Nutritional Assessment of Children With Cancer

Terezie Tolar Mosby, MS, RD, CSP, IBCLC, LD/N
Ronald D. Barr, MB, ChB, MD
Paul B. Pencharz, MD, PhD

Regardless of which parts of the world they live in, most children will develop and grow at a similar rate if proper nutrition is ensured. Children from developing countries are at risk for primary malnutrition. Children undergoing anticancer therapy are at higher risk for secondary malnutrition, including obesity and growth retardation. Periodic nutritional assessments are important for planning effective dietary interventions for such children. In this review, we describe malnutrition as it occurs in children with cancer and various ways of assessing the nutritional status of these children, depending on the availability of resources in their local hospitals. Objective and subjective data should be used to complete the nutritional assessment. We discuss screening methods, including the use of subjective global assessment. Different parts of nutritional assessment include medical history; physical examination; biochemical and hematological data, such as visceral proteins, blood glucose levels, and lipid profiles, hemoglobin and hematocrit, and the lymphocyte count; anthropometric measurements; and food and nutrition history. We review medical tests and procedures to determine nutritional status, including nitrogen balance, delayed cutaneous hypersensitivity, prognostic nutritional index, creatinine height index, malabsorption tests, indirect calorimetry, and dual energy X ray absorptiometry (DXA scan). Evaluation and interpretation of data and estimation of nutritional risk are discussed, including proper techniques and use of anthropometric measures, selection and use of growth charts, calculation of caloric and protein needs, and the percentage of calories ingested. These methods will enable local health care providers to accurately assess the nutritional status of children with cancer, identify children at risk, and plan adequate nutritional interventions.

Key words: assessment, nutrition, pediatric, oncology

Introduction

A child’s appropriate physical and psychological development stems in large part from proper nutrition during fetal development and childhood (Bhutta et al., 2008; Tielsch et al., 2008). With anticancer treatment, ensuring proper nutrition is a challenging task because of the side effects of chemotherapy and radiation, which include taste changes, nausea, vomiting, diarrhea, anorexia, and mucositis. Therefore, children undergoing anticancer therapy are at higher risk for undernutrition than their healthy peers.

Malnutrition is any disorder related to nutritional status, including a deficiency of nutrient intake (undernutrition), impaired nutrient metabolism, and overnutrition (American Society for Parenteral and Enteral Nutrition Board of Directors, 1995). In this
article, we will use the term malnutrition to refer to undernutrition. Primary malnutrition is related to inadequate food intake, and children from low-income countries are at high risk for primary malnutrition at the time of diagnosis. Secondary malnutrition is caused by a disease state, and children undergoing anticancer therapy are at risk for this type of malnutrition. Weight for height is an indicator of acute malnutrition when a child is too thin for a given height (wasting; World Health Organization [WHO], 1999). Height for age can be an indicator of chronic malnutrition. When a child is exposed to inadequate nutrition for a long period of time, growth is reduced, resulting in stunting (Milman, Frongillo, DeOnis, & Hwang, 2005).

The focus of this review is on methods of nutritional assessment with an emphasis on protein energy malnutrition (PEM). PEM occurring in association with cancer is usually a mixture of inadequate intake combined with the stress and catabolism caused by the disease and adverse side effects of the treatment. An inadequate energy intake is associated with loss of adipose tissue, which can be measured as a fall in skin fold thicknesses. It is useful to think of PEM as adapted or disadapted. The central concern is whether the person’s protein homeostasis is able to adapt to an insufficient intake; if so, the serum albumin will be normal. In the disadapted state protein homeostasis is unable to adapt; albumin falls, and there is rapid wasting of muscle mass as occurs in cancer cachexia (see below). Most often there are differing degrees of energy and protein insufficiency. Hence the use of the term PEM, which was first introduced to describe malnutrition occurring in children.

