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Blenderized Tube Feeding in Pediatric Patients: A Systematic review

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ABSTRACT

Background: Enteral feeding (EF) is the delivery of liquid nutritional support through a tube for hospitalized patients with gastrointestinal dysfunction who are incapable of eating or unable to meet their nutritional requirements via the oral route. Hospitals' reports indicate an increased interest and demand for blenderized tube feeding (BTF) as an alternative to commercial enteral formulas particularly in families of tube fed children. In particular, by increasing food sensitivity and more complex identification in children, BTF allows families to adjust their diet to their children's needs. This systematic review aimed to summarize the published evidence regarding BTF in pediatric patients.

Methods: Literature search was conducted in four databases, including Scopus, PubMed, Science Direct, and Google Scholar, using multiple keywords, such as blenderized tube feeding, blended formula, homemade enteral nutrition, pediatric, and children. Out of 103 retrieved articles, 6 were selected and reviewed.

Results: Six articles were eligible to be included in the current review. The results showed that calories were approximately 1kcal/g, protein 13 -22%, fat 30 - 34%, and carbohydrates intake 45-55% of total energy intake.

Conclusions: The results indicated that BTF is acceptable and can be administered to children; however, due to concerns about calorie and macronutrients deficiency, it should be providing under the supervision of a nutritionist. BTFs are a good choice among children; since they can improve gastrointestinal symptoms and are a good option for families who use EF for their children at home. Most pediatric patients use BTFs as a portion of their EF, making it necessary that nutritionists and physicians expand their knowledge about BTFs to appropriately care for these pediatric patients.

Keywords: Blenderized Tube Feeding, Pediatric, Patients, Children, Systematic Review

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Introduction

It has been proven that children need high protein and energy intake to grow, and malnutrition in childhood can affect their health for the rest of their life *[1]*. Malnutrition is related to increased length of hospital stay, disease and mortality, infection, and increased hospital costs in children *[2-4]*. Studies

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have shown that the prevalence of pediatric malnutrition is about 24.1% in Germany, 18.7% in Brazil, 11% in France, 9.9% in New Zealand, 8.2% in Spain, and 31.8% in Turkey *[5-11]*. Enteral feeding (EF) is the preferred route of nutritional supplementation which is necessary for the management of patients who are unable to ingest food orally *[12]*. Although commercial formulas have been available for over 30 years, they have high osmolality and do not taste good. Several properties of commercial formulas that are rich in carbohydrates, high in saturated fat, and devoid of fiber, fruits, and vegetables are heavily involved in the pathogenesis of the cardiovascular disease and pulmonary diseases. The preservatives in these formulas may also be associated with inflammatory diseases *[13-15]*. Children with swallowing problems, neurological disorders, and etc. often need enteral nutrition using primarily commercial formulas; however, BTFs have become more popular for pediatrics and have come out as part of home enteral feeding in recent years *[16-19]* because BTFs are more natural, healthier, and better tolerated than the commercial formula *[19, 20]*. Studies also have shown a positive clinical outcome for using BTFs in children *[13, 21]*. A study conducted in 2015 reported that 57% of nutritionists use and recommend BTFs for pediatric populations *[18]*. Concerns about contamination, infection, and nutrient content of BTFs should be thoroughly trained by a nutritionist to minimize their hazards *[22]*. Advantages of BTFs include using organic foods or genetically modified organism free foods, preventing food allergies, reducing feeding intolerance, such as reduced gagging and retching, improving intestinal function, increasing dietary diversity, as well as reducing oral aversion, chronic diarrhea, and costs *[14, 20, 21, 23, 24]*. In particular, BTFs allow children's families to tailor a diet to their pediatric needs *[14]*. Given that, the use of BTFs in children has increased in recent years and no review study has been conducted in this regard. Therefore, this study aimed to investigate the effect of blenderized tube feeding in pediatric patients.

Materials and Method

Information sources

The articles conducted on the blenderized tube feeding in pediatric patients were reviewed from 2010 to 2020, to find the recent investigations. Four databases were used: Scopus, PubMed, Science Direct, and Google Scholar. The references of included articles were also checked for related studies. The search strategy used for the systematic search was: ("blenderized tube feeding" OR "blended formula" OR "homemade enteral nutrition") AND (" pediatric" OR "Children").

