SI UNITS FOR CLINICAL MEASUREMENT

Donald S. Young, MB, PhD
Edward J. Huth, MD
With Additional Contributors

临床检验国际标准

ACP SERIES MEDICAL WRITING AND COMMUNICATION

世界图书出版公司

SI UNITS FOR CLINICAL MEASUREMENT

重庆医科大学附属第一医院图书馆
馆藏专用章

世界图书出版公司
西安·北京·广州·上海

(陕)新登字 014 号

陕版出图字　著作权合同登记　25—1999—006 号

SI Units for Clinical Measurement

临床检验国际标准

by Donald S. Young et al.

任卫军　重印责任编辑

世界图书出版西安公司　重印发行

（西安市南大街 17 号　邮编：710001）

西安七二二六印刷厂印刷

787×1092 毫米　开本 1/16　印张：21.5　字数：344 千字

1999 年 7 月第 1 次印刷

ISBN　7-5062-2237-X/R・375

Wx2237　　定价：105.00 元

ACP

Manager, Books Program: David Myers
Production Supervisor: Allan S. Kleinberg
Production Editor: Amy L. Cannon
Interior Designer: Anne O'Donnell
Cover Designer: Elizabeth F. Swartz

Copyright © 1998 by American College of Physicians

All rights reserved. No part of this publication may be reproduced in any form or by any means (electronic, mechanical, xerographic, or other) or held in any information storage or retrieval systems without written permission from the publisher.

Printed in the United States of America
Composition by Fulcrum Data Services, Inc.
Printing/binding by Victor Graphics, Inc.

Library of Congress Cataloging-in-Publication Data

Young, Donald S.
SI units for clinical measurement / Donald S. Young and Edward J. Huth, with additional contributors.
p. cm.—(Medical writing and communication)
Includes bibliographical references and index.
ISBN 0-943126-51-7 (alk. paper)
1. Metric system—Handbooks, manuals, etc. 2. Medicine—Measurement—Handbooks, manuals, etc.
I. Huth, Edward J. II. Title. III. Series.
[DNLM: 1. International System of Units. 2. Clinical Medicine.
WB 16 Y69s 1998]
R857.M4Y68 1998
610'.28'7—dc20
DNLM/DLC
for Library of Congress
96-30174
CIP

98 99 00 01 02 / 9 8 7 6 5 4 3 2 1

SI Units for Clinical Measurement

Donald S. Young, MB, PhD
Edward J. Huth, MD
With Additional Contributors

American College of Physicians
Philadelphia, Pennsylvania

此为试读,需要完整PDF请访问: www.ertongbook.com

Contributors

We are grateful to the persons listed below for their well-informed and highly useful contributions to the text and tables of this book. The parts contributed by them are identified after their affiliations. Parts of the texts and the tables submitted have been revised for consistency of style and to eliminate redundancies, but we have endeavored to maintain the accuracy of their content.—*DSY, EJH*

Judith H. Dickson, MS, ELS(D), Science Editing, Inc., Rockville, Maryland: Chapter 4, Section 4·5, Nutrition

Matthew J. McQueen, MB, ChB, PhD, Hamilton Health Sciences Corp., Faculty of Medicine, McMaster University, Hamilton, Ontario, Canada: Chapter 5, Introducing SI Units to the Hospital

Edward R. Powsner, MD, President, Eastside Nuclear Medicine, Grosse Pointe Farms, Michigan: Chapter 1, The Metric System and Its Development into The International System of Units (le Système International d' Unités; SI)

Robert D. Reynolds, PhD, Department of Human Nutrition and Dietetics, University of Illinois at Chicago, Chicago, Illinois: Chapter 4, Section 4·5, Nutrition

Arthur S. Slutsky, MD, Division Director, Respiratory Medicine, University of Toronto, Toronto, Ontario, Canada: Chapter 4, Section 4·7, Pulmonary Medicine

Jesus Villar, MD, PhD, Director of Research, Universitario de Candelaria, Tenerife, Canary Islands, Spain; Associate Scientist, Mount Sinai Hospital, Toronto, Ontario, Canada; Professor of Critical Care Medicine, Mercer University, Macon, Georgia: Chapter 4, Section 4·7, Pulmonary Medicine

Preface, with Information for Users of this Manual

The United States is the only major country in the world that has not moved decisively to the use of the metric system throughout its businesses, schools, universities, and public facilities. Some of its industries depending heavily on export business have shifted to metric units, at least for export products. As described in Chapter 1, American medicine has adopted the metric system for some uses but has lagged behind the rest of the medical world in not widely shifting to the modern metric system, the Système International d' Unités (SI).

