Osmolality of modified enteral tube feeds for adults in hospitals across the Western Cape Province

[a] **Schafer L,** BScDiet [a] **Templin K,** BScDiet [a] **Dlamini P,** BScDiet [b] **Kruger JM,** BScDiet, MNutr [a] **Van Wyk E,** BScDiet
[a] Division of Human Nutrition, Stellenbosch University, South Africa
[b] Department of Interdisciplinary Health Sciences, Stellenbosch University and Tygerberg Hospital, South Africa
Correspondence to: JM Kruger, e-mail: ck1@absamail.co.za
Keywords: enteral; tube feeds; osmolality; modular; semi-modular

Abstract

Objectives: The first aim of this study was to determine the incidence of use, reasons for use, and procedures/recipes followed in modifying enteral tube feeds (ETFs) for adults in state and private hospitals across the Western Cape Province (WCP), South Africa (baseline data). The second aim was to determine the osmolality of the modified ETFs used by these hospitals (osmolality data).

Design: A descriptive cross-sectional study.

Setting and subjects: The study was conducted in January/February 2007. The baseline data was collected by means of a coded questionnaire sent to all state and private hospitals in the WCP (n = 111), excluding all children's hospitals. The osmolality data was obtained by means of freeze-point depression of the modified ETF recipes obtained from the participating hospitals.

Results: A total response rate of 94% was obtained. Of the participating hospitals (n = 104), 48% were state (n = 50) and 52% were private hospitals (n = 54). Sixty-two per cent of hospitals (n = 64) made use of ETFs, with 25% modifying their feeds (n = 16). Twelve recipes were obtained for the osmolality testing. Eight recipes (66%) were significantly lower ($p < 0.001$), two (16%) were significantly higher ($p < 0.001$) and two of the recipes did not differ from the standard enteral product. Eight recipes (66%) had a significantly higher average osmolality ($p < 0.001$) than that of body fluid. The concentrated ETF recipe (1.43 kcal/ml) had the highest osmolality (707 mOsm/kg/$H_2$0).

Conclusions: Modular ETFs had lower average osmolality than those of the semi-modular and the standard enteral products, and of body fluid (300 mOsm/kg/$H_2$0).

S Afr J Clin Nutr 2009;22(2):81-87

Introduction

Nutritional support is the delivery of formulated enteral or parenteral nutrients to appropriate patients for the purpose of maintaining or restoring nutritional status.[1] The maintenance of appropriate nutritional support in patients with acute and chronic illness is known to be a fundamental part of patient care. Some patients require specialised nutrition support such as enteral tube feeding (ETF).[2] Enteral tube feeding refers to the provision of nutrients into the gastro-intestinal tract through a tube when oral intake is inadequate.[1] The importance of establishing enteral access, initiating enteral nutrition early and maintaining enteral nutrition therapy is well supported in a number of clinical investigations.[3] Early ETF, in particular, plays a vital role in the hospitalised patient. It prevents mucosal atrophy of the intestine, maintains gut barrier function[1] and ensures optimal nutritional care for patients at risk of developing nutritional deficits.

Polymeric formulae are the most commonly prescribed enteral formulae and contain protein, carbohydrates and fat in the form of whole-protein, partially digested starch and triglycerides, respectively, together with electrolytes, minerals, vitamins and trace elements.[4] Such formulae are used as the sole source of nutrition intake for patients with normal or near normal gastro-intestinal function.[4] An ETF formula generally has a caloric density of 1 kcal/ml and is isotonic, but it may be concentrated to 1.5–2 kcal/ml.[2] There are, however, patients for whom standard enteral formulae may not be optimal and who could benefit from modular formulae. A module consists of a single nutrient or multiple nutrients that can be combined to produce a nutritionally complete feed or given individually to enhance an existing standard enteral formula.

The modular concept allows one to alter the ratio of a constituent nutrient without affecting other nutrients. An enteral tube feed (ETF) can be modified in two possible ways. The first option is referred to as supplemental use (also sometimes referred to as semi-modular) and includes the addition of a nutrient module to a standard enteral formula. These nutrient modules can be used to either increase caloric density or to modify one constituent nutrient without substantially changing the remaining nutritional composition. Modification can also include concentrating a feed; this is when a standard commercial enteral product is prepared at a higher concentration than its standard concentration, i.e. more powder is added to a restricted volume during reconstitution. This is often used in fluid-restricted patients. The second option, referred to as De Novo synthesis (also referred to as modular feeds), involves the combination of separate nutrient modules (e.g. carbohydrate, protein and fat sources) to formulate a patient-specific solution or feed.[5]

Vitamins and/or minerals are also frequently added to these feeds to make them nutritionally more complete.[1] Indications for modular formulae are organ dysfunctions such as renal failure and cardiac failure, where disease-specific formulae are required, as well as acid–base balance and electrolyte disturbances.[2] Although disease-specific enteral products are available commercially; standard enteral products are often modified by some hospitals to meet the highly specialised nutritional requirements of certain individual patients.