Selection criteria and quality assessment

Two reviewers independently screened the databases and reviewed the titles, abstracts, and full texts to determine the articles which met the inclusion criteria and any discrepancies were resolved by consensus.

Studies which investigated the effect of blenderized tube feeding formulation in pediatric patients and provided data on their calories and macronutrients were included. The exclusion criteria included failure to report the used formulation, and failure to report calories, fat, protein, and carbohydrates content of BTFs.

Data extraction

The details extracted for each of the studies included the first author's last name, the time of conducting the study, publication date, and blenderized tube feeding in pediatric patients.

Results

Figure 1 depicts the selection process of the studies within the PRISMA diagram. In the systematic literature search, 103 articles were obtained from Scopus, PubMed, Science Direct, Google Scholar as well as the relevant studies identified in cross-references. After the elimination of

duplicates, 79 articles were considered eligible for title/abstract screening, 24 of which were retrieved for full-text assessment. Finally, 6 eligible studies were selected for the systematic review. The results showed that the calories of BTFs were about 1 1kcal/g, protein 13%-22%, fat 30%-34%, and carbohydrates 45%-55% (Table 1). The carbohydrates in BTF are easily obtained from fruits, starchy vegetables, whole grains, and carbohydrate-based calorie additives. Protein is also provided through cow milk or milk powder and meat. Vegetable oil, olive oil, and etc. have also been used to satisfy fat intake. The blenderized tube feedings also contained fiber and phytochemicals. Phytochemicals are an extensive category of plant compounds that have been shown to have significant health benefits from fruits, vegetables, beans, cereals, and plant-based beverages.

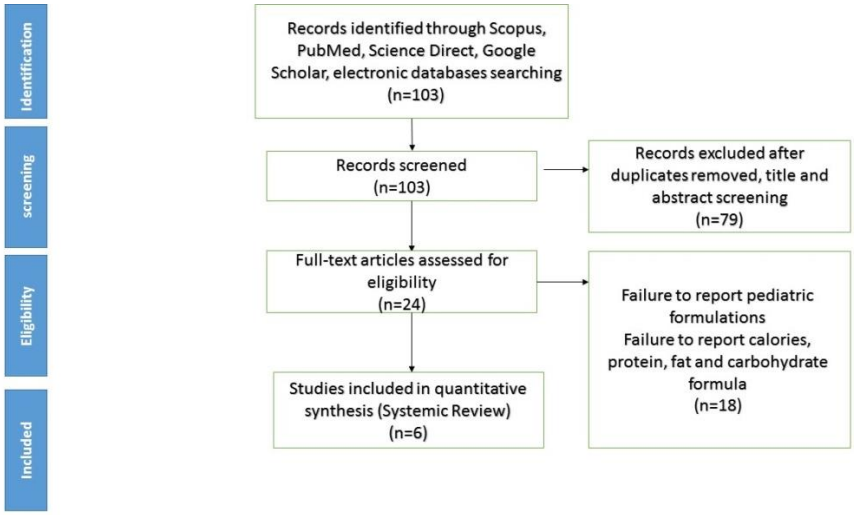

Figure 1. Flow diagram showing the results of the searches

Table 1. Blenderized tube feeding in pediatric patients

Author, year (reference)	Ingredients	Energy and macronutrients/ 1 L
Johnson et al., 2019 *[25]*	Two cups of whole milk, One 1-ounce jar baby food Chicken, three 2-ounce jars baby food carrots, two 2-ounce jars baby food peas, four 2-ounce jars baby food, apple and blueberry, 2 teaspoons olive oil, ½ teaspoon cod liver oil	calories: 995, carbohydrate: 54%, fat: 31%, protein: 15%
Samela et al., 2017 *[15]*	Total fat: medium-chain triglyceride (MCT): long-chain triglyceride (LCT) ratio: 20:80, omega-3 fatty acids (n6): omega-6 fatty acids (n3) ratio: 3.7:1 (9.7g), sodium 190 mg, potassium 410 mg, total carbohydrate 33 g, dietary fiber (fiber content (source): 6.8g/l (nutrisource fiber, fruits, and vegetables) 1.7 g Protein: protein source: chicken, sodium caseinate, pea puree, NPC:N ratio: 142:1 9.5g	Calories: 250 kcal, Total fat (34%), Total carbohydrate (51%), Protein (15%),
Walia et al., 2017 *[26]*	One cup of mixed cooked vegetables, 3/4 cup of mixed fruit, 2 ounce (oz) cooked meat 16 oz whole milk, 1/4 cup cooked brown rice, 1 teaspoon flax seed oil 1 teaspoon corn oil, 1/8 teaspoon table salt, 1/2 Flintstones complete chewable multivitamin, 1 mL Enfamil D-Vi-Sol, 12 oz water Additional water as needed to meet desired consistency	700 kcal/d: calories 696, protein: 22.7%, carbohydrate: 45.4%, total fat: 31.9%