We have prepared this book for American physicians needing guidance in the proper use of SI units in their practices, their hospitals, and their books and articles. We offer them guidance in converting older metric units to proper SI applications. We have not written this manual to act as polemical advocates of the SI. When the conceptual advantages of the SI and the practical gains from joining the rest of the medical world become apparent, the shift to the use of SI in medicine in the United States will accelerate. We hope this book helps in making that shift.

The style used for citations and references in this book is that recommended for the name-year system by the Council of Biology Editors style manual, *Scientific Style and Format,* Cambridge University Press, 1994. References cited in the text are given at the end of each chapter except Chapter 4, in which references are listed at the end of each section. Entry terms (row headings) in tables are not capitalized unless they represent proper names such as trademark names.

—DSY, EJH

Contents

CHAPTER 1

The Metric System and Its Development into The International System of Units (le Système International d'Unités; SI)

EDWARD R. POWSNER AND EDWARD J. HUTH

THE EARLY YEARS

Two of the central principles in the metric system, "natural" base units and the decimal division of units, were concepts set forth long before French law established the metric system late in the 18th century (Danloux-Dumesnils 1969). The advantages of decimal units were described in 1585 by Simon Stevinus, inspector of dikes in The Netherlands, in a pamphlet, *La Disme*. Around 1660 the Royal Society of London considered a scheme for decimal units of measure, but no action was taken toward establishing such a system. Around 1670 the Abbé Gabriel Mouton proposed a unit of length as a decimal fraction of the length of the 1-minute fraction of a meridian arc. His proposal (EB 1987) also incorporated decimals and rational prefixes for unit names. In 1754 Diderot's *L'encyclopèdie* (EB 1987) discussed it in volume 4 under "Decimal," the rules proposed by Stevinus. Even though the decimal concept was probably widely known then in scientific circles, realists about human affairs were surely aware of likely strong resistance to changes from traditional units. In commenting on this problem, Danloux-Dumesnils (1969) brings to our attention how Montesquieu, in considering "ideas of uniformity" relevant to systems of measurement and other regulating principles in human affairs, raised the question in his *Esprit des Lois:* "Is the evil of changing always less than that of suffering?"

Finally, in 1790, Talleyrand presented a plan embodying the principles of what became the metric system to the Constituent Assembly in France. Collaborative participation by other countries was part of the plan, but this was rejected by the United Kingdom and, a bit later, by the United States. The plan was eventually embodied in appropriate legislation, and by 1799 the metric system reached full formal and legal status in France. Other European countries soon adopted the system, but the United Kingdom did not legalize metric units, and then only for optional use, until 1864.

The American Perspective

The foundation for the present international system of measurement, le Système International d'Unités, widely known as SI, was laid with the convening of the International Commission of the Metre in 1870 and firmly set in place in 1875 by the Metric Convention, to which the United States (USC 1975) was one of the original signatories. Even in 1875 the units of the system were not new; they had evolved from the system that had been adopted by the French after their Revolution. Although 30 nations signed the original agreement, not all have implemented it. Different national systems persist, that of the United States being the most notable example. Under the Convention of 1875, participating nations send delegates to the General Conference on Weights and Measures (Conférence Général des Poids et Mesures [CGPM]), which meets at intervals of approximately 6 years. It is the ultimate authority for the day-to-day operation of the International Bureau of Weights and Measures located near Paris. Among its other duties the Bureau acts as the official keeper of the primary standards (NBS 1977) of length and mass.

