MEDICAL PRACTICE

Contemporary Themes

SI Units

D. N. BARON

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In the United Kingdom doctors are now accustomed to using the metric system in patient care. Height in centimetres, mass in kilogrammes, temperature in degrees Celsius, dose in millilitres, and other non-imperial measures have all been accepted over the last five years. Laboratory reports have used metric measures, such as concentration in mg/100 ml (or mg/100 cc), for fifty years or more.

The original metric system, which has been in wide international use for a hundred years, was based on three independent base units, those of length (centimetre), mass (gramme), and time (second). In the early 1900's this system was found to be inadequate for many measurements in physics, including electromagnetism, and an amended system based on the metre, kilogramme, and second plus a further base unit, the ampere (the unit of electric current), was introduced and widely accepted in science. This system in its turn proved unable to encompass many newly developing fields of science and three additional base units were found to be needed in order to bring thermodynamics, illumination, and physical chemistry into a single universal and coherent system.

In 1960 the international organization responsible for units and measurements, the General Conference on Weights and Measures (C.G.P.M.), authorized the revised and extended metric system for general use as the "Système International d'Unités (SI)."¹ Since 1960 a few minor changes have been made to SI, and this is now the internationally accepted "language" for measurements throughout science and industry.

Units

The independent base units of SI are:

<i>Physical Quantity</i>	<i>Name of SI Unit</i>	<i>Symbol for SI Unit</i>
length	metre	m
mass	kilogramme	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

There are also the supplementary units of radian [plane angle] and steradian [solid angle].

The mode of presentation is standardized. Symbols are printed without a full stop (except at the end of a sentence) and do not alter in the plural. Decimal multiples and submultiples of the units are formed by prefixes, most of which are familiar:

<i>Multiple</i>	<i>Prefix</i>	<i>Symbol</i>	<i>Submultiple</i>	<i>Prefix</i>	<i>Symbol</i>
10 ¹²	tera	T	10 ⁻¹	deci	d
10 ⁹	giga	G	10 ⁻²	centi	c
10 ⁶	mega	M	10 ⁻³	milli	m
10 ³	kilo	k	10 ⁻⁶	micro	μ
10 ²	hecto	h	10 ⁻⁹	nano	n
10 ¹	deca	da	10 ⁻¹²	pico	p
			10 ⁻¹⁵	femto	f
			10 ⁻¹⁸	atto	a

The decimal point is a full stop or comma on the line, and in continental Europe the comma is almost universally used. A raised point is a multiplication sign. In the writing of large numbers, groups of three figures are to be separated by a space and not by a comma which may be a decimal point. Thus two-million-five-hundred-thousand is 2 500 000 or 2.5×10^6 or $2,5 \times 10^6$. When there is a combination of units the divider ("per") may be expressed as a single solidus or by the use of negative powers. Thus grammes per metre squared is g/m² or g·m⁻²—the raised multiplication point is optional but makes for clarity. With more than two

CONVERSION SCALES (1)
Traditional to SI units

CHEMICAL PATHOLOGY: BLOOD PLASMA

CONVERSION SCALES (2) Traditional to SI units

CHEMICAL PATHOLOGY: BLOOD PLASMA

PROTEINS
Total and Albumin

PBI

CORTISOL

URINE

OESTRIOL
("Oestrogens")

GENERAL MEASUREMENTS

HEIGHT

MASS

Normal ranges

TEMPERATURE

VOLUME

ENERGY

PRESSURE

units, ambiguity can best be avoided by negative powers. Thus grammes per metre squared per hour is $\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$ or $\text{g}/\text{m}^2\cdot\text{h}$.

Other units are derived from the base units by division and multiplication without numerical factors being involved. A new derived unit is that for force, the newton (N). One newton is the force which gives a mass of one kilogramme an acceleration of one metre per second squared— $1\text{ N} = 1\text{ kg}\cdot\text{m}\cdot\text{s}^{-2}$. There is a new unit of pressure, the pascal (Pa). One pascal is the pressure exerted by one newton acting on an area of one metre squared— $1\text{ Pa} = 1\text{ N}\cdot\text{m}^{-2}$. The universal unit for energy is the joule (J). One joule is the work done by a force of one newton acting over one metre— $1\text{ J} = 1\text{ N}\cdot\text{m}$.