Cancer cachexia is a well-recognized condition in which there is rapid deterioration in body composition. Wasting of skeletal muscle as well as other components of lean body mass occurs. Furthermore, there is disturbance of whole protein homeostasis with net catabolism, negative nitrogen balance, increase in blood urea nitrogen, and fall in serum albumin. If untreated, cancer cachexia results in rapid deterioration of the patient’s nutritional status heading toward a “nitrogen death.” In children with cancer, cachexia is influenced by several factors, including type of disease, socioeconomic status, and type of treatment. Malnourished children are at higher risk for treatment-related complications (Gomez-Almaguer et al., 1995; Mauer et al., 1990), reduced tolerance of therapy, altered drug metabolism, increased susceptibility to infection, and poorer outcome (Mauer et al., 1990). Such children are also at higher risk for improper physical and psychological development (Grantham-McGregor & Fernand, 1997; United Nations Children’s Fund, 1996). As they age, malnourished children may have permanent mental and physical disabilities (Kroll, 2007).

Malnutrition caused by lack of essential nutrients can result from insufficient food intake, malabsorption, vomiting, or diarrhea. In children with cancer, medication may interfere with the use of food elements. Especially in these children, nutritional assessment is important for prevention, recognition, and early treatment of malnutrition. There are many techniques that can be used to evaluate the nutritional status of children. The choice of technique will depend on hospital resources, diagnosis, type of treatment, and other factors. In any case, both objective and subjective data should be used to complete the nutritional assessment. One marker alone should not be used to evaluate nutrition; therefore, health care providers should use critical thinking skills to assess nutritional status.

Screening

Screening is usually a prelude to nutritional assessment, which may consist of several parts, including data collection, evaluation, and interpretation, followed by estimation of nutritional risk. Nutritional assessment is a dynamic process performed to measure body size and composition for comparison with standards to estimate nutritional needs and to evaluate nutritional status and intake adequacy (American Dietetic Association, 2003).

Screening should be performed within 24 to 48 hours of admission for every patient and repeated regularly depending on the patient’s age, diagnosis, treatment, and other risk factors. However, in-depth assessment of all patients is not essential or practical. In contrast to some components of nutritional assessment, which should always be undertaken by dietitians or other appropriately trained health care providers to ensure accurate measurements, nutritional screening can be performed by other personnel from the multidisciplinary team. A careful selection of parameters to screen is essential. Nutritional screening should
include weight history, usual body weight, and a subjective history of current symptoms that includes, but is not limited to, nausea, vomiting, diarrhea, and appetite. Questions about food availability and who is responsible for food preparation should be asked. Such screening can identify children who are at risk of malnutrition and need a more comprehensive nutritional assessment. Screening criteria will differ by hospital. Please see Table 1 for an example of a screening form used in St Jude Children’s Research Hospital.

Subjective Global Assessment

Subjective global assessment (SGA) is a simple screening tool to readily identify who is at risk and hence who needs a full assessment with anthropometric and biochemical evaluations. It is a form partially filled out by the patient or caregiver and completed by a trained health care provider (dietitian or nurse). It is widely used in the adult population and is considered better for predicting nutrition-associated complications than medical tests or procedures (Detsky et al., 1984; Detsky et al., 1987). The first part of the SGA is filled out by the patient or caregiver and does not require any special skills. The part of the SGA that requires assessment of the physical appearance of the patient needs to be done by a professional who is well trained in nutrition assessment. It was validated recently in a preoperative pediatric population for assessing nutritional status and identifying patients at higher risk for nutrition-associated complications and prolonged hospitalization (Secker & Jeejeebhoy, 2007). It is an inexpensive and valuable tool, but it has not yet been evaluated for its effectiveness specifically in children with cancer.

Nutritional Assessment

In-depth nutritional assessment should be provided any time patients are at risk of malnutrition. Patients can be identified as at risk by medical personnel, other caregivers, or by periodic screening. Unlike nutritional screening, nutritional assessment should only be done by trained personnel experienced in assessing patients at nutritional risk. Data collection should include medical history, physical examination, biochemical and hematological data, anthropometric measurements, food/nutrition history, and medical tests and procedures.

Medical History

The medical history should include current and past information about acute and chronic illnesses, surgical and diagnostic procedures, medications and use of dietary supplements, and social history.