Just as the French Revolution had a part in establishing the original metric system, the American Civil War was associated with a period of rapid change in American medicine. Concerned with, or more likely propelled by, emerging concepts and new methods, the leaders of the American Medical Association (AMA) were quick to recognize the value of a uniform international system of units. In 1872, 3 years before the United States officially signed the Treaty of the Metre, the Section of Materia Medica and Chemistry of the AMA passed a resolution (Barclay 1980):

> [T]he inclusion of the decigram and cubic centimeter in the list of official weights and measures is considered as desirable, and to the advance of medical science.

Three years later the report of the AMA delegate to a preliminary meeting in Europe to adopt uniform weights and measures included the following view:

> [I]t is . . . important that the AMA be represented this year [1875] in Bruxelles in order to represent there the original plan for uniformization of clinical observation in its integrity and entirety.

Responding to its leaders, the AMA House of Delegates adopted a resolution (Barclay 1980, Vawter and De Forest 1971) that included the following points:

> The AMA . . .
>
> [A]dopt[s] the International Metric System and uses it in its Transactions.
>
> Requests those who present papers at its future meeting employ this system in their communications, or reprints thereof.
>
> Requests the medical boards of hospitals and dispensaries . . . and the faculties of the medical and pharmaceutic schools adopt [the Metric System] . . .

此为试读,需要完整PDF请访问: www.ertongbook.com

> Requests the physicians familiar with the Metric System to help their confreres and the druggists in its application; and the delegates present . . . to work up the acceptance of the Metric System by their respective county and state societies.
>
> Requests our President to name a Metric Executive Committee . . . to give unity and rapidity to this metric movement.

The next year the House noted (Barclay 1980) that it was established policy of the AMA to work with the British Medical Association "to render the use of the metric system simultaneous and uniform in both countries."

Continuing History: World War I to the Recent Past

Despite this early enthusiasm, the momentum for change did not last. What appears to have remained was limited general support for adoption of metric units by American doctors. This support appeared in the records of the AMA and the U.S. Congress several times over the next 50 years. In 1921, for example, the AMA House of Delegates referred a resolution (Barclay 1980, Vawter and De Forest 1971) to the Board of Trustees recommending the use of the metric system in AMA publications with the provision that "English weights and measures and the Fahrenheit scale may be added in parentheses, if desired."

Perhaps the single important exception to the overall lack of action was the adoption of metric units in medical laboratories. Clinical laboratory science developed substantially in the period between the two world wars; as a developing science it assimilated the metric units that were then in general use in chemistry laboratories of universities.

More typical was the slowness with which metric units were adopted for writing prescriptions after World War II. During the war, metric units were taught in pharmacology courses in medical schools, and this change began to affect practice. Unlike their predecessors, students graduating in the 1950s had learned to prescribe in grams and milligrams but found many members of hospital staffs still prescribing in grains and other units of the apothecaries' system. General acceptance of the metric units for prescribing came gradually as older physicians retired and the newer trainees entered practice.

The metric system itself continued to evolve. By the time the gram had become well accepted in teaching and for the clinical laboratory, several important changes had been proposed for units in chemistry and physics. The most important change was made at the 10th General CGPM in 1954 (NBS 1977) when the system of units was recodified. In 1960, the 11th CGPM adopted (NBS 1977) the present name for the system, le Système International d'Unités, with its abbreviation SI, to replace the older designation, the metric or "practical" system of units. The 1960 CGPM affirmed the six basic units: meter, kilogram, second, ampere, kelvin, and candela. A seventh unit, the mole, was added in 1971. An eighth unit, the katal, was proposed but has not yet been adopted by the CGPM.

Proposed SI for Laboratory Medicine

Proposals for the use of the SI in medicine, and in particular those for the clinical laboratory, have included changes beyond those required by the 1960 Conference on Weights and Measures. These changes in units imposed major changes for clinical laboratory reports. The new units necessitated, of course, new numeric values and, by implication, restatement of reference intervals (normal ranges). Partly because of the extent and effects of these changes, U.S. physicians in general have not been enthusiastic about accepting SI units, and opposition to some of the changes has been vociferous. In contrast, new units for radiation measurements, if not always used, have been accepted by radiologists with little argument.

