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Metabolic Assessment and Individualized Nutrition in Children Dependent on Mechanical Ventilation at Home

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Objective To evaluate the nutritional and metabolic status and body composition of children on long-term mechanical ventilation using a home-based model.

Study design Children on home mechanical ventilation, for at least 12 hours a day, were eligible. We performed anthropometry, bioelectrical impedance analysis (BIA), actual energy intake (AEI), and indirect calorimetry in the subject's home. Agreement between measured energy expenditure (MEE) from indirect calorimetry, and estimated energy expenditure by the Schofield equation and a novel volumetric carbon dioxide production-based equation was examined. Agreement between fat mass estimates from anthropometry and BIA was examined and compared with population norms.

Results We enrolled 20 children, 11 (55%) male; mean age 8.4 years (SD 4.8). Mean weight for age z-score was −0.26 (SD 1.48); 9/20 had z-scores <−1 or >+1. Thirteen were underfed (AEI:MEE <90%) or overfed (AEI:MEE >110%); 11 of 19 had protein intake that was less than recommended by guidelines. Fifteen subjects were hypo- or hypermetabolic. Mean (SD) fat mass % was 33.6% (8.6) by anthropometry, which was significantly greater than matched population norms (mean 23.0%, SD 6.1, $P < .001$). The estimated energy expenditure by a volumetric carbon dioxide production-based equation was in stronger agreement with the MEE than the Schofield equation (mean bias 0.06%, limits −15.98% to 16.16% vs mean bias −1.31%, limits −74.3% to 72%, respectively). BIA and anthropometric fat mass values were not in agreement.

Conclusion A majority of children on home ventilation are characterized by malnutrition, altered metabolic status, and suboptimal macronutrient intake, in particular low protein intake. A multidisciplinary home-based model facilitates individualized energy and protein delivery and may improve outcomes in this cohort. *(J Pediatr 2015;166:350-7)*.

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The population of children dependent on long-term home transtracheal mechanical ventilation is growing steadily.[1-3] The nutritional requirements of this cohort are likely unique in the setting of restricted mobility, associated comorbidities, and challenges to estimation and delivery of nutrient requirements. Malnutrition, which includes both over- and under-nutrition for the purpose of this study, has been described in other cohorts of children with special health care needs and in adults with chronic respiratory insufficiency.[4-9] The use of standardized equations for estimating energy expenditure and guiding diet prescription may further contribute to suboptimal nutrient provision.[10,11] This may result in caloric overfeeding or underfeeding, contributing to nutritional deterioration and a potential for negative impact on outcomes.[9,12-14] A comprehensive assessment of nutritional status, body composition, and metabolic state in this population would facilitate the provision of optimal macronutrients (energy and protein) and prevent complications related to suboptimal intake.

Our main aim was to describe the nutritional and metabolic status of children dependent on long-term transtracheal mechanical ventilation in the home setting. We used a novel home-based approach to perform a multidisciplinary assessment of: (1) nutritional status; (2) body composition; (3) adequacy of macronutrient intake; and (4) metabolic state, in this cohort. We hypothesized that a majority of the cohort would have an altered nutritional and metabolic state, have low lean body mass (LBM) compared with published standards, would be either underfed or overfed, and have lower protein intake

AEI	Actual energy intake	EEE	Estimated energy expenditure
ASPEN	American Society for Parenteral and Enteral Nutrition	LBM	Lean body mass
		MEE	Measured energy expenditure
BIA	Bioelectrical impedance analysis	TBW	Total body water
BMI	Body mass index	VCO_2	Volumetric carbon dioxide production
CAPE	Critical Care, Anesthesia, Perioperative Extension	VO_2	Volumetric oxygen consumption
DXA	Dual-energy X-ray absorptiometry	WAZ	Weight for age z-score

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per day than recommended by national guidelines. In an effort to evaluate currently used methods for nutritional assessment in this group, our secondary aim was to examine the estimated values of energy expenditure and body composition in this cohort in relation to measured values. We hypothesized that energy expenditure estimated via a volumetric carbon dioxide production (VCO_2) measurement-based equation would be more reliable than a standard equation for predicting the measured energy expenditure (MEE).[15] We hypothesized that anthropometric assessment of fat mass would not be in agreement with measurements from bioelectrical impedance analysis (BIA).