Physical Examination

The physical examination of a child with cancer is an integral part of nutritional assessment and should never be omitted. It should include the general appearance and activity level of the patient. The clinician should focus on the presence of edema, ascites, cachexia, obesity, skin changes, dry mucous membranes, petechiae or ecchymoses, healing of wounds, glossitis, stomatitis, and cheilosis (American Society for Parenteral and Enteral Nutrition, 2002). The physical examination should include an evaluation of body composition, including fat and muscle stores. Places to assess fat stores are overlying the lower ribs, orbital fat pads, triceps skin fold, groin,
and armpits. Places to assess muscle stores are temples, clavicles, calves, and quadriceps (thighs) (Norman et al., 2005; Pham, Cox-Reijven, Wodzig, Greve, & Soeters, 2007).

Other physical signs of malnutrition are liver enlargement and changes in skin, hair, eyes, face, lymph glands, mouth, teeth, and psychological status (Alvarez, 1995; Balint, 1998; Psoter, Gebrian, Prophete, Reid, & Katz, 2008). Nutritional skin disorders are also common as part of vitamin or mineral deficiencies (Oumeish & Oumeish, 2003).

Biochemical and Hematological Data

Biochemical data, such as visceral proteins, blood glucose levels, and lipid profiles as well as hemoglobin, hematocrit, and lymphocyte count can be used to help estimate nutritional status.

**Visceral proteins.** More than 30 years ago, serum albumin became the gold standard for indicating nutritional status in patients. Over the years, other visceral proteins such as prealbumin, transferrin, and retinol-binding protein have emerged as indicators of nutritional status. All 4 parameters have their limitations, and none can be regarded as a “gold standard.” It is rather the change in any 1 parameter over time that is a useful indicator of nutritional status. The half-life of albumin is 21 days, which can limit its value for determining a patient’s immediate nutritional status. Albumin concentrations can be increased by the use of corticosteroids, insulin, or thyroid hormone and by dehydration (as can the other markers). Albumin concentrations decrease in acutely or chronically ill patients because of the effects of inflammatory mediators on hepatic protein synthesis (Ingenbleek & Young, 1994; Mendez, McClain, & Marsano, 2005). Severe liver and renal disease, malabsorption, intravascular volume overload, and zinc deficiency decrease serum albumin levels. Many studies have shown that a person with trauma or infection will have decreased albumin status (Fuhrman, 2002), which is often believed to indicate malnutrition (Bistrian, Blackburn, Hollowell, & Heddle, 1974; Butterworth, 1974). However, this conclusion is false because it is low in sensitivity and specificity because of the effects of all the factors mentioned above.

Prealbumin and retinol-binding protein, with their short half lives, reflect more recent protein intake rather than an integration of protein nutritional status. An analogy is serum folate (which reflects recent dietary folate intake) and red cell folate which is a reflection of body folate status. Folate contributes to DNA synthesis and is a major coenzyme for many metabolic processes (Bailey, 1990). Prealbumin is a visceral protein that is sometimes used to indicate nutritional status. A study done to determine the usefulness of visceral proteins in assessing patients after hematopoietic stem cell transplants found that prealbumin, retinol-binding protein, and transferrin all were sensitive markers—unfortunately other measurements of nutritional status, such as anthropometry, were not included, and hence, it is not possible to be sure whether the changes were a result of changes in nutritional status (Rzepecki, Barzal, Sarosiek, & Szczylik, 2007). Prealbumin, retinol-binding protein and transferrin have also been shown to be useful for nutritional assessment of patients in intensive care units (Raguso, Dupertuis, & Pichard, 2003). However, prealbumin is influenced by some of the same factors that affect albumin (Raguso et al., 2003). If prealbumin is used as an indicator of nutritional status, it must be recognized that its concentration can be affected by the inflammatory response and not just by the nutritional status of the patient (Raguso, Genton, Dupertuis, & Pichard, 2002). Inflammatory responses can induce anorexia, which prevents the patient from receiving adequate nutrition to maintain metabolic stability. This in turn causes a rapid depletion of nutritional status which correlates with the concentrations of visceral proteins. In this respect, prealbumin can indicate the need for nutritional support to help a patient maintain adequate metabolic stability (Devoto et al., 2006; Fuhrman, Charney, & Mueller, 2004; Rzepecki, Barzal, Sarosiek, Oborska, & Szczylik, 2007). Another factor that affects levels of prealbumin is kidney failure. In this context, prealbumin levels will be high because of a lack of degradation by the renal tubules (Cano, 2002). However, serial prealbumin analysis is also a good predictor of subsequent albumin levels and adverse outcomes (Holland, Meers, Lawlor, & Lam, 2001).