Osmolality is a measure of the number of particles of a substance per kilogram of solvent (mOsm/kg), whereas the osmolarity is the measure of the number of particles of a substance per litre of solution.[6,7] Osmolarity is not commonly used in osmometry as it is temperature dependent: the volume changes with temperature.[6] However, if the concentration is very low then osmolarity and osmolality are considered equivalent.[6] Plasma osmolality is a measure of the concentration of substances such as sodium, chloride, potassium, urea, glucose and other ions in human blood. It is calculated as the number of osmoles (Osm) of solute per kilogram (kg) solvent.[6] The normal osmolality of plasma is approximately 280–303 milli-osmoles (mOsm) per kilogram, and is affected by changes in water content.[6] According to Krey and Murray, the particle size and osmolality of an ETF is dependent upon the form and structure of its nutrient components in relation to the total water content of the feed.[8] The degree of hydrolysis of the constituent nutrients greatly influences the osmolality of an ETF, as it contributes to the form and structure of the nutrients.[8] A feed consisting of larger-sized particles such as large starch molecules, long-chain fatty acids and polypeptides will have a lower osmolality, whereas a feed consisting of smaller-sized particles such as disaccharides, short-chain fatty acids, hydrolysed proteins (small peptides) and amino acids will have a higher osmolality.[1]

Currently, there is limited information available on how the methods of modification may influence the osmolality of an ETF and whether a possible increase in osmolality can be related to, for example, the aetiology of ETF-induced diarrhoea, as it is known that osmolality influences the osmotic balance between the intestinal lumen and the vascular system.[1] The possible higher osmolality is of concern, especially as medical literature regards diarrhoea as the most common complication of ETF[8–10] and, although its aetiology is regarded as multifactorial,[9] hyperosmolar formulae could be seen as a *potential* causal factor in gastric stasis and osmotic diarrhoea.[10]

Currently, limited information is available on the use of different ETF products for adults in state and private hospitals across South Africa. There is also a lack of information on the extent to which these products are modified by hospitals, and whether this modification process leads to an increase in the osmolality of an ETF.

This study was undertaken to, firstly, obtain *baseline data* on the incidence of use, the reasons for use, and the procedures/recipes followed in modifying ETF for adults and, secondly, to determine the osmolality of the modified ETFs used by these hospitals (*osmolality data*).

Materials and methods

Design

A descriptive cross-sectional study was carried out from 1 January to 28 February 2007.

Study population and sample selection

The study population for the baseline data comprised patients of all state and private hospitals in the Western Cape Province (WCP) of South Africa, excluding all children's hospitals. A detailed list of all the state and private hospitals (n = 111) was obtained from the hospitals' management groups (Department of Health (DOH)), Netcare, Medi-Clinic, Life Healthcare and Melomed). No sampling was done, as the questionnaire was sent to the entire study population. All recipes received in the questionnares that were used for the osmolality testing, were first sifted according to set criteria and only those that fitted the inclusion criteria were used for determining the osmolality data. Recipes used included those that added items to the standard enteral product, those that used the standard enteral product at a higher concentration, as well as all modular ETF recipes. Semi-modular recipes with items added to another type of enteral product (other than the standard polymeric enteral product) were excluded.

Data collection

Baseline data: A questionnaire was developed and sent to all hospitals (n = 111) in order to determine the baseline data over a two-month period in 2007. The questionnaire consisted of structured and open-ended questions (23 in total) and covered four sections: (1) general information with regards to ETFs in the hospital; (2) ETF products used by the hospital; (3) the use of semi-modular ETFs, and (4) the use of modular ETFs. The questionnaire, available in both Afrikaans and English, included clear instructions for completion and was sent with a pre-stamped envelope, cover letter and letter of authorisation from the hospital's management group. The face validity and efficacy of the questionnaire and cover letter were tested during a pilot study on four dietitians: two from state and two from private hospitals outside the WCP. The questionnaire was pre-coded in order to enable follow-up. A list of all the hospital dietitians in the WCP was also obtained from the Department of Health for the purpose of a follow-up via telephone and/or email in order to encourage the completion of the questionnaire. In the case of hospitals where no dietitians were employed, contact was made with the persons mostly involved with, or responsible for ETFs in the hospitals.