If the response of the pathologists seems at odds with the widely held view that medical laboratories have long worked with metric units or seems contrary to the century-old official position of the AMA, it is probably a consequence of what Myrton Beeler, while chairing a committee of the American Society of Clinical Pathologists, referred to as the "Danish Nomenclature Proposals by Dybkaer and Jorgensen."[1] In 1957 a committee of the Danish Physiologic Society chaired by Rene Dybkaer, likely influenced by the 1954 action of the CGPM, developed the proposals (Dybkaer and Jorgensen 1967) in question. These contained two main points: Chemical and physiologic measurements were to be expressed in a standard format, and the units were to be those of the SI, albeit with some restrictions and additions.

As proposed by the Danish committee, the standard format began with an abbreviated name for the system measured, for example, P for plasma, U for urine, Sp for spinal fluid; it continued with the name of the analyte and kind of quantity measured; and it ended with the numeric value and unit. The proposals also included some new and unusual names for chemical analytes and for blood cells, for example, carbamide for urea, plattulocyte for platelet. Except for the unusual names, this part of the document provoked no strong reaction. What did provoke controversy were the choices of acceptable SI units and the proposed additions to the SI.

The first point of contention was the limitation on the acceptability of units. There were two major restrictions: The liter itself rather than its submultiples must be used in expressions of concentration; and the prefixes must be limited to multiples of 1000 or $\frac{1}{1000}$.

The other important source of contention was the addition to the SI of the mole and the katal. The mole was proposed for expressing the quantity of an analyte, to replace mass expressed in grams or their subunits whenever the molecular weight of the analyte is known. At the time the mole was not part of the SI; it was added in 1971. The katal (kat) was proposed for enzyme activity in place of the international unit (U).

Using the report of the Danish committee for guidance, the International Federation of Clinical Chemistry (IFCC) and the International

[1]Letters: M Beeler to R Frazier, November 1968; M Beeler to DS Young, February 1969. Copies in possession of ER Powsner.

Union of Pure and Applied Chemistry (IUPAC) published detailed recommendations for quantities and units in 1966 (Dybkaer and Jorgensen 1967), which were successively revised and reissued as Recommendation 1973 (Dybkaer 1974) and Recommendation 1979 (Dybkaer 1979). In its turn the World Health Organization (WHO) published its recommendations (WHO 1977) for conversion to the SI in 1988. The units proposed by the WHO for laboratory medicine were based on the IFCC-IUPAC recommendations of 1973 and supported the use of the mole in laboratory reports, but they departed less from the current practice. In the WHO recommendation (WHO 1977), the katal was omitted, customary names such as urea were retained for analytes, and the millimeter of mercury was retained "for the time being" as a unit of pressure as an alternative to the kilopascal.

United States Government Policy

The U.S. government has been little more than advisory or permissive with respect to the SI. Congress passed the Metric Conversion Act in 1975, but this act has much less force than its title suggests. The act was intended only to facilitate voluntary conversion to the metric system. Specifically, it (USC 1975) declares that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the country. The motive for this action was much less the conversion of U.S. usage at home than the standardization of military supplies for the United States and NATO forces overseas and for exports of U.S. manufacturers.

Because the primary impetus was commercial exporting and military integration, the organizations working for conversion to the SI were concerned principally with engineering and manufacturing issues. They did not, at least initially, consider the implications of the SI for medicine. No one, for example, had considered the problems created for U.S. military physicians trained and equipped with Fahrenheit thermometers working alongside NATO physicians using Celsius thermometers, or worse, the confusion caused by American syringes marked both in minims ($\frac{1}{480}$ fluid ounce, or about 1 drop) and in millimeters but used by nurses who had never heard of minims and assumed the markings and the abbreviation "m" were for milliliters.