In addition a few special units are accepted as convenient working units. Though the derived base unit for volume is the metre cubed (m^3), this is inconveniently large for many purposes. The familiar litre (l), being an alternative name for the decimetre cubed (dm^3), will remain in use with its submultiples for volume measurements in medicine. The kelvin temperature interval is identical with the degree Celsius temperature interval ($^{\circ}\text{C}$), but the kelvin scale starts at absolute zero (-273.16°C). This is inconvenient to the familiar Celsius scale, starting at the freezing point of water (0°C), will be retained in medicine for all clinical purposes. "Celsius" is preferred to "centigrade."

Why should British Medicine go over to SI?

The use of SI completes the process of metrication, which will mean that all industry and science throughout the world will be using the same language for its measurements. Thus error and confusion will be diminished. In medicine all numerical information on patients will be comparable, with great benefits to doctors and patients as medical science and the practice of medicine continue to become more international. The use of SI will mean that medical science and practice will work in parallel with the basic sciences, where the advantages of SI are now accepted. Guide lines on the use of SI for medical publications have been issued.² The present generation of entrants to medicine have learnt only SI at school and for them non-SI units are unfamiliar.

The problems of conversion affect first of all pathology and other branches of laboratory medicine, and many results expressed in SI units on patients will at first be unfamiliar. An interdisciplinary working party has been considering the problems since 1970,^{3,4} but in this field the lead seems to have been taken by Western Europe and Australia. The United States is beginning to consider conversion.⁵

Some Practical Effects

The litre will be the reference unit of volume for all concentrations and cell counts. Molar concentrations will be used for almost all substances measured, excluding only those of uncertain relative molecular mass (mainly proteins) either of the whole molecule or of the active unit. The concentration of haemoglobin in blood will be expressed as

g/dl —a decilitre being 100 millilitres. The mole is the amount of a substance that contains a standard number of specific particles (referred to the mole of ^{12}C atoms, which has a mass of 12 g exactly), whether atoms, ions, molecules, or radicals.

As the physiological and pharmacological activity of a substance is normally proportional to the concentration of molecules or ions present and not to the mass concentration, the use of the mole expresses concentration in biologically relevant terms. The mole avoids certain ambiguities in the use of the equivalent, and brings in non-ionized substances whose concentration could not be expressed on the equivalent scale. For monovalent ions—for example, Na^+ —one mole is numerically the same as one equivalent. As the molar mass of calcium ions is 40 g a plasma calcium concentration of 10 $\text{mg}/100\text{ ml}$ becomes 2.5 mmol/l ; as the molar mass of glucose is 180 g, a plasma glucose concentration of 90 $\text{mg}/100\text{ ml}$ becomes 5.0 mmol/l ; and as the molar mass of phenobarbitone is 232 g, a plasma phenobarbitone concentration of 46 $\text{mg}/100\text{ ml}$ becomes 0.2 mmol/l . The mole system is difficult to apply to substances of ill-defined molecular weight, or to mixtures.

The change-over date will vary according to the convenience of individual hospitals and laboratories. The introduction of SI will need much local discussion and consideration of requirements for new forms and conversion tables. Local educational programmes are important, but these will also be the responsibility of training organizations at all levels. Outside laboratory medicine the main changeover from imperial units to metric units has already been established and there would be advantages in working towards a common change-over date for all medicine. As related sciences make the change from calorie to joule (for heat energy from food is no different from any other energy) so will medicine. Though the pascal will be used for purposes of calculation and in medical literature (for blood pressure is no different from any other pressure), simple column measurements expressed as millimetres of mercury or centimetres of water will remain in common medical practice for some considerable time to meet clinical convenience and understanding and until new instruments are available and accepted.

The D.H.S.S. has circulated all possible medical and related user organizations for their views on the implementation of SI before working out the change over. There are plans for the preparation of a booklet for the widest possible circulation to explain the principles and practice of SI in relation to medicine. A pocket conversion card will also be needed until new "normal ranges" become familiar. It is expected that the change to SI units will be complete in British medicine by autumn 1975.

References

- 1 British Standards Institution, *The Use of SI Units*. PD 5686. B.S.I., London, 1965.
- 2 Ellis, G. (editor), *Units, Symbols and Abbreviations*. Royal Society of Medicine, London, 1972.
- 3 Royal College of Pathologists' Working Party, *Journal of Clinical Pathology*, 1970, 23, 818.
- 4 Baron, D. N., *Journal of Clinical Pathology*, 1973, 23, 729.
- 5 Young, D. S., *New England Journal of Medicine*, 1974, 290, 368.