These tests may be expensive and require drawing of blood. A variety of factors can affect laboratory values, including chemotherapy and other medications, infection, and meals. Therefore, visceral proteins may not be adequate for assessing nutritional status (Fuhrman, 2002). Other biochemical data, such
as blood glucose levels and lipid profiles as well as hemoglobin, hematocrit, lymphocyte count, and nitrogen-balance studies can be used to help estimate nutritional status.

**Blood glucose levels and lipid profile.** In a state of malnutrition, most people are not consuming enough calories to maintain metabolic demands. In cancer patients who are malnourished, increased glucose production occurs in the fasting state, and there are abnormalities with insulin secretion and action (Heber & Tchekmedyian, 1992). Malnutrition can cause glucose intolerance and impairment of insulin secretion (James & Coore, 1970; Milner, 1971). There is speculation that diabetes mellitus can be induced later in adolescence or adult life because of malnutrition during early childhood resulting from abnormal development of the B-cells in the pancreas (James & Coore, 1970). However, insulin resistance caused by disease or medication used during treatment, including glucocorticoids and L-asparaginase, is more common (Robertson et al., 2008). When hyperglycemia occurs, synthesis of very low-density lipoprotein (VLDL) is driven up, and both triglyceride and cholesterol levels rise.

A lipid profile is a group of tests to measure total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides. Nutrition can significantly improve or worsen a person’s lipid profile. A diet high in saturated fats and trans fats can increase total cholesterol levels. Plant-based diets high in fiber and unsaturated fatty acids can lower total cholesterol levels. In cases of PEM, patients experience an increase in plasma total triacylglycerol concentration, a measure of fat stored in the body, and decreased HDL concentration. This is caused by a reduction in the activity of lipoprotein lipase. Adult cancer patients have had similar lipid profiles (Vlassara, Spiegel, Doval, & Cerami, 1986). In one study involving children with cancer, results showed that bone marrow transplant and solid tumor patients had significantly higher triacylglycerol levels as a result of increased VLDL and LDL particles in the blood and significantly lower HDL than healthy children (Taskinen, Antikainen, & Saarinen-Pihkala, 2000). L-asparaginase induces prominent changes in the lipid profile, especially hypertriglyceridemia (Halton, Nazir, McQueen, & Barr, 1998). During anticancer treatment, the focus of nutrition is to maintain healthy weight. If total cholesterol levels remain elevated after treatment, the patient should be educated to follow a diet aimed at lowering cholesterol levels (plant based, low fat, high fiber).

**Hemoglobin/Hematocrit.** In a state of malnutrition, hemoglobin and hematocrit tend to decrease because of inadequate amounts of protein consumption and possibly iron deficiency. Other causes that lead to decreased hemoglobin and hematocrit in pediatric cancer patients include chemotherapy, penetration of malignant cells into the bone marrow, radiotherapy, inflammation, and blood loss (Michon, 2002). However, the hemoglobin and hematocrit can be falsely high if the person is dehydrated.

Iron status needs to be considered when evaluating hemoglobin and hematocrit, and the best single marker is serum ferritin. However, ferritin is also an acute phase reactant and hence may be falsely elevated. In this case, measurement of the transferrin receptor may help establish whether the patient is truly iron deficient (Cooper & Zlotkin, 1996). Many children with cancer experience iatrogenic myelosuppression and anemia of sufficient severity that repeated red blood cell transfusion is required, resulting in some degree of iron overload rather than iron deficiency.

**Lymphocyte count.** Malnutrition can also be indicated by a trend of low total lymphocyte counts, but this may be because of chemotherapy or the impact of the disease (Brugler, Stankovic, Schlefer, & Bernstein, 2005; Grzegorzewska & Leander, 2005).

**Anthropometric Measurements**

Anthropometric measures include weight, height, mid-upper-arm circumference, mid-upper-arm muscle circumference, and triceps skin fold thickness. Estimation of nutritional status using anthropometric measures includes calculation of body mass index (BMI), ideal body weight, waist-to-height ratio, percentage of ideal body weight, and percentage of weight loss.

