (APUTS) Reporting Terminology and

- Codes Haematology, RCPA <https://www.rcpa.edu.au/Library/Practising-Pathology/PTIS/APUTS-Downloads>
21. Australian Pathology Units and Terminology (APUTS) Standards and Guidelines (v2.2) RCPA <https://www.rcpa.edu.au/Library/Practising-Pathology/PTIS/APUTS-Downloads>
22. Fink A, Kosecoff J, Chassin M, Brook RH. Consensus Models: characteristics and guidelines for use. *Am J Public Health* 1984;9:979–83.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Results of ICSH International Survey of Committee Members 2013 and subsequent data gather 2014.

Appendix S2. ICSH corporate and affiliate members.