American National Metric Council

Of the several organizations working to popularize SI units generally, the American National Metric Council (ANMC) has been one of the most active in discussing units applicable to medicine, but even it began slowly.[2] The

[2]U.S. organizations that have considered or are considering using medical SI units, especially laboratory units, include the American Society of Clinical Pathologists (ASCP), the College of American Pathologists (CAP), the American Association for Clinical Chemistry (AACC), and the National Committee for Clinical Laboratory Standards (NCCLS). The ASCP and the CAP had committees studying the issue since at least 1965. The NCCLS, organized in 1968, was the center of laboratory SI activity in the United States from then until about 1980. In the early committee notes of the NCCLS comments from the membership on the "Danish nomenclature proposals" ranged from "Well worth supporting . . ." and ". . . generally cau-

ANMC was established under the auspices of the American National Standards Institute (ANSI) in 1973; it became a separate organization in 1976. Among its stated purposes (ANMC 1981) was "to prepare and coordinate industry conversion plans; to keep subscribers and others informed . . . [and] to act as a representative of the private sector. . . ." For the several years after its establishment, the ANMC discussed the units of medicine and the clinical laboratory only as they touched on the engineering problems of the medical and scientific instrument industry. The generally held view that medicine was already using metric units and the failure to appreciate the distinction between customary metric usage and the SI were responsible for the lack of concern with clinical medicine.

In February 1979, the ANMC formed a Biomedical Sector Committee; this was soon reorganized as the Medicine and Health Coordinating Group. This group, which included three of the authors of this book (Huth, Powsner, and Young), adopted guidelines and collected data to prepare for conversion to SI units in medicine. In many respects this book is an outcome of the discussions of the Coordinating Group.

American Medical Association

The AMA was actively involved in the work of the ANMC. At the ANMC's request the AMA organized and initially chaired both the Biomedical Sector Committee and the Coordinating Group. Concurrently AMA representatives to the ANMC proposed that the AMA support use of the SI for U.S. medicine as its stated policy. This proposal was gradually moved forward through AMA committees and councils and, at the interim meeting of 1984, the AMA House of Delegates adopted the report of the AMA Council on Scientific Affairs, which included these principal recommendations (AMA 1984):

> A one-step change to reporting medical laboratory data in SI units in 1987 with the explanation that "This specifically requires the use conceptually of amount of substance where atomic composition is known and . . . the liter as reference volume for all concentrations."
>
> No action to adopt the katal or to change pH or the osmole, both of which were to be retained.
>
> Advising the Pharmaceutical Manufacturers Association of the desirability of dispensing drugs of known chemical composition in mole units.
>
> The AMA "develop and implement an educational effort for all physicians to assist them in making an error-free clinical conversion to SI units."

The report was adopted on the consent calendar in December 1984. Despite the lack of floor debate, support had not been unanimous. Indeed,

---

tious but favorable . . ." to " . . I confess as an elderly clinician who has passed thru the phases of reporting values in mgm% to milliequivalents/liter and now to mmol/L, I would view these proposals with some alarm." No agreement was reached on this or on subsequent proposals for SI units in the clinical laboratory. By 1983 the NCCLS Board of Directors concluded that a consensus could not be reached, published the proposal as a committee report (NCCLS 1983), and suggested informally that the ANMC was the proper forum in which to continue the discussion.

the report of the Council of Scientific Affairs had been strongly opposed by several state delegations and by a number of pathologists. Three resolutions to reverse the new policy were submitted prior to the July 1986 AMA meeting. One asked for a "delay of the effective date and/or broad implementation" of the SI for clinical chemistry. Another expressed concern about a "lack of practical need [for the SI] in daily patient care" and proposed that "the AMA House [of Delegates] oppose adoption of SI units."

Over the next year and after further committee debate, the matter was again argued by the AMA Board of Trustees during the July 1987 AMA meeting. In the end the continuing controversy proved to be more than the Board wished to handle; it simply reported that the AMA "should not pursue a leadership role in medical SI unit conversion."