Weight should be measured daily while the patient is in the hospital and during each outpatient visit. Weight can be influenced by the patient’s body composition, fluid status, medication use, organ enlargement, or tumor mass. Weight should be measured at
The same time of day, and similar clothing should be worn for consistency. Height should be assessed more often during rapid growth and can be affected by chronic malnutrition (stunting), marginal deficiency of several micronutrients (Rosado, 1999), or impaired growth because of anticancer therapy and steroid use (Olshan et al., 1992).

Arm anthropology is useful in assessing nutritional status, especially in children with a tumor mass (Brennan, Eden, Watt, Rennie, & Thomas, 1997; Brennan, Ross, & Barr, 1999; Oguz, Karadeniz, Pelit, & Hasanoglu, 1999). Triceps and subscapular skinfold thickness provide an index of body fat, and mid-upper-arm muscle circumference provides a measure of muscle mass (Jeejeebhoy, 2000). Fat folds can be used to objectively and directly assess body fat reserves and should be reexamined for accuracy. A strict technique should be followed to obtain reproducible measurements. Anthropometric measures are an inexpensive option for assessing nutritional status, but they can be affected by fluid retention, dehydration, or steroid therapy (Hall, Pollard, & Campbell, 1992; Manning & Shenkin, 1995).

The calculation of weight as a percentage of ideal weight for age, height, and gender as well as BMI is shown in Table 2, and their use for nutritional assessment is shown in Table 3. Anthropometrics can provide a considerable amount of nutritional information about the patient. However, it is important to have trained individuals performing the anthropology to ensure that the measurements are taken accurately and precisely. Inappropriate measurements by untrained professionals can provide misleading information on nutritional status.

### Table 2. Weight and Height Measurements for Nutritional Assessment

<table>
<thead>
<tr>
<th>Option #</th>
<th>B. Weight as a percentage of ideal body weight:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot weight at the 50th percentile on the weight for length/height growth curve</td>
<td>Express actual weight as percentage of IBW</td>
</tr>
<tr>
<td>(actual weight/ideal weight-for-height) × 100&lt;sup&gt;b&lt;/sup&gt;</td>
<td>(actual weight/ideal weight calculated using BMI) × 100</td>
</tr>
<tr>
<td>C. Body mass index:</td>
<td>Weight (kg) divided by height (m) squared</td>
</tr>
<tr>
<td>D. Calculating the percentage weight loss:</td>
<td>Weight loss expressed as a percentage of actual weight (Weight loss (kg)/actual weight (kg)) × 100</td>
</tr>
</tbody>
</table>


d. Bunting et al. (2008).


### Table 3. Nutritional Risk

| Screen: periodically |
| Assessment: at diagnosis and depending on the screen values |
| Estimation of risk |
| Anthropometric measurements |
| Weight for age<sup>c</sup> |
| <5th or > 85th percentile |
| >5% weight loss in 1 month |
| Current percentile weight or height fallen by 2 channels or more |
| Length or height for age (may indicate chronic malnutrition)<sup>d</sup> |
| <5th percentile height-for-age |
| Weight for length or height (may indicate acute malnutrition)<sup>d</sup> |
| <5th percentile or > 95th percentile weight-for-length (under 3 years) |
| <5th percentile underweight (indicator of inadequate weight gain) |
| >95th percentile indicator of obesity |
| Body mass index (BMI)<sup>c</sup> |
| <15th percentile or >85th percentile BMI-for-age (<3 years of age) |
| >85 percentile overweight |
| >95 percentile obese |
| <15 percentile undernutrition |
| <5 percentile severe undernutrition |
| Ideal body weight (IBW) calculated from weight for length/height<sup>f</sup> |
| <90% or >110% IBW-for-height |
| 85% to 89% mild undernutrition |
| >75% to 84% moderate undernutrition |
| <75% severe undernutrition |
| Ideal body weight (IBW) calculated from BMI<sup>d</sup> |
| 50% or >120% of IBW-for-height age |
| >120% overweight |
| 80% to 89% mild undernutrition |
| 70% to 79% moderate undernutrition |
| <70% severe undernutrition |
| Head circumference for age<sup>d</sup> |
| <5 percentile (may indicate microcephaly or chronic malnutrition during fetal life or early childhood) |
| Arm anthropology |
| Assessment of subcutaneous fat and muscle mass for signs of under/overweight |
| Triceps skin fold estimation of energy stores: compare with reference values<sup>e</sup> |
| Mid-upper-arm circumference: indicator of lean body mass |
| Nutrient intake<sup>c</sup> |
| <80% of estimated energy needs for a longer period of time |
| <50% of estimated energy needs for more than 3 days |