Osmolality data: Prior to testing the osmolality of the modified ETF recipes, the standard enteral product was tested at four different volumes (500 ml, 1000 ml, 1500 ml, 2000 ml) to confirm that a change in volume did not influence the osmolality of a feed. A standard error of 3.08% indicated only a small variation. The assumption was thus made that a change in volume, given that the concentration of a feed is increased proportionately, did not substantially influence the osmolality of an ETF.

Owing to time and financial constraints, the researchers decided on the following: (1) to prepare all recipes at a standard volume of 500 ml; (2) to record the average of 10 sampling observations per recipe, and (3) to compare the modified ETF with a standard enteral product at standard concentration.

The authors prepared two recipes per day in the tube feed preparation unit of Tygerberg Academic Hospital. Ten preparations of each of the two recipes were prepared daily between 10h00 and 11h00 in accordance with the reconstitution protocol of the unit. Each recipe was reconstituted to 500 ml and ten 5–7 ml samples were put in sterile plastic, and individually marked, screw-cap test tubes

(B&M Scientific, South Africa). Thereafter the full batch of 20 samples was immediately transported to the Chemical Pathology Laboratory located at Tygerberg Academic Hospital. A freezing point osmometer (800 cl, Slamed) was used to determine the osmolality of the recipes, using the colligative property of freezing point depression. The laboratory results were obtained daily at 15h00. A normal probability plot was drawn to ensure that the 10 sampling observations of each recipe were distributed according to a normal distribution.

Ethics

The study was approved by the Committee for Human Research of the Faculty of Health Sciences of Stellenbosch University (Nr N06/12/232). Authorisation was acquired from the Department of Health and the hospitals' management groups (Medi-Clinic, Netcare, Melomed, Life Healthcare) for the participation of the state and private hospitals, respectively. The respondents were assured that the identity of the hospitals would remain confidential.

Statistical analysis

The baseline data obtained from the completed questionnaires were analysed using the Statistica 7.111 (2006) program. Frequencies were tallied for the closed-ended questions. For the open-ended questions similar answers were grouped and frequencies tallied. Descriptive and comparative statistics were performed for the osmolality data. The paired t-test was used to compare values that were normally distributed and the Wilcoxon and Bootstrap tests[12] were used for values that were not normally distributed. The first null hypothesis was that the modification of an ETF did not influence its osmolality. The second null hypothesis was that the osmolality of a modified ETF was equal to that of body fluid. A value of $p < 0.05$ was considered to be statistically significant.

Results

Baseline data

Fifty-six participating hospitals returned completed questionnaires (50% response rate). On further follow-up via telephone, relevant information was obtained from another 48 hospitals (44% response rate). This amounted to 104 hospitals in total (94% response rate), of which 50 (48%) were state hospitals and 54 (52%) private hospitals. Of the participating hospitals (n = 104), 64 hospitals (62%) used ETF, while the remaining 40 hospitals (38%) did not. Of the ETF hospitals (n = 64), 16 hospitals (25%) modified their ETF, while the remaining 48 hospitals (75%) did not modify their ETF (Figure 1). Of the ETF hospitals (n = 64), 34 used only powdered ETF (53%), 23 used both powdered and ready-to-hang ETF (36%), four used only ready-to-hang ETF (6%), one only used clear fluids as an ETF (2%), while two hospitals did not specify.

The responses from the ETF hospitals were mostly given by hospital dietitians (67%). Other respondents included nurses (16%), main food service managers (8%), senior food service supervisors (3%), doctors (3%), pharmacists (2%) and hospital managers (2%).

Modified enteral tube feeds

Of the 16 hospitals (n = 16) that modified the ETF, nine only used semi-modular ETF (56%), one only used modular ETF (6%), and six used a combination of semi-modular and modular ETF (38%). In terms of the semi-modular ETF, a variety of additional items were added to the standard commercial enteral products, including: a carbohydrate supplement (93%), protein supplement (73%), long-chain fat sources (46%), medium-chain triglycerides (20%), as well as raw egg (7%) (Figure 2). The types of additional items added to the commercial enteral products during modification are tabled in terms of the structure of the carbohydrate, protein and fat constituents in the different products/items used (Table I).

