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Significant Loss of Macronutrients During Passage Through Feeding Tube: An Observational Study

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ABSTRACT

Objective: Feeding infants born before week 34 of gestation is based mainly on providing nutrition directly to the gastrointestinal tract through a nasogastric tube. Little is known about the impact of formulas passage through nasogastric tube on their macronutrient content. The aim of our study was to evaluate changes in macronutrient content of various formulas after transfer through a feeding tube.

Methods: Eleven frequently used formulas were chosen. Ten consecutive measurements were performed for each formula. Simulated real-life practice tube feeding was performed by using an infusion pump connected to a feeding tube. A Human Milk Analyzer, using an infrared spectroscopy method, was used to compare the preinfusion and postinfusion macronutrient contents of the different formulas.

Results: A total of 220 measurements were performed. Variations in at least one macronutrient were observed in 5 out of 10 formulas. Fat and energy content were modified in 1 preterm formula.

Conclusions: Changes in the macronutrient content after tube feeding transfer were observed for some infant formulas, including those designed for very low birth weight infants. These alterations might relate to specific formulation of each formula. The biological significance of our results to the very low birth weight infants should be studied further.

Key Words: preterm infant, human milk, tube feeding, preterm formula, macronutrient

What Is Known

- Feeding infants born before week 34 of gestation is based mainly on providing nutrition directly to the gastrointestinal tract through a nasogastric tube.
- Previous studies have concluded that tube infusion could decrease the fat content of human milk.
- Little is known about the impact of passage through nasogastric tube on formula composition.

What Is New

- Macronutrient composition of infant formula is altered after passage through a feeding tube.
- These alterations might relate to specific formulation of each formula.

Nasogastric tube (NGT) feeding is necessary in preterm infants who do not have yet mature suck and swallow capability. Suck–swallow coordination, cough, and gag mature only at 32–34 weeks' gestation (1). Gastric feeding in the Neonatal Intensive Care Unit (NICU) can be given via nasal or oral tubes, either as intermittent bolus feeding or as continuous feeding (2). During the process of tube feeding, substantial losses of nutrients may occur due to refrigeration, freezing, heating, adherence to the tubing system, and/or photodegradation (2–10). Previous studies have concluded that tube infusion could decrease the fat content of human milk (HM) (3,5–10). However, little is known about the impact of passage through NGT on the formula composition.

The aim of the present study was to evaluate possible changes in macronutrients content of several standard infant formulae after transfer through a feeding tube. We hypothesized that similar to HM, passage of a formula through NGT leads to a decrease in fat and energy content.

METHODS

Sample Collection

We examined 11 infant formulas commonly used in the NICU at the Tel Aviv Sourasky Medical Center. The formulas that were studied included 2 preterm formulas (Nos. 1 and 2), 4 extensively hydrolyzed formulas (Nos. 3–6), 2 amino acid–based formulas (Nos. 7 and 8), and 3 standard cow's milk–based formulas for term infants (Nos. 9–11). Ten consecutive measurements were performed for each formula by a single investigator (M.A.). Three formulas were ready to feed (RTF, Nos. 1–2, 11) and the other 6 were powder-based formulas (Nos. 3–9, 10). Table 1 depicts the formula tested according to brands and types of formulas. The preparation was done according to the manufacturer's guidelines in a routine manner as per NICU protocol.

