DEPARTMENT OF EDUCATION

METHOD OF CALCULATING THE PERCENTAGES OF INDIVIDUAL ANESTHETIC AND THERAPEUTIC GASES CONTAINED WITHIN AN ADMINISTERED MIXTURE

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Foreword:
With the advent of machine-administration of anesthetic and therapeutic gases, the need for calculating the percentage of the several gases embodied within an administered mixture, became an important part of anesthesia technique.

Whereas such “percentage” computations had been unnecessary in the administration of drop ether (the local irritant reaction of which promptly warned the anesthetist of approaching high concentrations, before the tension of the vapor reached apnoeic levels) such clearly evident advance forewarning did not always present itself at the administration of sub-oxygenated nitrous oxide mixtures to certain individuals, (anemic, icteric, et cetera); or at the administration of high concentration carbon dioxide mixtures to unconscious patients. In the case of nitrous oxide-oxygen mixtures, “uncalculated percentage” administration could result in initial delivery of asphyxial tensions of the mixture. In the case of mixtures containing carbon dioxide, “uncalculated percentage” administration could result in accidental delivery of damaging concentrations of that agent. In the case of mixtures containing potent cyclopropane, uncalculated percentage administration could result in the presentation of toxic concentration of that gas to the patient. “Uncalculated percentage” administration of combinations which includes helium (a simple asphyxiant when administered without a sufficient accompanying protection of oxygen) could result in damage from anoxia.

Obviously, the calculation of percentages of the gases embraced within a delivered mixture became a highly important function of the anesthetist who administered these modern anesthetic and therapeutic gases. In computing the percentage of an individual gas contained within a given mixture, it is to be borne in mind that a statement of the “percentage concentration” of that gas represents its relation to the entire mixture of gases, not merely to one other gas contained within the mixture. In the past, confusion was introduced when literature stated, and some anesthetizing machines were calibrated in, graduations which indicated the percentage of oxygen merely in terms of its relation to one anesthetic gas contained in the mixture, instead of to the total volume of the mixture of gases which was to be delivered to the patient.

As an illustration of the earlier technique: administration of a mixture composed of “130 gallons of nitrous oxide” and “26 gallons of oxygen,” was stated by some writers (and was indicated by some machine calibrations) to contain 20 per cent of oxygen; whereas in reality such mixture contained only 12.82 per cent of oxygen. What was meant by the statement of those commentators, and by the calibration of the machines, was that the mixture contained 20 per cent as much oxygen as it did nitrous oxide, which is an entirely
different thing than the *physiologically* important factor of the percentage of oxygen contained within the total breathed mixture.

**Method of Calculation of Percentage:**

To calculate the percentage of a given gas contained within an administered mixture, the *total volume* of flow of the *combined* gases is noted as the basis of the calculation. Such total flow, representing as it does the *entire amount*, constitutes 100 per cent. For example: if anesthesia is being induced by an administrative mixture consisting of 4 liters of nitrous oxide and 1 liter of oxygen, the *total volume* of gases (5 liters) becomes the basis of the calculation, as constituting 100 per cent of the flow. Of this total flow of 5 liters, the 4 liters of nitrous oxide constitute 4/5 or 80 per cent of the total flow. The liter of oxygen constitutes 1/5 or 20 per cent of the total flow. Similarly, if anesthesia is being maintained by valvular mask continuous flow method, with a mixture consisting of

\[
\begin{align*}
2\ 1/2 \text{ liters nitrous oxide} & \quad (2500 \text{ cc.}) \\
1/2 \text{ liter oxygen} & \quad (500 \text{ cc.})
\end{align*}
\]

the *total volume* of 3 liters (3000 cc.) constitutes 100 per cent. Of this total flow of 3000 cc., the 2500 cc. of nitrous oxide constitute 2500/3000 or 83-1/3 per cent, whereas the 500 cc. of oxygen represent 500/3000 or 16-2/3 per cent of the mixture.

Illustrating further: if hyperventilation is being conducted by administration of a mixture consisting of

\[
\begin{align*}
2 \text{ liters oxygen} & \quad (2000 \text{ cc.}) \\
2 \text{ liters helium} & \quad (2000 \text{ cc.}) \\
400 \text{ cc. carbon dioxide} & \quad (400 \text{ cc.})
\end{align*}
\]

the *total delivery* of 4400 cc. constitutes 100 per cent of the administered mixture. Of this 4400 cc. total flow, the 2 liters (2000 cc.) of oxygen constitute 2000/4400 of the flow, or 45.45 per cent of the mixture administered (45 per cent plus). Similarly, the 2 liters of helium constitute 2000/4400 of the flow, or 45.45 per cent. The 400 cc. of carbon dioxide constitute 400/4400 of the flow, or 9.09 per cent of the administered mixture.

**NOTE:** As a reminder of the rule for converting common fractions into per cent, such rule is here re-stated:

**Rule No. 1.** "To convert a common fraction to per cent, multiply the numerator by 100 (by adding two ciphers), then divide by the denominator."