The majority of hospitals (88%) only modified ETFs when a standard commercial enteral product could not meet the nutritional requirements of individual patients. Semi-modular or modular

Figure 2: Percentage distribution of the types of additional items added to the commercial enteral products during modification

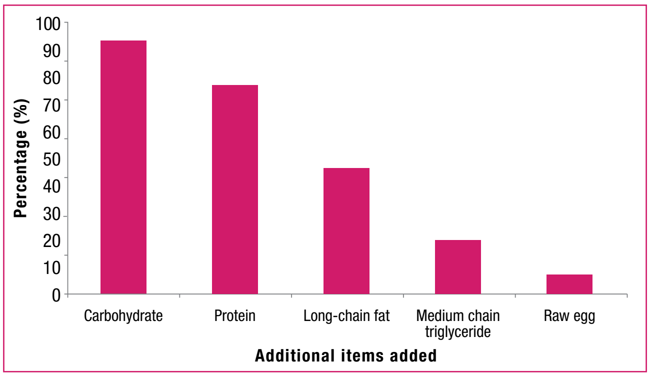


Figure 1: Distribution of ETF usage and ETF modification between the participating hospitals

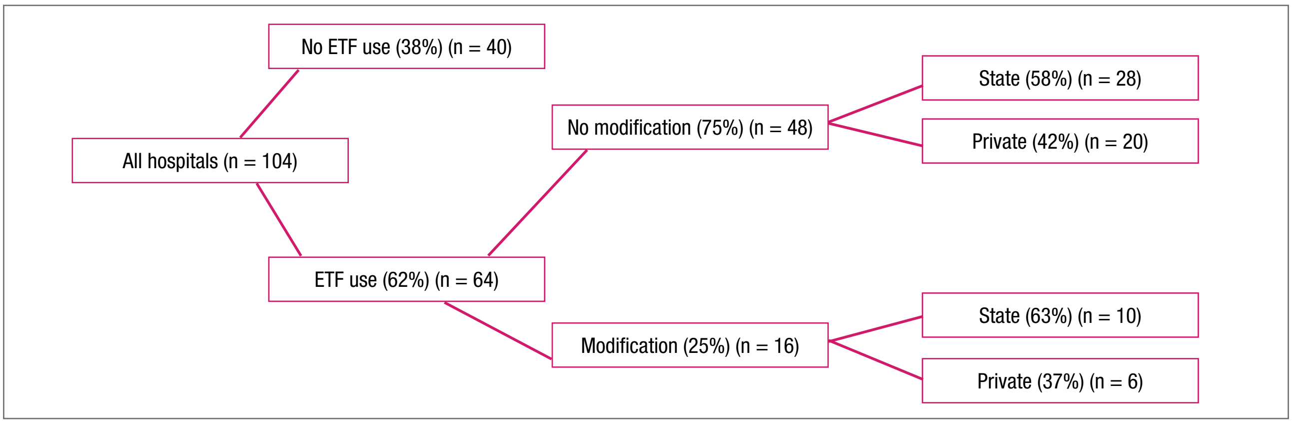


Table I: Structure of the different types of carbohydrate, protein and fat constituents found in the items used for the modification of the enteral tube feeds (ETF)

Macronutrient	Constituent	Structure	Standard ETF*	Carbohydrate supplement	Protein supplement	Fat supplement
Carbohydrate						
	Fructo-oligosaccharides	short-chain oligosaccharide	✓			
	Maltodextrin	glucose polymer	✓			
	Sucrose	disaccharide	✓			
	Glucose polymer	polysaccharide		✓		
Protein						
	Calcium caseinate	polypeptide	✓			
	Soy protein isolate	polypeptide	✓			
	Whey protein concentrate	polypeptide			✓	
Fat						
	High oleic sunflower oil	long-chain fatty acid	✓			
	Soy oil	long-chain fatty acid	✓			
	Sunflower oil	long-chain fatty acid				✓
	Coconut oil	medium-chain fatty acids	✓			✓
	Palm oil	short-chain fatty acids				✓
	Soy lecithin	phospholipids			✓	
		glycolipids				
		tryglycerides				
	Canola oil	medium-chain fatty acids				✓
	Medium-chain triglyceride oil	medium-chain fatty acids				

feeds were then prepared as a means of meeting the nutritional requirements of such patients. Ten (63%) of the hospitals that modified ETFs employed a dietitian/s on either a part-time or full-time basis, while the remaining 6 (37%) hospitals did not employ a dietitian.