Author, year (reference)	Ingredients	Energy and macronutrients/ 1 L
Bobo et al., 2016 *[24]*	Two cups of 2% milk, 2 oz roasted chicken, 1 cup (1/2 cup of 2 different vegetables, such as spinach and carrot) of vegetables, 1 cup (1/2 cup of 2 different fruits, such as banana and pear) of fruits, 1.5 cups of white rice, 1.5 tbsp oil (eg, extra-virgin olive oil, vegetable oil)	986 calories, 52% carbohydrate, 17.8% protein, and 30.1% fat
O'Flaherty et al., 2011 *[27]*	Recipe #1 with commercial formula Eight oz PediaSure 1.5, 4 oz Strained sweet potato, 4 oz Strained applesauce, 6 oz Plain yogurt, 2 Tablespoons oil, ½ Cup of dry infant cereal, 6 Tablespoons sugar or cornstarch Recipe #2 without commercial formula Eight oz whole milk, 2.5 oz strained chicken meat, 4 oz strained banana 4 oz strained carrots, 1 tablespoon oil, 4 tablespoons sugar or cornstarch, 6 oz Greek yogurt, ½ cup dry infant cereal	Recipe #1 with commercial formula: Caloric content 1200 kcal 32% kcal from fat 55 % kcal from carbohydrate 13 % kcal from protein 65% Free water Recipe #2 without commercial formula: Caloric content 980 kcal 30% kcal from fat 55% kcal from carbohydrate 15% kcal from protein 64% Free water
Pentiuk et al., 2011 *[21]*	Five oz strained meats, 8 oz strained plums or bananas, 4 oz strained pairs or applesauce, 4 oz strained squash or sweet potatoes, 6 tbsp infant cereal, 1 tbsp oil, 4 oz yogurt, 3 tbsp cornstarch or sugar, 60 mL commercial formula or milk, total volume 25 oz (750 mL) Feeding regimen	Calorie content 942 kcal 30% kcal from fat, 55% kcal from carbohydrate 15% kcal from protein, 65% free water content

Discussion

The most common diseases in children that require enteral feeding include congenital abnormalities (42%), perinatal problems (38%), and neurologic diseases (16%)*[28]*. Tables 2 reveal the criteria for selecting the appropriate patients for BTF *[29]*. Although children also use commercial formulas, due to the benefits of BTFs, health professionals and patients' families have become more interested in using BTFs. However, studies have shown that the risk of microbial contamination can lead to insufficient energy and nutrient content. This is due the fact that BTFs prepared in hospitals do not have a specific formula and are prepared by mixing different foods, such as milk, meat, juice, vegetables, etc. in completely different amounts. Therefore, the amount of energy, carbohydrates, proteins, and fats of these solutions are different *[30-32]*. After the preparation of BTFs, they should be stored within the temperature range of 2-8°C. Personnel should wash, dry, and disinfect hands frequently and use masks before preparing BTFs for non-sterile, blended, diluted, or decanted foods. Notably, the administration time should not exceed four hours *[29, 33]*. During the handling process, foods should not be exposed to temperatures of 10-60°C for more than 30 minutes, and the storage time should be less than 12 hours *[34]*. Parents and hospitals could follow the guidelines provided by American Academy of Nutrition and Dietetics (**www.homefoodsafety.org)** and United States governmental agencies (**www.foodsafety.gov)**, which have been published to minimize microbial contamination. The optimal and safest approach to minimize microbial contamination is the implementation of a hazard analysis critical control

points (HACCP) system. The wide variety of microorganisms that have been detected so far may be due to inappropriate manufacturing practices and storage conditions. Efficient manufacturing practices and the contentious control of processing lines could reduce the rate of contamination, especially in the case pathogenic species. In addition, the strict implementation of microbial recipes (e.g., HACCP), good manufacturing practices, and good hygiene practices (GHPs) proposed by the World Health Organization (WHO) and Food and Drug Administration (FDA) could reduce the microbiological contamination of enteral nutrition *[35]*.

