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Short Communication

Dilution Formulas in Nurses' Practice

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Highlights

- The responsible of the dilution of medicines in the clinical environment is the clinical nurse.
- The available literature approaching the use of mathematical formulas in the preparation of medicines to nurses is scarce
- The dilution formula is a simple but mostly unknown by clinical nurses, here we show a few uses
- The preparation of hypertonic saline in base of NaCl 0,9% is safer but difficult to calculate, here we demonstrate an accurate formula for its preparation

Introduction

The solutions used in the clinical practice are not always prepared in the required concentration. The responsible of the dilution is the clinical nurse. The available literature in this subject is focused mainly for pharmacists and not for nurses. This work aims to show the clinical utility of two mathematical formulas in the nursing practice.

Dilutions

To dilute is the act of decreasing the concentration of a solution by adding a solvent. When diluting, the mass of the solute remains constant, while the volume of the solvent and the concentration (Weight/volume in this case; since it is the most used form in clinical practice) vary.

Concentration (weight/volume)	$\frac{\text{Mass (Solute)}}{\text{Volume (Solvent)}}$	$\rightarrow \text{Mass} = \text{Concentration} \times \text{Volume}$
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The mass is constant both at the beginning and at the end of the process, so we obtain:

$$\begin{aligned} \text{Initial mass} &= \text{Final mass} \\ \text{Initial Concentration} \times \text{Initial volume} &= \text{Final concentration} \times \text{Final volume} \end{aligned}$$

This formula is well-known by pharmacists, biochemicals, and biomedical researchers. However, it is also useful in nursing practice; for example, to prepare hypertonic nebulization, where a concentration of 3% in 4 mL volume is required [1]. Diluting 10% NaCl in double distilled water:

$$C1 \times V1 = C2 \times V2 \rightarrow 10\% \times V1 = 3\% \times 4 \text{ mL} \rightarrow V1 = \frac{3\% \times 4 \text{ mL}}{10\%} \rightarrow V1 = 1,2 \text{ mL}$$

That is, 1.2 ml of 10% NaCl must be diluted in double distilled water to obtain 4 ml of 3% NaCl. This formula can also be used to dilute sodium bicarbonate (NaHCO₃). NaHCO₃ can be found at 1 molar, 2/3 molar or 1/6 molar concentrations, which have an osmolarity (mOsm/L) of 2000, 667 and 334, respectively. At 1 molar concentration is highly vesicant and its extravasation is complex to handle, so its administration by Peripheral Venous Catheter (PVC) is not recommended [2], at 2/3 molar its concentration is 0.67 mEq/mL, which is above the recommended limit (0.5 mEq/mL) [2]. Therefore, to administer by PVC it is preferred to 1/6 molar, however, this solution is not always available and is obtained by diluting NaHCO₃ 2/3 molar:

$$C1 \times V1 = C2 \times V2 \rightarrow \frac{2/3 \text{ M} \times 250 \text{ mL}}{1/6 \text{ M}} = V2 \rightarrow V2 = 1000 \text{ mL}$$

That is, 250 ml of 2/3 molar NaHCO₃ should be diluted in 750 mL in 5% glucose serum (5% SG, recommended diluent [2] to reach 1/6 molar, in other words, in a 1:3 ratio. As the 5% SG does not provide the same solute to the solution, it can be considered as only a diluent. The formula described above could be used to prepare hypertonic saline (NaCl 3%), nevertheless, double-distilled water is required as a base. The use of double-distilled water causes reticence because its intravenous administration can be fatal and, although it can be done taking the necessary precautions during its preparation, it has been described that the nurse is interrupted during her functions with high frequency [3,4], and that this makes it easier for you to make mistakes during your activities [3], especially in critical patient units [5] which is where these solutions are usually prepared. Therefore, the preparation using 0.9% NaCl as a base is safer.

