The Scientific Basis of Nutritional Assessment

A. W. Goode

Nutritional assessment is the essential first step in the adequate nutritional care of a patient. Simple bedside impressions of nutritional status or change with therapy are invariably erroneous (Walesby et al., 1979) and are to be deprecated. Recent surveys (Bollet and Owens, 1973; Bistrian et al., 1976; Hill et al., 1977; Letsou, Connaughton and O'Donnell, 1977; Willicutts, 1977) have shown that up to 50% of patients in hospital were moderately or severely malnourished. Malnutrition may have a profound influence upon clinical practice. Acute weight loss of more than 40% is invariably fatal while degrees of wasting are associated with increasing mortality and morbidity. Such depletion results in poor wound healing and callus formation, immunological depression, disordered coagulation, reduced enzyme synthesis, altered drug metabolism, decreased tolerance to radiotherapy and chemotherapy, and prolonged convalescence after surgery.

The formulation of an appropriate feeding regimen for the wasted patient can only be done after accurately establishing the nature and degree of depletion. However, a recent study (Ray and Dickerson, 1979) has shown that clinicians faced with many available tests are both uncertain about those most appropriate, and confused as to the ultimate aim of management.

Brozek and Henschel (1961) described how Rubner in 1902 conceived the idea of an oxidizing protoplasmic mass as the component of the body responsible for energy consumption and chemical and mechanical work performed. Moulton (1923) reinforced this concept, showing that body fat was a variable quantity and emphasized the constant composition of the lean body weight; which on analysis was hydrated and both nitrogen- and potassium-rich in contrast to neutral fat. Since then Kinney, Lister and Moore (1963) have demonstrated that resting energy expenditure was directly related to the size of the lean body mass.

Thus body weight is composed of the relatively inert skeletal mass, body fat—the portable personal energy store,—and the energy-utilizing component, the lean body mass. Moore and colleagues (1963) further refined the concept of the lean body mass, pointing out that some of its constituent tissues—dermis and connective tissue—are functionally inert; thus they proposed a more precise term for the active cellular mass: the body cell mass.

Peaston (1974) studied weight loss in long-term starvation and concluded that the body utilizes fat and the skeletal muscle component of the body cell mass in a ratio of 2.5 : 1. Similarly, Burkinshaw, Morgan and Hill (1978), studying weight loss before operation, concluded that protein was lost from skeletal muscle, but that in the patient after operation two-thirds was lost from skeletal muscle and the remainder from visceral protein. Regardless of the source of the protein utilized to provide glucose by gluconeogenesis, the loss of body cell mass represents the increasing inability of the body to utilize energy to support vital functions and ultimately will lead to death. Accelerated loss—hypercatabolism—is seen in burns, sepsis and acute pancreatitis. Thus, from theoretical considerations, measurement of total body protein (the body cell mass) is the most important single parameter.

General indices of nutritional depletion

In clinical practice the critical factor initiating nutritional assessment is awareness of the possibility that the patient may be wasted. A routine clinical history usually neglects nutritional intake and a specific dietary history may be most valuable in revealing specific deficiencies (Mueller and Thomas, 1975). Weighing the patient is the simplest guide to nutritional deficiency although it gives no indication of the nature of the tissue loss and may be misleading in clinical conditions with water retention or dehydration. The comparison of actual weight with ideal weight for height and age derived from anthropometric tables (Documenta Geigy, 1962; Kemsley, Billewicz and
Thompson, 1962; Jelliffe, 1966) gives a guide to the severity of depletion. The calculation of percentage weight loss and its interpretation with time is shown in table I (Blackburn et al., 1977).

**Table I. Evaluation of percentage weight loss. Weight loss calculated using the equation: percentage weight change = (usual weight – actual weight)/(usual weight) x 100**

<table>
<thead>
<tr>
<th>Time</th>
<th>Significant weight loss (%)</th>
<th>Severe weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 week</td>
<td>1-2</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>1 month</td>
<td>5</td>
<td>&gt; 5</td>
</tr>
<tr>
<td>3 months</td>
<td>7.5</td>
<td>&gt; 7.5</td>
</tr>
<tr>
<td>6 months</td>
<td>10</td>
<td>&gt; 10</td>
</tr>
</tbody>
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Another simple measurement is the mid upper-arm circumference of the non-dominant arm. Reduction to 85% or less of adult standard values is associated with significant morbidity after surgery (Kammerling, Foster and Karran, 1978). Standard adult values and their interpretation are given in table II.