Despite the withdrawal of overt AMA support, a valuable objective of the 1984 resolution had been preserved, namely, the authorization for AMA journals to use SI units. George Lundberg, editor of *Journal of the American Medical Association*, was now able to require authors to use SI units in the journal. He argued that SI units were needed if the journal was to retain its foreign subscribers; by 1987 it was published in non-English versions in other countries. Other major American medical journals were also either requiring or accepting SI units, notably *American Journal of Clinical Pathology, Annals of Internal Medicine, Clinical Chemistry*, and *The New England Journal of Medicine.*

Current Use of SI Units in Clinical Laboratories

Except for the United States and a few small countries, official usage of metric units around the world generally follows the 1977 WHO recommendations (WHO 1977) for SI units. Canada, for example, published its official SI manual (MCC 1981) in 1981 and later a second, "final" edition (MCC 1982). In the same year hospitals and laboratories in the Hamilton, Ontario, region converted to SI units, and the rest of the province followed in April 1983. Not incidentally, several of the Canadians who prepared or implemented the conversion plans contributed to the discussions or participated at several of the American meetings noted above, both those of the ANMC and, subsequently, those of the AMA. Canadian laboratories now generally report with SI units.

The widely accepted laboratory surveys (CAP 1996) distributed by the College of American Pathologists are provided in SI units for users in other countries. With these and a few other exceptions, SI usage in the United States has been very limited; most U.S. hospitals and laboratories continue to use the older metric units.

Journals, Medical Schools, and the Future of SI Units in the United States

The use of the SI in some U.S. medical journals and the teaching of the SI in medical schools are important steps leading to a wider conversion to SI

units. The process is slow but is likely to continue. There is a parallel with the shift from apothecaries' units to metric units during and after World War II. At the end of the war many departments of pharmacology were teaching with metric units while most clinicians were still writing prescriptions and hospital orders with apothecaries' units. For the next several decades an increasing number of recent graduates were using metric units whereas older clinicians continued with apothecaries' units. The shift continued and apothecaries' units are now little more than a memory. A few older clinicians may still think of a morphine dose as "one sixth of a grain," but even they prescribe antibiotics in milligrams. Similarly, as new graduates are increasingly accustomed to the SI and reports of new laboratory tests appear in moles per liter, the older customary metric units can be expected to disappear.

The second impetus to a shift to SI units in medicine in the United States is the growing international movement of medical information, most readily seen in the growing publication of papers from U.S. authors in non-U.S. journals insisting on the use of SI units and of papers in U.S. journals from non-U.S. authors with their national preferences for SI units. The rising use of medical information transmitted via the Internet will also surely contribute to a growing acceptance of SI among U.S. clinicians.

References

[AMA] American Medical Association, Council on Scientific Affairs. 1984. Council report: SI units for clinical laboratory data. Chicago: AMA.

[ANMC] American National Metric Council. 1981. Bethesda (MD): ANMC. ANMC fact sheet nr 81-01-15.

Barclay WR. 1980. Medicine, metrication, and SI units. JAMA 244:241-2.

[CAP] College of American Pathologists. 1996. Clinical chemistry survey. Northfield (IL): CAP.

Danloux-Dumesnils M. 1969. The metric system: a critical study of its principles and practice. London: Athlone Pr.

Dybkaer R. 1974. Quantities and units in clinical chemistry: recommendation 1973. Pure Appl Chem 37:549.

Dybkaer R. 1979. Approved recommendation (1978): quantities and units in clinical chemistry. Clin Chim Acta 96:157F-83F.

Dybkaer R, Jorgensen K. 1967. Quantities and units in clinical chemistry including Recommendation 1966 of the Commission on Clinical Chemistry of the International Union of Pure and Applied Chemistry and of the International Federation of Clinical Chemistry. Copenhagen: Munksgaard.

[EB] *Encyclopedia Britannica*. 1987. Measurement and observation. In: Encyclopedia Britannica. 15th ed. Volume 23, Macropaedia. Chicago: Encyclopedia Britannica. p 787-9.

[MCC] Metric Commission Canada, Section 9.10 Health and Welfare. 1981. The SI manual of health care. Ottawa (ON): MCC.

此为试读,需要完整PDF请访问: www.ertongbook.com