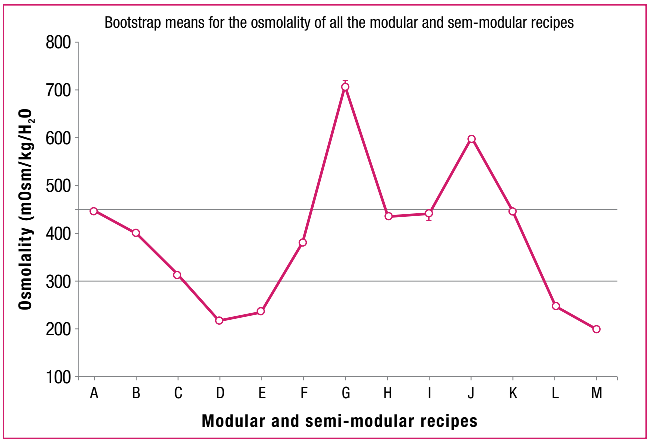
The semi-modular ETF prescriptions were mostly written by the hospital dietitian (63%), by a multi-disciplinary team (including nurses and doctors) (20%), or solely by the doctor (7%). The modular ETF prescriptions were mostly written by the hospital dietitian (67%), by a multi-disciplinary team (including doctors and nurses) (17%), or by a nurse (17%). The actual preparation and modification of the semi-modular ETFs were done mostly at ward level (47%), in the kitchens of the respective hospitals (27%), or in a tube feed preparation area (25%). The modular feeds were mostly prepared in a tube feed preparation area (83%) or in the kitchens of the hospitals (17%).

Forty-four per cent (n = 7) of the hospitals that modified ETF (n = 16) also added vitamins and minerals to their modified ETF. These vitamins and minerals included; multivitamin syrup, thiamin, folate, vitamin C, vitamin D, vitamin E, pyridoxine, B-Complex, sodium chloride, magnesium glycerophosphate, zinc gluconate and potassium chloride.

Osmolality data

A total of 16 recipes were obtained from the completed questionnaires. Twelve of these recipes fitted the inclusion criteria and were used for the osmolality testing (Table II). When compared to the osmolality of the standard enteral product (recipe A), the osmolality of eight recipes (66%) (recipes B, C, D, E, F, H, L, M) was significantly lower ($p < 0.001$) two recipes (16%) (recipes G, J) was significantly higher ($p < 0.001$), while two of the recipes (recipes I, K) did not differ significantly ($p = 0.313$ and $p = 0.794$) from that of the standard enteral product (Figure 3). Furthermore, four (33%) of the recipes' osmolality was significantly lower ($p < 0.001$), while that of the remaining eight (66%) was significantly higher ($p < 0.001$) than that of body fluid (300 mOsm/kg/H_2O) (Figure 3).

Figure 3: Difference in osmolality between the standard enteral product (A) (448 mOsm/kg/H_2O), body fluid (300 mOsm/kg/H_2O), and the tested modular and semi-modular recipes used in this study



The osmolality values of the individual modular recipes (recipes B, D, E, L, M) were all lower than those of the standard enteral product, and the average osmolality of the modular recipes (261 mOsm/kg/H_2O) was significantly lower ($p < 0.001$) than that of the standard enteral product (448 mOsm/kg/H_2O) and of body fluid. The individual semi-modular recipes all had higher osmolality values than body fluid (300 mOsm/kg/H_2O). The average osmolality of the semi-modular recipes (recipes C, F, G, H, I, J, K) was 437 mOsm/kg/H_2O, which was significantly higher ($p < 0.001$) than that of the modular recipes, but similar to the standard enteral product. The concentrated semi-modular recipe (1.43 kcal/ml) had the highest osmolality (707 mOsm/kg/H_2O) of all the tested recipes.