**Table II. Arm circumference values in adults. The measurement should be made in the middle of the non-dominant arm**

<table>
<thead>
<tr>
<th></th>
<th>Male (cm)</th>
<th>Female (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>29.3</td>
<td>28.5</td>
</tr>
<tr>
<td>90% of standard</td>
<td>26.3</td>
<td>25.7</td>
</tr>
<tr>
<td>80% of standard</td>
<td>23.4</td>
<td>22.8</td>
</tr>
<tr>
<td>70% of standard</td>
<td>20.5</td>
<td>20.0</td>
</tr>
<tr>
<td>60% of standard</td>
<td>17.6</td>
<td>17.1</td>
</tr>
</tbody>
</table>

**Fat stores**

Measurements of body fat are an estimate of endogenous energy stores, some measuring the absolute size and others dynamic function. Triceps skinfold thickness measured on the non-dominant arm with skinfold calipers will give a simple measure of suspected loss of body fat. Standard values for adults and their interpretation are given in table III. Measurement of skinfold thickness at four sites—mid-biceps, mid-triceps, subscapular and suprailiac—may be used to determine the absolute size of the body fat being expressed as a percentage of body weight (Durnin and Womersley, 1974).

**Table III. Triceps skinfold thickness values in adults**

<table>
<thead>
<tr>
<th></th>
<th>Male (mm)</th>
<th>Female (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>12.5</td>
<td>16.5</td>
</tr>
<tr>
<td>90% of standard</td>
<td>11.3</td>
<td>14.9</td>
</tr>
<tr>
<td>80% of standard</td>
<td>10.0</td>
<td>13.2</td>
</tr>
<tr>
<td>70% of standard</td>
<td>8.8</td>
<td>11.6</td>
</tr>
<tr>
<td>60% of standard</td>
<td>7.5</td>
<td>9.0</td>
</tr>
</tbody>
</table>

The rate of clearance of injected intralipid—an i.v. fat tolerance test—is a measure of fat utilization (Feggetter, 1980). The clearance of a bolus injection occurs at two rates, $K_1$ and $K_2$. $K_2$ is a first-order reaction where clearance is exponential and a constant fraction is removed. The clearance curve is plotted semilogarithmically and the regression line fitted by the least squares method. The slope of the regression line is the fractional clearance rate. Surgery and heparin therapy increase the exponential ($K_2$) clearance.

In patients whose dietary intake is known to be inadequate, there is an increase in ketone body production which may reduce gluconeogenesis from protein (Wedge et al., 1976). Conversely, failure of ketone production may be of serious consequence as energy will then be principally derived from protein stores (Williamson et al., 1977). Rich and Whitehouse (1979), investigating ketone body production in the wasted patient before operation, have observed that, in patients similar in all other nutritional parameters, those who were unable to produce more ketone bodies after a 6-h fast had a significantly greater mortality rate after surgery.

Essential fatty acids have three principal functions: as energy substrates, in the synthesis of structural lipoprotein and as precursors for prostaglandin synthesis (Press, 1980). Diagnosis of deficiency states have in the past been dependent upon recognizing specific clinical features of deficiency—dermatitis, diarrhoea, abnormal platelet function and fatty infiltration of the liver. Patients fed on regimens composed only of amino acids and glucose and patients with extensive bowel resections are especially liable to develop essential fatty acid deficiency. The basic essential fatty acids which can only be synthesized by plants are linoleic and linolenic acids; as about 10% of adipose triglyceride is linoleic acid, there is a considerable reserve. The enzymes which convert linoleic acid to arachidonic acid are also capable of
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converting the non-essential oleic acid to eicosatrienoic acid. In normal circumstances linoleic acid is the preferred substrate. However, in fatty acid deficiency oleic acid inhibition is removed and eicosatrienoic acid concentrations become detectable. A ratio of eicosatrienoic acid/arachidonic acid of 1.0 or less is diagnostic of deficiency.

Protein stores

This is the most important nutritional component and the majority of available tests are directed towards measuring the total size of the body cell mass, reflecting the relative daily change of tissue synthesis or breakdown rate. Plasma amino acid profiles are altered by the underlying disease process in the wasted and fasted patient. In chronic protein calorie malnutrition total amino acids are decreased, particularly branched-chain amino acids, while glycine and serine are usually increased (Waterlow and Harper, 1975). In infections total amino acids concentrations are again decreased, with increase in phenylalanine and tryptophan (Wannemacher et al., 1972). After surgery there is a progressive decrease in the glucogenic amino acids for up to 3 days with a corresponding increase of branched-chain amino acids (Dale et al., 1977). In patients with cancer alanine, arginine and branched-chain amino acids values are decreased whilst, in contrast to starvation, glycine is normal or decreased (Glass and Goode, unpublished observations).

However, amino acid analysis facilities are limited and interpretation of individual patterns may be difficult as well as not quantifying tissue loss from the body cell mass.

Indices of total body protein

Absolute size of the body cell mass may most simply be quantified by measuring the fat-free mass using Durnin and Womersley's method (1974) of skinfold thickness measurements. This gives the percentage of body weight as fat and, by simple calculation, the fat-free mass in kilograms may be derived. In patients clinically free from oedema and with a normal packed cell volume this gives excellent agreement with other more complicated but precise methods of measurement (Goode and Hawkins, 1978).