Table 2. Indications and contradictions for candidating children for BTF

Indications
Medically stable; stable growth
≥ 14 Fr feeding tube
Bolus feeds
Motivated family
Adequate resources and equipment (high-grade blender, refrigerator, electricity, access to clean water and food, storage containers)
Access to knowledgeable medical providers
Contraindications
Acute illness or immunosuppression (greater risk of infection from contaminated food)
Fluid restrictions (may be difficult to meet nutrient needs)
Continuous feedings (requires formula to be unrefrigerated for several hours)

Designing the diet

Energy

Energy needs vary considerably between people depending on the patient's age, activity, and health status, but infants and children require more energy than adults (Table 3) *[36]*. As a starting point in nutrition, nutritionists may want to consider consuming 10% more energy than the amount a child currently consumes *[37]*. Tools for the starting point to create a diet plan based on calorie goals are presented in Table 4. Examples of food sources for BTFs can be found in Table 5. Nutrients can be categorized into carbohydrates, proteins, and fats that provide calories, and vitamins, and minerals. The energy in foodstuffs is released via the oxidation of carbohydrates, fats, and proteins in the body, and the chemical energy needed to maintain metabolism and other body functions is produced *[38]*. Lack of macronutrients can be categorized as marasmus (primary calorie deficiency), kwashiorkor (primary protein deficiency), and marasmic kwashiorkor (calorie and protein deficiencies). Calorie deficiency is a primary nutrient deficit among these children *[39]*. The amount of energy provided by macronutrients is as follows: carbohydrate: 4 kcal/g, fat: 9 kcal/g, and protein: 4 kcal/g *[38]*. The acceptable range of macronutrients for children and adolescents is as follows: carbohydrates: 45% -65% of total calories, protein: 5%- 20% of energy intake for ages 1 to 3 and 10%-30% for ages 4 and older, fats: 30%-40% of energy intake for ages 1 to 3 and 25%-35% for ages 4 and older *[39]*. The practice of BTFs should be controlled by nutritionists *[20]*.

Table 3. Average energy requirements for the different age groups

Age group	Energy (total kcal/kg/d)
Premature infants	120 to 150
1–12 months	100 to 120
1–6 years	75 to 90
7–12 years	60 to 75
12–18 years	30 to 60
Adult	30 to 40

Table 4. Tools for the starting point to create a diet plan based on calorie goals

Tools	Website Address
USDA Choose My Plate	http://www.choosemyplate.gov/supertracker-tools/supertracker.html
Homemade Blended Formula Handbook Mealtime Notions, LCC, Tucson, AZ, 2007; 117-128;	www.mealtimenotions.com
Sample Blenderized Tube Feeding Recipes	www.ginutrition.virginia.edu
Use a nutrition planning program like Food Processor®, Nutritionist Pro™ under Resources for Nutrition Support Clinicians The worksheets were adapted from the USDA My Pyramid	https://www.usda.gov
USDA National Nutrient Database for Standard Reference	http://www.nal.usda.gov/fnic/foodcomp/search.
USDA Nutrient Database:	http://ndb.nal.usda.gov/ndb/search/list
USDA Diet tracking/analysis:	www.supertracker.usda.gov
Seattle Children's: Homemade Blenderized Tube Feeding (website)	www.seattlechildrens.org
Food Safety and Inspection Service, US Department of Agriculture	www.fsis.usda.gov/ www.choosemyplate.gov/

Table 5. Examples of food sources for BTFs

Food group	Possible sources
Grains	Cooked cereals, boiled white or brown rice, cooked quinoa, oats, regular or whole grain bread
Fruits	Avocado, applesauce, peach, pear, banana, papaya, blueberries, 100% fruit juice (pulp free)
Vegetables	White potato, sweet potato, carrots, squash, well-cooked broccoli
Protein	Chicken, beef, legumes, soft tofu, smooth 100% peanut butter, cooked eggs, canned tuna or other fish without bones
Milk or milk substitutes	Cow milk, soy milk, almond milk, rice milk, yogurt, non-fat milk powder
Fats	Canola, olive, flaxseed, hemp, and corn oils