Table II: Characteristics of the recipes and the standard enteral product used for the osmolality determinations

Recipe	Description	Modular (M)/ Semi-modular (SM)	Composition/ 500 ml	Amount (g or ml)	p-value	Osmolality mOsm/kg/H_2O	Carbo-hydrate (g)	Protein (g)	Fat (g)	kJ density (kcal/ml)	Na (mg)	K (mg)	Cl (mg)
A	Standard enteral product (SEP)	Not applicable	SEP	116 g		447.8	69.4	18.6	16.2	1.01	423.4	781.8	715.7
B	Low sodium (Na) + 5 ml Multivitamin syrup (Multivitamin)	M	Carbohydrate supplement	107 g	p < 0.001 *	400.6	103.7	23.0	24.8	1.45	232.7	217.7	238.6
			Protein supplement	23 g									
			Fat supplement	22 ml									
C	High fat	SM	SEP	85 g	p < 0.001 *	316.2	51.8	20.6	21.7	0.98	345.3	635.9	524.5
			Fat supplement	9 ml									
			Protein supplement	7 g									
D	Modular NPE:N**= 150:1	M	Protein supplement	24 g	p < 0.001 *	219.1	62.4	24.0	21.9	1.07	189.3	222.3	140.5
			Carbohydrate supplement	62.5 g									
			Fat supplement	19 ml									
E	Modular NPE:N = 100:1	M	Protein supplement	34 g	p < 0.001 *	235.7	63.8	34.0	22.1	1.17	239.3	312.3	140.5
			CHO supplement	63 g									
			Fat supplement	17.5 ml									
F	Kidney failure: 50 g protein (8000 kJ)	SM	SEP	6 g	p < 0.001 *	381.1	81.0	9.6	16.4	1.03	271.8	409.2	477.2
			Carbohydrate supplement	48 g									
			Fat supplement	8 ml									
G	Fluid restricted	Concentrated	SEP	164 g	p < 0.001 *	707.2	98.1	26.3	23.0	1.43	598.6	1105.4	1011.9
H	High protein	SM	SEP	113 g	p < 0.001 *	436.1	68.2	23.1	16.4	1.04	437.5	806.6	697.2
			Protein supplement	5 g									
I	Burn wounds	SM	SEP	116 g	0.3129	441.6	70.6	27.6	17.3	1.11	468.4	862.8	715.7
			Protein supplement	9 g									
J	40 g protein low electrolyte (recipe 1) + 5 ml Multivitamin	SM	SEP	105 g	p < 0.001 *	596.7	100.8	19.8	25.1	1.43	442.3	738.7	737.1
			Protein supplement	2.5 g									
			Carbohydrate supplement	40 g									
			Fat supplement	10 ml									
K	40 g protein low electrolyte (recipe 2) + 3.3 ml Multivitamin	SM	SEP	70 g	0.7940	448.5	91.9	13.2	23.0	1.26	323.8	542.8	550.1
			Protein supplement	1.67 g									
			Carbohydrate supplement	53.3 g									
			Fat supplement	13.3 ml									
L	Low electrolyte feed + 7.5 ml Multivitamin + 2.5 mg folic acid	M	Protein supplement	25 g	p < 0.001 *	247.9	72.0	25.0	18.0	1.09	205.3	232.3	162.8
			Carbohydrate supplement	72.5 g									
			Fat supplement	15 ml									
M	Diabetic low electrolyte feed + 7.5 ml Multivitamin + 2.5 mg folic acid	M	Protein supplement	27.5 g	p < 0.001 *	199.6	55.5	28.0	26.4	1.13	200.5	257.5	122.7
			Carbohydrate supplement	55 g									
			Fat supplement	23 ml									

* p-value is significant

** Non-protein energy:Nitrogen

The osmolality results rejected both null hypotheses. Results of this study revealed that the modification of an ETF did influence its osmolality, and that the osmolality of a modified ETF was not equal to that of body fluid.

Composition of recipes and osmolality

Modular recipes: The modular recipe (recipe B) with the highest carbohydrate content (103.7 g) and the higher energy density (1.45 kcal/ml) also had the highest osmolality (400 mOsm/kg/H_2O) compared to the other modular recipes (Table II).