Food history consists of information about current dietary orders, diet history (current home feeding
regimen, food consumption patterns, quality and quantity of food, food preferences, feeding environment, and food allergies and intolerances), social history (socioeconomic status, caregivers’ perception of the patient’s nutritional status, and religious or cultural factors that affect food intake), and clinical factors (vitamin and supplement use, stool habits and characteristics, activity level, developmental level, and sleep patterns). Oral intake can be estimated by 24-hour dietary recall (ask about all oral intakes from the previous day), a 3-day food record count, or a food frequency questionnaire (Fraser, Butler, & Shavlik, 2006). Obtaining the food history is an inexpensive way to determine the child’s current eating habits. It requires caregivers to be able to recall what the child eats and estimate portion sizes. It is important to realize that fat is much more energy dense than protein or carbohydrate. Hence, if energy deficiency is a problem, focus should be applied to the fat content of the diet.

After taking a food history, a health care professional may find the patient to be consuming less calories than required to maintain current weight. In several studies, cancer treatment has been found to cause decreased food intake, decreased nutrient absorption, and increased metabolic demand (Lai, Cella, Peterman, Barocas, & Goldman, 2005). In some cases, the use of medications during radiation, chemotherapy, and hematopoietic cell transplantation can cause changes in taste perception (Chiodi et al., 2000), leading to malnutrition. Altered taste perceptions include increased sourness, bitterness, or a metallic taste when consuming food (Epstein et al., 2002; Wickham et al., 1999). One study showed that 82% of patients of all ages undergoing chemotherapy avoided at least 1 food since starting treatment (Holmes, 1993).

**Medical Tests and Procedures**

Following the screening assessment, the choice of tests and the timing of their performance will be dictated by the particular clinical circumstances.

**Nitrogen balance.** Nitrogen balance studies are a way of assessing protein metabolism in the body, but they are not commonly used as a clinical tool because of the necessity of urine collection. Nitrogen balance occurs when nitrogen output equals nitrogen input. Negative nitrogen balance indicates inadequate protein intake, and positive nitrogen balance indicates nitrogen retention (Suarez, 2004). In cancer patients, negative nitrogen balance is a result of inadequate intake of protein and/or increased protein catabolism. If a negative nitrogen balance is allowed to continue, protein malnutrition will in time occur, which is a cause for concern in patients undergoing anticancer treatment (Geibig et al., 1991). Studies have shown patients’ nitrogen balance improving with the use of high-nitrogen total parenteral nutrition versus the standard regimen (De Cicco et al., 1993; Geibig et al., 1991; Mulder et al., 1989). It is important to monitor nitrogen balance to prevent lean body mass deterioration and ensure quicker recovery in cancer patients. Measurement of total nitrogen is not usually available, but a reasonable surrogate is to monitor nitrogen balance by 24-hour urinary urea excretion and to determine how it responds to an increase in protein intake. Nitrogen intake is measured by dividing grams of protein consumed by 6.25, as it is estimated that 6.25 grams of protein contain 1 gram of nitrogen. Urine collected for 24 hours over 3 consecutive days is the ideal way to estimate nitrogen output (University of Washington, 1997). Such collections are challenging in children.

