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ORIGINAL ARTICLE

# Validation the use of refractometer and mathematic equations to measure dietary formula contents for clinical application

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**KEYWORDS**
Refractometer;
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**Summary**
*Background & Aims:* Gastric residual volumes are widely used to evaluate gastric emptying for patients receiving enteral feeding, but controversy exists about what constitutes gastric residual volume. We have developed a method by using refractometer and derived mathematical equations to calculate the formula concentration, total residual volume (TRV), and formula volume. In this study, we like to validate these mathematical equations before they can be implemented for clinical patient care.
*Methods:* Four dietary formulas were evaluated in two consecutive validation experiments. Firstly, dietary formula volume of 50, 100, 200, and 400 ml were diluted with 50 ml water, and then the Brix value (BV) was measured by the refractometer. Secondly, 50 ml of water, then 100 ml of dietary formula were infused into a beaker, and followed by the BV measurement. After this, 50 ml of water was infused and followed by the second BV measurement. The entire procedure of infusing of dietary formula (100 ml) and waster (50 ml) was repeated twice and followed by the BV measurement.
*Results:* The formula contents (formula concentration, TRV, and formula volume) were calculated by mathematical equations. The calculated formula concentrations, TRVs, and formula volumes measured from mathematic equations were strongly close to the true values in the first and second validation experiments ($R^2 > 0.98$, $P < 0.001$).

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*Conclusions:* Refractometer and the derived mathematical equations may be used to accurately measure the formula concentration, TRV, and formula volume and served as a tool to monitor gastric emptying for patients receiving enteral feeding.


## Introduction

Gastric residual volumes, obtained by nasogastric tube aspiration, are widely used in clinical practice to evaluate gastric emptying for patients receiving nasogastric tube feeding.[1,2] The gastric residual volume is determined by the dynamic balance between input (endogenous secretions: saliva plus gastric juice and formula delivered) and output (gastric emptying) of the stomach.[3,4] High gastric residual volumes raise concern about intolerance to gastric feeding and the potential risk for aspiration pneumonia.[4] However, controversy exists about what constitutes high gastric residual volume (diet formula or digestive juice), and how it should affect management.[5–7]

The refractive index of a refractometer, also known as the Brix value (BV), is constant for a substance under standard conditions of temperature and pressure.[8,9] The BV, a measure of total soluble solids in solution, correlates closely with the molar fractions of the components.[8,9] BVs have been widely used to determine the concentration of substances such as drugs, food, fruit juices, dietary formula, and parenteral nutrition solution.[10–17] Recently, we proposed a theoretical model by using the refractometry and BV measurement to monitor gastric emptying for patients receiving enteral feeding.[11–15] Among these studies, three mathematical equations (Table 1) have been used to measure the formula concentration, gastric residual volume, and formula volume remaining in the stomach.[13–15] However, these mathematical equations should be validated before they can be implemented for clinical patient care. In this paper, we performed the in vitro validation experiment to verify these mathematical equations and hope that they can be used as a bedside tool to monitor gastric emptying for patients receiving enteral tube feeding.

## Materials and methods

### Study samples

Three commercial available feeding formulas Osmolite HN (Ross, Ohio, USA), Resource (Novartis, Minneapolis, MN, USA), Vital HN (Ross), and one hospital-made tube feeding formula were used in this study. The hospital-made tube feeding formula, which contains protein 20.4%, fat 26.3% and carbohydrate 53.0%, was gifted by the Department of Food and Nutrition, Tri-Service General Hospital, Taiwan. The BV measurements were measured by using a hand-held refractometer (Model N.O.W. 507-1, Nippon Optical Works, Tokyo, Japan), with a BV scale of 0–32 that could be read in 0.2 increments. The refractometer was calibrated with distilled water before each measurement. One or two drops of the specimen fluid were placed on a designated window and the BV measurement was made at room temperature using natural light.[14,15]

### Formula concentration calculation[11,14]

BV measurements for the four dietary formulas (Osmolite HN, Resource, Vital HN, and hospital-made feeding formula) were determined by the refractometer. Serial dilutions of the dietary formula (0%, 6.2%, 12.5%, 25%, 50%, 75%, and 100%) were made with distilled water. The BV measurements were made on six different samples for each dilution of the four dietary formulas. The full strength polymeric diet (Osmolite HN) diluted to 0%, 12.5%, 25.0%, 50.0%, 75.0%, and 100% with distilled water had corresponding BVs of $0\pm0$, $3.0\pm0.1$, $6.0\pm0.1$, $12.0\pm0.1$, $17.8\pm0.2$, and $23.2\pm0.3$, respectively ($R^2 = 0.99$, Slope $= 0.23$) (Fig. 1A). Based on this tight linear relationship, the unknown formula concentration could be

**Table 1** Mathematical equations used to calculate the dietary formula contents.

| Measurement | | Mathematical equation | |
|---|---|---|---|
| Formula concentration | = | BV/slope | Eq. (1) |
| Total residual volume (ml) | = | (50 ml × post-dilution BV)/(pre-dilution BV–post-dilution BV) | Eq. (2) |
| Formula volume (ml) | = | Formula concentration × total residual volume | Eq. (3) |

Brix value, BV; Formula concentration = % full strength formula concentration.