Semi-modular recipes: The concentrated recipe (recipe G) with the highest quantity of standard enteral product powder (164 g) and a carbohydrate content of 98 g and energy density of 1.43 kcal / ml, had the highest osmolality (707.2 mOsm/kg/H_2O). Recipe J with 105 g standard enteral product powder, added carbohydrate supplement, a high total carbohydrate content (100 g) and a high energy density (1.43 kcal/ml), had the second highest osmolality (596 mOsm/kg/H_2O). Recipe K with 70 g standard enteral product powder, added carbohydrate supplement, a total carbohydrate content of 91 g, a energy density of 1.26 kcal/ml had an osmolality of 448 mOsm/kg/H_2O. Recipe F with 60 g standard enteral product powder, added carbohydrate supplement, a total carbohydrate content of 92 g, a energy density of 1.03 kcal/ml, had an osmolality of 381 mOsm/kg/H_2O. The semi-modular recipes (recipes H, I) with 113 g and 116g standard enteral product powder respectively, no additional added carbohydrate supplement , together with a lower total carbohydrate content (< 71 g), had lower osmolalities (436–441 mOsm/kg/H_2O). Recipe C with 85 g standard enteral product powder, no additional added carbohydrate supplement, a total carbohydrate content of 51.8 g, had an osmolality of 316 mOsm/kg/H_2O.

Discussion

In this study the factors that possibly influenced the osmolality of the modified ETF were (1) the **total** carbohydrate content; (2) the structure of the carbohydrate constituents; and (3) the concentration and energy density of the feeds.

The first trend observed was that an increase in the total carbohydrate content, either in modular recipes or by the addition of a carbohydrate supplement to a standard enteral product in semi-modular recipes, resulted in an increased osmolality. The main contributors to the carbohydrate content of the recipes were the carbohydrate constituents found in the standard enteral product (short-chain oligosaccharides, glucose polymers, disaccharides and polysaccharides) and in the carbohydrate supplement (polysaccharides) used during ETF modification. The increase in osmolality in the semi-modular recipes seemed to be greater when smaller-sized carbohydrate constituents were used, as was shown for the recipes that used higher quantities of the standard enteral product powder, together with the additional carbohydrate supplement and higher carbohydrate content.

There appeared to be some type of relationship between the sodium, potassium and chloride content of a modified ETF and its osmolality. The standard enteral product had the highest sodium, potassium and chloride content when compared to the carbohydrate, protein and fat supplements. The high electrolyte content of the standard enteral product could be a possible reason for the recipes with higher quantities of standard enteral product powder resulting in a higher osmolality.

The concentrated feed used in this study (indicated for fluid-restricted patients) had the highest energy density (1.43 kCal/ml) and the highest osmolality (707 mOsm/kg H_2O).This finding is not unexpected, as a concentrated feed has a greater particle concentration per kilogram solution and thus a higher osmolality. According to the results of this study, other factors that could also have contributed to the high osmolality of the concentrated feed were (1) the high total carbohydrate content, (2) the structure of the carbohydrate constituents in the standard enteral product, (3) and the high sodium, potassium and chloride content of the feed.

The possible influencing factors identified in this study are in agreement with existing literature, namely that the osmolality of an ETF is dependent upon the size and structure of its nutrient components in relation to the total water content of the feed.[9] As sodium and its associated anions contribute to up to 90% of plasma osmolarity, it was expected that the osmolality of a modified ETF will also be influenced by its electrolyte content (especially by sodium and its associated anions).[8] In this study it appeared that the fat and protein content of the recipes did not influence the osmolality of the feeds. This could possibly be due to the fact that all the protein and fat constituents in the recipes were larger-sized. The osmolality of the high-fat semi-modular recipe C (fat source added to standard enteral product) was significantly lower than that of the standard enteral product (recipe A). This could be ascribed to the fact that in the former recipe less of the standard enteral product was used than the latter recipe, and thus it had a lower total carbohydrate content, contained less of the smaller-sized carbohydrate constituents (fructo-oligosaccharides and sucrose) of the standard enteral product, and it had a lower electrolyte (sodium, potassium and chloride) content. The osmolality of the high-protein semi-modular recipe (recipe H) did not differ significantly from that of the standard enteral product. The assumption that the protein content did not cause an increase in osmolality was further confirmed by the burn-wound recipe (recipe I), where the osmolality of the feed was not increased upon addition of a protein supplement to the standard enteral product. On the contrary, the addition of a carbohydrate supplement to the standard enteral product caused an increase in osmolality (as found in recipes J, K and F).

When the semi-modular feeds were compared with each other, the osmolality increased when (1) the total carbohydrate content was increased and (2) the standard enteral product to carbohydrate supplement ratio increased. Upon comparing the modular feeds with each other, it appeared that the osmolality increased as soon as more carbohydrate supplement was added. This once again confirmed that an increase in the carbohydrate content of a recipe causes an increase in its osmolality.