**Delayed cutaneous hypersensitivity (DCH).** This is a test to see if the body reacts to foreign substances such as antigens or allergens injected into the skin. A reaction should occur 24 to 48 hours after exposure to the foreign substance. This type of test measures cell-mediated immunity. The test was developed for use in adult patients and requires prior exposure to an antigen; hence, it is less useful in infants and young children. Malnutrition can affect the levels of circulating antibodies that respond to the stimuli or prevent the cells from recognizing foreign stimuli, giving a person a false negative reading for DCH (Rowland, 1991). Therefore, an improvement in nutritional status should increase DCH by preventing transitions from positive to negative. In one study involving 160 cancer patients receiving surgery, chemotherapy, radiation, or supportive care, nutritional repletion through intravenous hyperalimentation was provided, and skin tests before and after the procedure were examined (Daly, Dudrick, & Copeland, 1980). The researchers showed that cancer patients with nutritional repletion either remained positive or converted from negative to positive. This test is not commonly done in pediatric clinical settings.

**Prognostic nutritional index (PNI).** This is a method to determine nutritional status and risk of complications. PNI involves using a formulated
equation that can involve variables such as albumin, prealbumin, delayed hypersensitivity, transferrin, and triceps skinfold. There is a direct negative correlation between PNI percentage and risk of infection. In one study involving 67 hospitalized gynecological oncology patients (adult women), the relationship between PNI and length of hospital stay was investigated. PNI was determined at admission, and a value of at least 40 meant that one was adequately nourished, whereas a value less than 40 meant malnutrition. The researchers found a significant difference in hospital stay of 2 days between nourished and malnourished patients (Santoso et al., 2000). This test has not been validated for infants and children. A similar test, the simple pediatric nutritional risk score, was found to be suitable for routine use to identify patients at risk of malnutrition during hospitalization. The test included assessment of dietary intake, diarrhea and vomiting, pain, and ability of the patient to eat (Sermet-Gaudelus et al., 2000). The simple pediatric nutrition risk score has not been tested for children undergoing anticancer treatment.

**Creatinine height index (CHI).** This is a method to establish relative muscle mass in an individual. Creatinine is excreted in the urine and is a derivative of creatine, a storage form of protein in muscle. When an increased breakdown of muscle occurs in the body, a loss of creatinine is seen in the urine. The CHI can be used to assess children’s muscle mass and determine whether they are protein malnourished and need protein repletion in the diet. The CHI is defined for children as the ratio of 24-hour creatinine excretion by the patient to the amount of excretion of a healthy child of similar height. Age is not considered in children. If the CHI is close to 1.0, the child is within the normal range. If it is closer to zero, the child may be protein malnourished and may need nutritional supplementation (Viteri & Alvarado, 1970). One study used CHI as a way of identifying a patient population as malnourished or well nourished before surgery and to determine whether there was a difference in postoperative complications (Hatado & Miki, 2000).

**Maldigestion and malabsorption tests.** An important issue is whether a child with cancer has maldigestion or malabsorption, for which the gold standard is a 3-day fecal fat test and calculation of the percentage of dietary fat absorbed (3-day stool collection combined with 3-day dietary record). Coefficient of fat absorption values are <85% for infants and <93% for older children, and can be used to define steatorrhea (Ramsey, Farrell, Pencharz, & Consensus Committee, 1992). Maldigestion can be a result of loss of regulated gastric emptying, insufficient pancreatic exocrine function, bile salt deficiency, or mucosal disease. Malabsorption can be a result of loss of intestinal surface area, impaired circulation or lymphatic damage in the gut, mucosal infiltration with abnormal cells, genetic mutations of transport proteins, or impaired motility.

**Indirect calorimetry.** The energy needs of a patient can be estimated either by using the World Health predictive equation (Food and Nutrition Technical Report Series, 2001) or measured directly by respiratory gas exchange using an indirect calorimeter. Indirect calorimetry, for example the metabolic cart test or MedGem, measures energy expenditure and determines the caloric needs of the patient. It measures oxygen consumption, carbon dioxide production, and the respiratory quotient to determine energy expenditure and caloric needs. It is useful to relate the measured resting metabolic rate (RMR) with the calculated RMR (AARC, 2004).

**Dual energy X-ray absorptiometry (DXA).** This is a noninvasive technique for measuring bone mineral content and bone mineral density with minimal exposure to ionizing radiation (Gordon et al., 2008). It is also becoming accepted as a standard in clinical practice for assessing body composition in children (Sala, Webber, Morrison, Beaumont, & Barr, 2007). The combination of whole body bone mineral content, fat mass, and fat free mass (very similar to lean body mass) summate to whole body weight. Deficits in bone mineralization are common sequelae of the treatment of cancer in childhood (Wasilewski-Masker et al., 2008).