Laboratory Methods

The preterm infants in our NICU are fed every 3 hours for a total of 8 meals per day. In the first phase of our study, we measured the average feeding time through gravity drainage of a gastric feeding tube in 22 preterm infants (gestational age ranging

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TABLE 1. Formulas that Were Tested (Brand and Type)

Number	Brand	Protein	Other Ingredients	Type
1	Abbott, RTF Similac Special Care 24	Whey, Casein	LC-PUFA	Preterm formula (24 Cal/flOz)
2	Nestlé, RTF Materna Preterm infants	Whey, Casein	LC-PUFA	Preterm formula (24 Cal/flOz)
3	Abbott Similac Alimentum	Casein	LC-PUFA; no lactose; MCT 33%	Extensively hydrolyzed formulas
4	Mead Johnson Nutramigen stage 1	Casein	LC-PUFA; no lactose	Extensively hydrolyzed formulas
5	Nutricia Nutrilon Pepti Junior	Whey	LC-PUFA; no lactose; MCT 50%	Extensively hydrolyzed formulas
6	Mead Johnson Pregestimil	Casein	LC-PUFA; MCT 55%; no lactose	Extensively hydrolyzed formulas
7	Nutricia Neocate	Amino acid	LC-PUFA; no lactose	Amino acid–based formulas
8	Mead Johnson Nutramigen AA	Amino acid	LC-PUFA; no lactose	Amino acid–based formulas
9	Nestlé Materna Extracare Stage 1	Whey, Casein	LC-PUFA	Cow's milk–based formulas for term infants
10	Abbott SimilacAdvance Stage 1	Whey, Casein	LC-PUFA	Cow's milk–based formulas for term infants
11	Nutricia, RTF Nutrilon stage 1	Whey, Casein	LC-PUFA	Cow's milk–based formulas for term infants

LC-PUFA indicates long-chain polyunsaturated fatty acids; MCT, medium-chain triglyceride; RTF, ready to feed.

from 26 to 34 weeks) who were admitted to our NICU. The average feeding time for a 5-ml HM sample was 14 minutes and 30 seconds. Therefore, simulated real-life practice tube feeding of intermittent bolus was performed by using an infusion pump (Alaris; CareFusion, Becton, Dickinson and Company, NJ) connected to a feeding tube (Metric/x-ray, 40 cm CH 05; Unomedical, Denmark) to transfer 30 ml of formula at a speed of 20 ml/h into 10-ml tubes. For each formula tested, we examined 10 samples before and after each passage through a feeding tube. The NGT was changed after each simulated meal and was not washed by saline or air after the meal. In order to minimize the risk of evaporation, each formula was kept in closed bottles until the analysis. Moreover, we constructed the simulated real-life practice of tube feeding as a "closed system" by connecting the feeding tube to an infusion pump and followed that by measuring the milk composition immediately after it exited the NGT. Analysis of the samples were done using the MIRIS milk analyzer (Uppsala, Sweden), an instrument based on mid-infrared transmission spectroscopy (11), as previously described by us (12–14).

Statistical Analysis

Statistical analyses were performed using Minitab version 16 (Minitab Inc, State College, PA). Paired *t* tests were used to compare macronutrient concentrations in all samples and in each formula before and after tube feeding. Continuous variables were expressed as median and range when not normally distributed and as mean ± SD when normally distributed. Dichotomous variables were expressed as percent/ratio. Stepwise multiple regression analysis was performed to determine the effect between formula type and macronutrients and energy content after tube infusion. A P value ≤0.05 was considered significant.

Ethical Considerations

The study protocol was approved by the institutional review board of the medical center (TLV-0062-11).

RESULTS

A total of 220 measurements were performed. Twenty measurements of 1 of the amino acid–based formulas (No. 8) were excluded from further analysis due to technical error.

Variations in at least 1 macronutrient were observed in 5 out of 10 formulas (Nos. 1, 2, 3, 5, and 6). Fat and energy content were altered in 1 preterm formula (No. 1). Fat content differed in 2 other extensively hydrolyzed formulas (Nos. 3 and 5), whereas carbohydrate content was affected in another extensively hydrolyzed formula (No. 6). Protein and energy content were affected in preterm formula No. 2 (Table 2). Stepwise multiple regression analysis demonstrated that the fat, protein, and energy content after tube infusion were affected by formula type ($P < 0.001$ for all).