Preparation of Hypertonic Saline Based On 0.9% NaCl

The formula above can be used only when dilution is made. The 0.9% NaCl provides the same solute to the preparation, so it is necessary to apply another formula for its calculation. For this, we must initially consider that, from the mixture of two solutions of the same solute, a new solution will be obtained at a certain concentration, different from those used in its preparation. This can be expressed:

H + L = T
H: High concentration solution
L: Low concentration solution
T: Target concentration solution

$$(Volume H \times Concentration H) + (Volume L \times Concentration L) = (Volume T \times Concentration T)$$

Since the concentrations of the solutions are pre-fixed, its impractical to advance based on them. Manipulating the volume to be mixed is something done routinely by the nurse, so we can base our calculus on volume. So:

$$Volume H + Volume L = Volume T \rightarrow Volume L = Volume T - Volume H$$

By replacing this in the previous formula we get:

$$\begin{aligned} & (VH \times CH) + (VL \times CL) = (VT \times CT) \\ & (VH \times CH) + [(VT - VH) \times CL] = (VT \times CT) \\ \text{Developing:} \quad & (VH \times CH) + (VT \times CL - VH \times CL) = (VT \times CT) \\ & VH \times CH - VH \times CL = VT \times CT - VT \times CL \\ \text{Factoring:} \quad & VH (CH - CL) = VT (CT - CL) \\ & VT = \frac{VH (CH - CL)}{(CT - CL)} \end{aligned}$$

VH: Volume H
VL: Volume L
VT: Volume T
CH: Concentration H
CL: Concentration L
CT: Concentration T

This is the same conclusion previously obtained by another author [6]. Applying it to an example: How much SF and 10% NaCl should we mix of to prepare 500 mL of 3% NaCl?

$$Y = 500 \text{ mL} \times \left(\frac{3\% - 0,9\%}{10\% - 0,9\%} \right) \rightarrow Y = 500 \text{ mL} \times \left(\frac{2,1\%}{9,1\%} \right) \rightarrow Y = 500 \times 0,23 \rightarrow Y = 115 \text{ mL}$$

Where "Y" corresponds volume of the solution with the highest concentration. In this way, it is concluded that 115 mL of 10% NaCl and 385 mL of 0.9% NaCl are required. This can be checked:

$$115 \text{ mL} \times 10\% = 11,5 \text{ g NaCl} \quad \boxed{14.965 \text{ g NaCl}} \rightarrow 14.965 \text{ g NaCl} / 500 \text{ mL} \rightarrow 2,993\% \approx 3\%$$
$$385 \text{ mL} \times 0,9\% = 3,465 \text{ g NaCl}$$

Discussion

The present work aims to promulgate two formulas to calculate the dilution of medicines made by nurses and demonstrate their usefulness in practice.

It is interesting the scarce bibliography available regarding this particular topic. One of the few jobs available was published by Fandiño [6]. The formula he described is the same one developed in this work, with the difference that his results were based on the percentage variation of concentration in the final solution, in relation to each one of the initial solutions, while the work presented here is based on chemical definitions and mathematical operations. In his work, Fandiño also mentions that, on his experience, he has noticed the difficulty of the nursing staff to perform such calculations. In my case (in a subjective way), I have also been able to notice it. A probable explanation for this fact is that his work has been published recently. Further studies are needed, both from the academy and from clinical practice, to validate whether performing the pre- preparation calculation provides benefits in terms of safety and accuracy, and if it is feasible to perform them in the healthcare environment.

The most notable pathophysiological context where this formula is useful is in the management of Intracranial Hypertension (HIC). Hyperosmolar solutions are considered as a cornerstone in the management of HIC. To the date, it has been shown that Hypertonic Saline (HS) effectively reduces intracranial pressure [7] without causing hypervolemia, osmotic diuresis, or hypotension, as it is caused by mannitol [8]. However, when administering HS there is the limitation of its hyperosmolarity. HS has been studied at concentrations ranging from 2% to 23.4% [9], and, currently, the FDA has approved the use of 3% and 5% concentrations for the management of HIC [10]. A recent study has shown that administration of 3% HS by peripheral venous route (16 G to 20 G caliber) produces 10% of adverse events, which are minor (Phlebitis or Extravasation) [11]. Although this work was carried out in a small cohort of patients (n = 28), the

results encourage further studies to avoid the installation of a central venous catheter with the only justification of deliver HS. Moreover, this fact is being discussed since, on certain occasions, it doesn't seem necessary to hospitalize patients in the ICU if they are only going to receive treatment with HS; as long as it is verified that the natremia rises <12 mEq/day, the management can be carried out safely by PVC in a non-intensive unit [12]. In fact, the administration of boluses between 100-150 mL of 3% NaCl is recommended, but that fact already escapes the focus of this work.

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Declarations of Interest

None declared.

Ethical Approval

Not applicable

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