Protein

The first step is to select the right source of protein; since plant proteins are not used as much as animal proteins [29]. Animal-derived proteins have a higher protein efficiency ratio (PER), biological value (BV), net protein utilization (NPU), and protein digestibility-corrected amino acid score than vegetable protein *[40, 41]*. Some children are allergic to foods, such as cow milk, egg, peanut, soybean products, finfish, shellfish, corn, and wheat *[42]*; therefore, these foodstuffs should be from their diets, and when they are removed, the allergic child might deficient in vitamin D, calcium, phosphorus, and B vitamins. Allergic children should seek the advice of a nutritionist to provide these nutrients through alternative sources *[22]*. At least consumption of 1.5 g/kg/d of protein and 58 kcal/kg/d can equilibrate nitrogen and energy balances in children up to 4 years *[43]*. The American Society for Enteral and Parenteral Nutrition (ASPEN) suggested that the protein required for pediatric is 2 to 3 g/kg/day for children less than 2 years, 1.5 to 2 g/kg/day for those aged 2 to 13 years, and 1.5 g/kg/day for those aged 13 to 18 years *[44]*. Foods, such as milk and formula can be used as part of liquid protein. It is not recommended to use more than 4 to 8 ounces of liquid protein; since a thicker viscosity is more

useful for retching and gagging. Then meat or yogurt can be used for the rest of the required protein. Of course, all the required protein can be obtained from meat and yogurt without liquid protein (milk), but the problem is the pressure through the syringe during feeding *[27]*.

Fat

Reducing fat intake in growing children which reduces the supply of omega-6 and omega-3 essential fatty acids, has unfavorable effects on growth and leads to unfavorable lipoprotein profiles, and increases the consumption of potentially harmful trans fatty acids *[45]*. The purpose of added fat is to provide calories and essential fatty acids. If linoleic acid provides at least 1% of the total calories, the deficiency of essential fatty acids can be prevented, but the recommended limit is 3-4% of the total calories *[46]*. In a 1500 kcal diet, the least amount of linoleic acid needed is recommended to be between 1.7 and 6.7 g/d *[47]*. Essential fatty acids can be obtained from safflower, sunflower, soy, and corn oils, but since these fatty acids are the main sources of Omega-6 fatty acids, their additional administeraton is harmful due to pro-inflammatory and immunosuppressive effects *[48, 49]*. Canola and olive oil are commonly used as fat sources because they have low saturated fat content (1 to 2 tablespoons) *[27]*. Medium-chain triglycerides can be used to provide fat due to their unique attributes (better water miscibility, faster hydrolysis, better absorption into intestinal mucosal cells, and transfer of medium-chain fatty acids into portal circulation than long-chain triglycerides) *[50]*. Total lipid consumption should be 3-4 $g.kg^{-1}.day^{-1}$ *[51]*.

Carbohydrates

Carbohydrates are usually tolerated except for lactose and they do not have any gastrointestinal side effects. Glucose is a fast source of energy and the only carbohydrate available in the circulation *[46]* . Carbohydrate sources can be obtained from fruits and vegetables. Squash, carrots, sweet potatoes, peaches, apricots are good sources of vitamin A, beta-carotene, carbohydrates, and calories. Prunes or bananas are also high in potassium and calories. Applesauce, pears, green peas, green beans, spinach sauces are also good sources of vitamin C. Cereals are also used to increase calories, carbohydrates, and fiber and as a thickener *[27]*. In BTFs use slowly digestible carbohydrates from legumes and whole grains, which decreases the hazard of airway inflammation compared to commercial diets *[52, 53]*. Low dextrose equivalent (DE) maltodextrins have longer chains of glucose molecules, are sweeter and more soluble than those with high DE and can be used in intestinal nutrition, while high DE maltodextrins increase osmolarity and diarrhea *[46]*. European Society for Clinical Nutrition and Metabolism(ESPEN) is recommends 15–30 g/d fiber in the diet of patients who use enteral nutrition *[54]*.