Methods

In this prospective cohort study, children between the ages of 1 month and 17 years who were dependent on at least 12 hours of mechanical ventilation per day were recruited from an established program, the Critical Care, Anesthesia, Perioperative Extension (CAPE) and Home Ventilation Program. Patients were included in the study if the fractional oxygen requirement was less than 0.6, they had a cuffed tracheostomy tube, and had a leak less than 10% around the cuff at the time of data collection. We excluded patients with: (1) less than 12 hours of mechanical ventilatory support per day; (2) a recent illness such as fever, seizure, and/or infectious disease in the 24 hours preceding the study; and/or (3) respiratory decompensation requiring an increase in ventilator settings of >20% from baseline in the 72 hours preceding the study. The CAPE and Home Ventilation Program census was examined for all patients who met inclusion and exclusion criteria. We determined a priori a sample size of 20 patients for this pilot study. Parents or legal guardians of eligible consecutive patients were contacted for recruitment, until 20 patients were enrolled (Figure 1). Baseline demographic, nutritional, and respiratory support data were collected. The Boston Children's Hospital institutional review board approved the study, and a written informed consent was obtained for each enrolled subject.

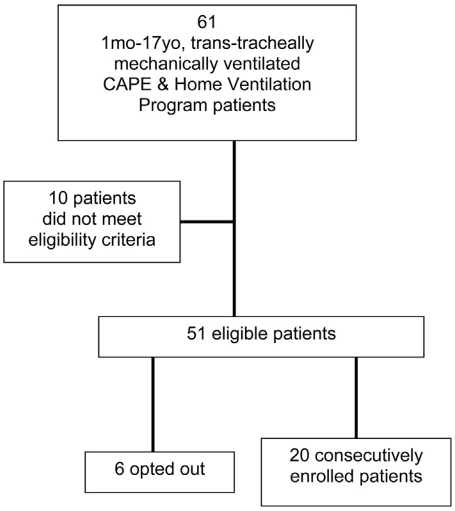

Figure 1. Flow chart of the patient selection process.

A multidisciplinary team composed of a respiratory therapist, dietitian, and physician, conducted a comprehensive nutritional, metabolic, and respiratory assessment during a scheduled visit to the patient's home. Study assessments, which are described in detail below, included anthropometry, BIA, macronutrient intake record, respiratory assessment by a portable respiratory monitor, and metabolic assessment by indirect calorimetry. In addition, estimated energy expenditure (EEE) was calculated by the Schofield equation and a VCO_2-based equation.[15] Body composition was calculated based on anthropometric measurements and total body water (TBW) from BIA measures.

Anthropometry

An electronic digital scale (seca 874, Chino, California) accurate to 0.1 kg was used to measure weight in kilograms (kg). Height or length (in recumbent patients or those younger than 1 year of age) in centimeters (cm) was measured using a rigid length board with a moveable headpiece to the nearest 0.1 cm. In patients with severe contractures, scoliosis, or hip dysplasia, segmental measurements were used to estimate length. In cases in which a reliable weight or length could not be obtained at the time of the visit, we used the most recent measured value in clinic. Mid-upper arm circumference was measured to the nearest 0.1 cm with a flexible, nonstretchable, plastic tape. Triceps, biceps, iliac, and subscapular skin fold thicknesses were measured to the nearest 0.5 mm, in triplicate, using Lange skin calipers (Beta Technology, Santa Cruz, California) by a single investigator. Anthropometric values were used to obtain estimates of LBM (kg, %) and fat mass (kg, %) from mid-upper arm circumference and skinfold measurements using previously published equations.[16]

BIA

A multifrequency impedance device (Bodystat Quadscan 4000, Bodystat, Ltd, Tampa, Florida) was used to derive TBW (L) from impedance measurements. Details of the BIA method have been previously described.[17] In brief, current-injector and detector electrodes were placed on the right upper and lower extremities per manufacturer's instructions. The procedure was completed with the patients in a resting, supine position. TBW was derived from impedance values measured by the BIA and via a hydration factor. Values for LBM (kg, %) and fat mass (kg, %) were then calculated from the TBW value, using a previously published equation.[18]

Macronutrient Intake

A 3-day food record was provided and explained to the parent or legal guardian prior to the visit. This was reviewed during the home visit by the dietitian.[19] Daily average actual energy intake (AEI, kcal/day), protein (g/day), carbohydrate (g/day), and fat (g/day) were calculated by the dietitian based on the food record, using the ESHA Food Processor software