When comparing the semi-modular with the modular feeds, it was found that the latter had a lower osmolality. This could possibly be due to the larger-sized carbohydrate constituents and the lower sodium, potassium and chloride content of the modular feeds, when compared to the semi-modular feeds.

Modular feeds are frequently significantly less expensive to make up than using an equivalent commercial product, and are particularly useful when fluid and specific electrolyte problems occur. Both modular and semi-modular feeds do however require strict adherence to sanitary technique and a level of expert supervision by the dietetic service.[13] It is thus understandable why so few hospitals make use of modified ETFs, as not all hospitals employ dietitians. However, the degree of flexibility offered by modified or modular feeds can be a great advantage and may potentially eliminate the need for certain commercial products in cases where cost is a strong consideration.[13]

Conclusion

In this study, the modular feeds had a lower average osmolality (261 mOsm/kg H_2O) than the semi-modular feeds (437 mOsm/kg H_2O), and the osmolality of the modular feeds was significantly lower than that of the standard enteral product (448 mOsm/kg H_2O). This is an important finding, as this fact was not previously known. It was also observed that the osmolality of an ETF was increased by the addition of a carbohydrate supplement, but not by the addition of a protein and fat supplement, and that the particle size of the carbohydrate constituent remains important. The ratio of the standard enteral product powder:carbohydrate supplement is therefore also important. Possible areas of concern, and recipes that should thus be used with caution, are (1) semi-modular feeds with a high quantity of standard enteral product powder, a high carbohydrate content, as well as a carbohydrate supplement added to it, and (2) concentrated feeds, especially when exceeding an energy-density of more than 1.43 kCal/ml.

It is recommended that in future studies the osmolality of modified semi-elemental feeds should be determined. Future investigations should also aim at achieving standardisation of the maximum energy density/concentration of a modified feed, as well as the maximum amount of carbohydrate supplement to be added to a semi-modular ETF. Case-control studies should also be undertaken to determine the possible relationship between the high osmolality of the modified ETF identified in this study and the incidence of ETF-induced diarrhoea.

Conflict of interest

All the authors declared no conflict of interest.

References

1. Bloch SB, Mueller C. Enteral and parenteral nutrition support. In: Mahan LK, Escott-Stump S, (eds). Krause's food, nutrition and diet therapy. 11th edition. Pennsylvania: Saunders; 2004:533–55.
2. Akbaylar H. Basic principles of enteral feeding. Turk J Gastroenterol 2002;13(4):186–91.
3. Zaloga GP. Early enteral nutrition support improves outcomes: hypothesis or fact? Crit Care Med 1999;27:259–61.
4. Silk DBA. Enteral diets; clinical uses and formulation. In: Payne-James J, Grimble GK, Silk DBA, (eds). Artificial nutrition support in clinical practice. 2nd edition. Cambridge: Greenwich Medical Media Limited. 2001:303 – 323.
5. Rombeau JL, Caldwell MD.. Clinical nutrition: enteral and tube feeding. 2nd edition. Philadelphia: Saunders 1990:129–35.
6. Worthly LI, Guerin M, Pain RW. For calculating osmolality, the simplest formula is the best. Anaesth and Intens Care 1987;15(2):199–202.
7. Whitmire SJ. Water, electrolytes and acid-base balance. In: Mahan LK, Escott-Stump S, (eds). Krause's food, nutrition and diet therapy. 11th edition. Pennsylvania: Saunders; 2004:164–79.
8. Krey SH, Murray RL. Enteral nutrition: a comprehensive overview In: Dynamics of nutrition support, assessment, implementation, evaluation. Appleton-Century-Crofts, Connecticut, USA. 1986:279–328.
9. Erstad BL. Osmolality and osmolarity: narrowing the terminology gap. Pharmacotherapy 2003;23(9): 1085–6.
10. Pearce CB, Duncan HD. Enteral feeding. Nasogastric, nasojejunal, percutaneous endoscopic gastrostomy, or jejunostomy: its indications and limitations. Postgrad Med J. 2002;78:198–204.
11. Efron, B, Tibshirani R. An introduction to the bootstrap. London: Chapman and Hall; 1993.
12. Statsoft Inc. (2007). STATISTICA (data analysis software system), version 8.0. Available from www.statsoft.com (Accessed February 2008)
13. Hill L. Choosing an enteral feed for the critically ill. SAJCC 2002;18(1):17–21.