Micronutrients

Specific micronutrient deficiencies that may occur more frequently are iron, zinc, calcium, vitamin D, and B vitamins deficiency. The sources of these micronutrients are summarized in Table 6 *[39]*. Vitamins and minerals are found in the market in liquid and solid form to be added to BTFs. Given sodium is often low in BTFs, in the first option, salt can be used to supply sodium, but if salt is not suitable, Pedialyte, juice (original), chicken broth, pacific foods vegetable broth, Knorr chicken bouillon can be used *[22]*. Cutting, post-harvest water loss (especially in leafy vegetables), and cooking cause loss of nutrients. The use of microwaves causes less nutrient loss than heating methods (except steam), and minimizing the amount of water consumed seems to further decrease these losses *[55]*.

Table 6. Sources of vitamins and minerals

Vitamins and minerals	Source
Iron	Beef, pork, lamb, chicken, turkey, fish, and shellfish
Zinc	Meat (especially red meat), some seafood, poultry, eggs, cheese, milk, whole grains, and beans
Calcium	Dairy products; calcium-set tofu; calcium-fortified milk, Chinese cabbage, broccoli, and kale
Vitamin D	Butter, cream, egg yolk, salmon, herring, and liver
B-Complex vitamins	Meat, fish, and poultry, white potatoes

Viscosity

Viscosity is defined as the resistor to flow or deformation by any material as a result of molecular cohesion and is often applied to liquids as the resistor of liquids to flow due to a shearing force *[56]*. One of the reasons that can explain the useful efficacy of health outcomes by BTFs is the increase in viscosity. In children, gastroesophageal reflux disease (GERD) can increase the hazard of asthma, pneumonia, and chronic cough. Studies have shown that BTFs increasing viscosity can reduce gastric reflux and gastric emptying rate [13, 20]. Hron et al. showed a reduced rate of respiratory infection in children fed BTFs compared to children fed commercial enteral feeding. They attributed these results to possible microbiome changes and reduced aspiration; since the BTF viscosity is higher than commercial enteral nutrition *[13]*. Hyperosmolar commercial formulas have low viscosity, which may lead to fast gastric discharging and symptoms of dumping syndrome *[20]*. Free water, freezing, and thawing decreased viscosity *[57]*. Other factors that affect the viscosity are the stirring time and the time passed for the preparation of the formula. They increase the viscosity because these thickeners can absorb water and also the viscosity of formulas with higher energy density is lower *[58]*. The viscosity of BTFs varies and can be used for different goals. For example, the extremely thick formulation can be used to improve gastrointestinal symptoms in children. Moreover, the specific thickness of BTFs can be used as a dysphagia protocol *[59]*. Weston, S., & Clarke, T. (2020) stated that the International Dysphagia Diet Standardization Initiative (IDDSI) framework can be used to measure viscosity, instead of using a viscometer, which is a method requiring expensive equipment, and can be done in a hospital or at home. This is a simple method for standardizing fluid thickness for physicians and caregivers *[59]*.

Osmolality

Another parameter that should be considered in BTFs is osmolality. Various factors, including the amount of hydrolyzed nutrients in the diet, the influence of solute loads, such as mono- and disaccharides, minerals and electrolytes, hydrolyzed proteins, crystalline amino acids, and medium-chain triglycerides can affect soluble osmolality *[60, 61]*. The recommended osmolality in infants and children under the age of 4 years is <400 mosm/kg and for older children is <600 mosm/kg [52].

Conclusion

The results showed that BTFs used for pediatric provides calorie, protein, fat, and carbohydrates and is acceptable. However, at the same time, BTFs should be prescribed under the supervision of a nutritionist, to provide sufficient amounts of nutrients. It has been approved that BTFs are a popular option for children; since they are made from natural foods, such as meat, milk, vegetables, and fruits, and are lower in sugar, and can improve gastrointestinal symptoms. This can be a good option for families who use enteral nutrition even for children at home. Most pediatric patients use BTFs as a part of their enteral intake, making it necessary that nutritionists and physicians expand

their knowledge related to BTFs to appropriately care for these pediatric patients.

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Nothing to declare

Authors' contributions

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Conflict of interest

The authors declare that there is no conflict of interest in this review.

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