**Evaluation and Interpretation of Data and Estimation of Risk**

**Growth Charts and Anthropometric Measures**

Weight and height, or length and BMI, or weight for height in children younger than 3 years, should be compared with values on age- and sex-specific growth
charts. For children living in the United States, Centers for Disease Control and Prevention (CDC) growth charts should be used (CDC, 2000a, 2000b). CDC charts have a higher percentage of children under the age of 2 years being at risk for malnutrition. The CDC charts were formulated using a broader, more diversified sample of children than the National Center for Health Statistics and Tanner-Whitehouse charts (Nash et al., 2005). For children from other countries, WHO charts should be used for children up to age 5 years because these charts only extend to this age, beyond which the CDC charts should be used (International Pediatric Association, 2006). The WHO created a growth chart using children from ethnicities and cultures from various parts of the world (WHO Multicentre Growth Reference Study Group, 2006). Studies have shown that infants who are exclusively breast fed grow at a rate different from that of formula-fed infants; therefore, WHO charts specific to breast fed children should be used for those infants (De Onis & Onyango, 2003). Fenton charts are used for preterm infants. These charts plot preterm infants from 24 to 50 weeks of gestation and are not sex specific. Specialized growth charts are also available for children with Down syndrome, cerebral palsy, Turner syndrome, Prader-Willi syndrome, and achondroplasia. Nutritional intervention is indicated for children at risk, as outlined in Table 3 (Children’s Oncology Group, 2004). The proper use of anthropometric measurements has already been discussed above.

**Dietary Intake**

The percentage of needed calorie intake should be estimated. RMR should be calculated using the FAO/WHO/UNU Expert Consultation for Human Energy requirements (Food and Nutrition Technical Report Series, 2001) and adding the activity quotient. Current dietary intake will be compared with estimated caloric needs. A patient is considered at nutritional risk if he or she consumes less than 50% of the estimated caloric needs for more than 3 days (Ringwald-Smith, Cartwright, & Mosby, 2000) or less than 80% for more than 3 days (Children’s Oncology Group, 2004). The recommendations for nutritional intervention are not consistent (Ladas, Sacks, Brophy, & Rogers, 2006). We are presenting the Children’s Oncology Group Guidelines (Rogers et al., 2008).

**Conclusion**

Cancer is the most common cause of disease-related death in children in the United States (Jemal et al., 2006; Ries et al., 1999), but it is not even among the top 10 causes of death in developing countries. In contrast, malnutrition (undernutrition) is one of the most common causes of death in children in the developing world, whereas it is decidedly uncommon in the general population of children in the United States. Another difference is that the complications of undernutrition before diagnosis is common in low-income countries, whereas childhood obesity is the more common problem in high-income countries. Both undernutrition and obesity can affect treatment outcome. Anticancer treatment in children is often very intense and may affect the nutritional status of children and therefore their physical and psychological development. Proper nutritional assessment is important for timely nutritional intervention and prevention of complications associated with malnutrition.

**Acknowledgment**

This review was funded in part by the American Lebanese Syrian Associated Charities (ALSAC). The authors thank Lisa Keung and Megan Hitt, graduate assistants in dietetics, for helping with the literature search, Margaret R. Williams, MS, EdD, for consultations, and David Galloway, ELS, for scientific editing.

**References**


---

<CE> Continuing Education Credit

The Journal of Pediatric Oncology Nursing is pleased to offer the opportunity to earn pediatric hematology/oncology nursing continuing education credit for this article online. Go to www.aphon.org and select “Continuing Education.” There you can read the article again or go directly to the posttest assessment. The cost is $15 for each article. You will be asked for a credit card or online payment service number.

The posttest consists of 11 questions based on the article, plus several assessment questions (e.g. how long did it take you to read the article and complete the posttest?). A passing score is 8 out of 11 questions correct on the posttest and completion of the assessment questions yields one hour of continuing education in pediatric hematology/oncology nursing for each article.

The Association of Pediatric Hematology/Oncology Nurses is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center’s Commission on Accreditation.