DISCUSSION

In the present study, we have been able to demonstrate a small but significant change in the macronutrients content for some infant formulas after tube feeding. Some of these formulas were designed for very low birth weight (VLBW) infants.

It has been known for years that tube feeding may result in quantitative loss of lipids due to separation of milk fat and adherence to tubing and syringe. In theory, since lipids are the major contributor of energy content of formula, a caloric reduction due to fat losses may have deleterious effect upon growth (2). Also, since premature infants have a limited endogenous essential fatty acid pool and limited fat stores, fat losses may lead to essential fatty acid deficiency

TABLE 2. Changes in Macronutrient Content After Tube Feeding Transfer

	Macronutrient	Content Before Transfer*	Content After Transfer*	Loss %	*P*†
Formula No. 1	Fat	5.98 ± 0.09	5.85 ± 0.08	2	0.002
	Protein	2.59 ± 0.03	2.55 ± 0.09	1.3	0.2
	Carbohydrate	6.7 ± 0.1	6.69 ± 0.3	0.1	0.6
	Energy	92.8 ± 0.9	91.4 ± 1.3	1.5	0.007
Formula No. 2	Fat	5.3 ± 0.04	5.28 ± 0.04	0.3	0.3
	Protein	1.58 ± 0.04	1.49 ± 0.03	2.2	0.005
	Carbohydrate	7.33 ± 0.02	7.32 ± 0.1	0.4	0.08
	Energy	67.6 ± 0.69	66.8 ± 0.63	1	<0.001
Formula No. 3	Fat	4.32 ± 0.06	4.25 ± 0.08	1.6	0.04
	Protein	1.62 ± 0.05	1.61 ± 0.05	0.6	0.08
	Carbohydrate	6.26 ± 0.1	6.21 ± 0.07	0.7	0.06
	Energy	70.1 ± 0.56	69.9 ± 0.73	0.2	0.08
Formula No. 4	Fat	3.93 ± 0.04	3.92 ± 0.04	0.2	0.5
	Protein	1.67 ± 0.03	1.66 ± 0.04	0.5	0.1
	Carbohydrate	8.3 ± 0.06	8.28 ± 0.07	0.2	0.5
	Energy	73.1 ± 0.3	72.9 ± 0.3	0.2	0.1
Formula No. 5	Fat	5.2 ± 0.04	5.1 ± 0.06	1.5	0.01
	Protein	1.69 ± 0.03	1.67 ± 0.04	1.1	0.1
	Carbohydrate	8.3 ± 0.06	8.28 ± 0.07	0.2	0.5
	Energy	73.1 ± 0.3	72.9 ± 0.3	0.2	0.1
Formula No. 6	Fat	5.3 ± 0.04	5.3 ± 0.06	0	0.7
	Protein	1.61 ± 0.03	1.59 ± 0.03	1.2	0.1
	Carbohydrate	6.86 ± 0.1	6.64 ± 0.04	3.3	0.002
	Energy	80.1 ± 0.7	79.6 ± 0.8	0.6	0.1
Formula No. 7	Fat	3.17 ± 0.04	3.1 ± 0.1	0	0.1
	Protein	1.2 ± 0.05	1.2 ± 0.03	0	1
	Carbohydrate	6.69 ± 0.1	6.68 ± 0.01	0.1	0.8
	Energy	60.7 ± 1	60.1 ± 0.8	0.9	0.2
Formula No. 9	Fat	3.89 ± 0.03	3.86 ± 0.03	0.2	0. 2
	Protein	1.22 ± 0.04	1.21 ± 0.03	0.1	0.2
	Carbohydrate	6.98 ± 0.06	6.97 ± 0.06	0.1	0.3
	Energy	67.6 ± 0.6	66.8 ± 0.6	1	0.3
Formula No. 10	Fat	3.67 ± 0.04	3.66 ± 0.05	0.2	0.1
	Protein	1.1 ± 0.5	1.1 ± 0.4	0	0.4
	Carbohydrate	7.75 ± 0.07	7.74 ± 0.1	0.1	0.5
	Energy	57.2 ± 0.3	57 ± 0.2	0	0.2
Formula No. 11	Fat	3.16 ± 0.04	3.15 ± 0.1	0.2	0.1
	Protein	1.2 ± 0.05	1.2 ± 0.03	0	1
	Carbohydrate	6.71 ± 0.1	6.7 ± 0.01	0	0.8
	Energy	60.2 ± 1	60.1 ± 0.8	0.1	0.2