**Illustrations:**

\[
\begin{align*}
4/5 \quad (\text{four-fifths}) & = 4 \times 100 = 400; \ 5)400 \\
& = 80\% \ \text{(eighty percent)}
\end{align*}
\]

\[
\begin{align*}
1/5 \quad (\text{one-fifth}) & = 1 \times 100 = 100; \ 5)100 \\
& = 20\% \ \text{(twenty percent)}
\end{align*}
\]

As a reminder of rules for converting common fractions *first* to "decimal fractions" and then to percent, the following are stated:
Rule No. 2: "To convert a common fraction to a decimal, divide the numerator by the denominator."

*Illustrating Rule No. 2:*

\[
\begin{align*}
4/5 & = 5)4.00 \\
1/5 & = 5)1.00 \\
\end{align*}
\]

.80 (eight tenths) or (eighty hundredths)
.20 (two tenths) or (twenty hundredths)

Rule No. 3: "To express a decimal fraction as per cent, move the decimal point two places to the right and add the word or symbol per cent (\%)."

*Illustrating Rule No. 3:*

The decimals "eighty hundredths" and "twenty hundredths" are converted to "percent" by moving the decimal point two places to the right and adding the percent designation:

.80 (eighty hundredths) = 80% (eighty percent)
.20 (twenty hundredths) = 20% (twenty percent)

In Conclusion:

The importance of calculating the percentage of individual gases contained within an administered mixture is at once apparent, when the student bears in mind some basic pharmacological facts, such as:

(a) Adequate oxygen concentration in a breathed mixture is of vital importance *physiologically*. (Anoxemic mixtures must be meticulously avoided).

(b) Nitrous oxide, being of relatively low anesthetic potency, is usually administered at a high concentration that is near to the tension at which by encroaching upon required oxygen tension, it could introduce asphyxial damage.

(c) Carbon dioxide introduces *toxic* reactions if permitted to constitute too high a percentage of (reach too high a concentration in) an administered mixture.

(d) Helium, while an inert gas, acts as a simple asphyxiant when permitted to constitute too high a percentage of a breathed mixture, (when its percentage is permitted to encroach too far upon the physiologically necessary tension of oxygen in an inspired mixture).

**ADDENDA**

**Arithmetical Terminology**

The word "percent" (written symbol \%) is derived from the Latin words per centum, meaning "by the hundred." Its translation into our usage might be stated as *hundredths of a whole*. To illustrate, "twenty-one percent" (21%) is merely another way of stating 21/100 (twenty-one hundredths). That value may be written in several ways, according to the system used, for instance,

- as a "common fraction," 21/100 (twenty-one hundredths)
- as a "decimal fraction," 0.21 (twenty-one hundredths)
- as "percentage," 21% (twenty-one percent)

An examination of the last two forms tabulated above, develops the fact that when the designation "percent" (\%) is used, the "decimal point" of the
“decimal fraction” is moved two places to the right, (thus multiplying that
decimal fraction by one hundred) and then designating the result as percent.
(either using the word “percent” or its symbol “%”). At this point, a few
reviewing definitions relating to arithmetical terminology may be timely.

A fraction is a part of anything that as a base is considered to be an en-
tirety. In other words, a “fraction” is a “portion” of a “whole.”

A common fraction is the designation of a numerical value by means of
a number above and a number below a “fraction line.” To illustrate:—

\[
\frac{1}{4} \text{ (one fourth), } \frac{3}{20} \text{ (three twentieths), } \frac{45}{100} \text{ (forty-five hun-
dredths), } \frac{755}{1000} \text{ (seven-hundred-and-fifty-five thousandths)}
\]

The numbers above the fraction lines (1, 3, 45, 755) are the numerators
(announcing the number of units contained within the fraction); the numbers
below the fraction lines (4, 20, 100, 1000) are the denominators (denoting the
size of units into which the whole has been divided).

Decimal fractions. When the denominators of fractions are tenths, hun-
dredths, thousandths, ten-thousandths, et cetera, the numerators may be written
without the denominators, those denominators being replaced by the use of
a “decimal point” and suitable ciphers. Thus in the decimal system, “common
fractions” whose denominators are 10, 100, 1000, 10,000, et cetera, could be
written as “decimal fractions,” as follows:

\[
\begin{align*}
\text{one tenth} & \quad 1/10 \quad = \quad 0.1 \\
\text{one hundredth} & \quad 1/100 \quad = \quad 0.01 \\
\text{one thousandth} & \quad 1/1000 \quad = \quad 0.001 \\
\text{one ten-thousandth} & \quad 1/10000 \quad = \quad 0.0001
\end{align*}
\]

Decimal fractions are more convenient to use than common fractions for or-
dinary arithmetical calculations (addition, subtraction, multiplication, division,
et cetera).

Recapitulating the foregoing, and extending it to our calculations of gas
percentages, it will be seen that the first step in our calculation consists of
resolving the various gas flows to common fractions \((4/5, 1/5, 2000/3000,
500/3000)\) (pages 39 and 40) and then converting those common fractions to deci-
tmal fractions; then expressing those decimal fractions in terms of per cent
in conformity with customary terminology.

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