Data are presented as mean ± SD.
*Fat, g/100 ml; carbohydrate, g/100 ml; fat, g/100 ml; energy, kcal/100 ml.
†Dependent *t* test.

faster than in term infants or adults (15). These essential fatty acids are known to be critical for adequate brain and retina development of the VLBW infants (15,16).

The results of our study differ from previous studies conducted on this topic. Tacken et al (3) examined triglyceride, α- and β-carotene, lutein, and lycopene concentrations of 30 samples of mature HM from mothers who delivered a term infant and 10 samples of infant formula (3 different infant fluid formulas for preterm infant, no specific fat composition indicated) after refrigeration, freezing, microwave heating, and tube feeding. They found that after tube feeding HM, triglyceride, lutein, and β-carotene concentrations decreased by 33%, 35%, and 26%, respectively. However, no differences were found when using infant formulas. Igawa et al (6) compared preinfusion and postinfusion fat contents of 15 fresh and 10 thawed HM samples and 6 formula samples (brand names and specific ingredients were not mentioned) and found that only thawed and fresh HM postinfusion fat contents were significantly lower, but none of the tested formula samples. They concluded that fat content of infant formulas was not affected by tube size, tube material, or infusion duration (6). In contrast, other studies using slow infusion rates showed a loss of fat up to 40% (17,18). In the study of Greer et al (17), mean fat loss had an inverse relationship with the rate of infusion. Mehta et al (19) measured fat residue in the feeding sets by gravimetry, and individual fatty acids were characterized by gas–liquid chromatography. They found that a major portion of medium-chain triglycerides were lost. This finding suggests that differences in formulation might change the tendency of the fat of a particular formula to adhere to the feeding tube. In our study, we used an intermittent bolus feeding model, and nevertheless, variations in at least 1 macronutrient were observed in 5 out of 10 formulas that were tested in our study. We documented fat loss in 2 extensively hydrolyzed formula and in 1 preterm formula; protein loss in standard cow's milk formula; and carbohydrate loss in 1 extensively hydrolyzed formula. The formulas we tested differed in many aspects, in particular in triglyceride fatty acid composition, in long-chain fatty acid percentage, and in protein type or size (Table 1). Continued study that will examine identical formulas with change in 1 component at a time will help identify the exact component that is responsible for the losses over time.

A strength of our study is its relatively large sample size (the largest that was documented in the literature until now) of formulas that were tested. However, our study has several limitations. First, we do not have longitudinal information on weight gain and development of these infants in order to understand the implication of our result. Another limitation of our study is the fact that we used the near-infrared spectroscopy method of macronutrient evaluation rather than direct biochemistry methods. However, near-infrared spectroscopy method has been shown to correlate quite well with biochemical analyses of milk (20). Moreover, the results of formula compositions at baseline were within the ranges of the manufacturer's published data.

In conclusion, we have shown that the macronutrient composition of infant formula is altered after passage through a feeding tube even at a rate simulating bolus feeding. Larger studies that employ direct biochemistry methods and compare different formulation and feeding practices are needed to better understand the biological significance of our findings as they relate to the VLBW infant, as the preferred practice for tube feeding in preterm infant in order to minimize nutrient loss during administration. If the current results will be verified in larger studies and in different feeding practice, it may be worthwhile to concentrate the formulas or add more volume when they are given to preterm babies through NGTs.

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