The two methods which most precisely measure the body cell mass—total body nitrogen and total body potassium—are complex and not suitable for daily clinical practice except in specialized centres.

Indices of relative protein change

Nitrogen balance is one of the most widely used methods of assessment. The daily comparison of a known intake with nitrogen loss from all sources allows a measure of the relative change of the body cell mass. It does not estimate the absolute size of the body cell mass. A positive nitrogen balance,
where intake and retention exceeds loss, is indicative of anabolism; excess loss indicates tissue catabolism. It has been suggested that compounding errors in collection may decrease its value after about 14 days. A negative nitrogen balance of 1 g indicates a loss of 6.25 g of protein or 30 g of muscle tissue.

Tissue synthesis rate may be most accurately measured by estimating whole body protein turnover by a constant rate infusion of $^{14}$C-leucine or $^{15}$N-glycine (O'Keefe, Sender and James, 1974). From this the anabolic rate may be calculated, while Clague and others (1980) have used $^{14}$C-leucine incorporation into plasma proteins as an index of the severity of injury. More simply, hair root morphology has been advocated as an indicator of protein synthesis with feeding (Jourdan, 1978).

Muscle breakdown is determined by measuring excretion of 3-methylhistidine, which is released from actin and myosin in skeletal muscle. 3-Methylhistidine when released is not reutilized, and is excreted unchanged in the urine (Young et al., 1972). Provided that a meat-free diet is taken for 24–48 h before measurement, 24-h urinary estimations may be made. The rate of muscle catabolism may be quantitated as 4.2 μmol of 3-methylhistidine represents 1 g of mixed muscle protein (Munro, 1978).

**Visceral protein status**

Serum albumin concentrations have most commonly been used as an index of hepatic protein synthesis. The plasma concentration is dependent not only upon the synthetic rate, but also the catabolic rate and distribution between the intra- and extra-vascular compartments (Fleck, 1976). Serum concentrations from 30 g litre$^{-1}$ to 21 g litre$^{-1}$ are indicative of moderate malnutrition, while values less than 21 g litre$^{-1}$ indicate severe malnutrition. No relationship has been demonstrated between low values and nutritional oedema (Golden, Golden and Jackson, 1980). In stable patients albumin concentrations have been used both as a nutritional index of longstanding malnutrition and to monitor the response to nutritional support (Olusi et al., 1975). Serum albumin concentrations show a poor response to short-term changes in protein and energy intake; on a daily protein intake of 20 g only a small decrease in serum albumin can be induced in 5 weeks.

Proteins synthesized by the liver but with a short half-life have been used as indices of visceral protein synthesis and are more responsive to refeeding. Serum transferrin is reduced in protein calorie malnutrition and has a half-life of 8 days (Awai and Brown, 1963). Serum transferrin may be measured directly using commercially available kits or indirectly from total iron binding capacity from the formula: Serum transferrin (mg dl$^{-1}$) = (Total iron binding capacity x 0.8) – 43. The normal values are 200–300 mg dl$^{-1}$. Serum concentrations between 100 and 150 mg dl$^{-1}$ are indicative of moderate malnutrition and values less than 100 mg dl$^{-1}$ reflect severe malnutrition. Caution must be used in patients with a history of chronic bleeding as increased concentrations of transferrin may occur. Plasma thyroxine-binding pre-albumin has a half-life of 2 days and may be used as a short-term nutritional index (Ingenbleek et al., 1975). Retinol-binding protein is, however, the most sensitive index of both subclinical malnutrition and the response to feeding, with a half-life of 12 h (Shetty et al., 1979).

**Immune status**

Adequate nutrition is essential for the maintenance of a normal immune system (Law, Dudrick and Abdou, 1974). A reduction in the total peripheral lymphocyte count is associated with depressed cellular immunity. A total lymphocyte count of 800–1200 mm$^{-3}$ is indicative of moderate protein calorie malnutrition and less than 800 mm$^{-3}$ indicates severe depletion. Circulating immunoglobulins may be directly measured as a standard laboratory procedure. Immunological challenge tests are also often used as a test of the cell-mediated immune response. Intradermal injection of a common recall antigen—candida, PPD, streptokinase, streptodornase or DNCB—should produce a cutaneous response within 24–48 h. A skin weal 0.5 cm or more in diameter is a positive response. Failure to respond indicates an anergic state, but the test may become positive with appropriate nutritional support.

**Vitamin status**

Daily requirements of vitamins vary greatly, for example the dose of vitamin C is 50 000 times that for vitamin B12. A good nutritional history is essential as often it will indicate a deficiency before its clinical manifestations. The requirements for the water-soluble vitamins are especially increased.
in disease states (Levenson et al., 1976). Vitamin C depletion is found in smokers, in association with aspirin and barbiturate therapy, and in post-operative patients. Decreased vitamin B6 concentrations are found with oral contraceptives and isoniazid therapy, vitamin B12 deficiency with oral hypoglycaemic agents, and low folate values with epileptic therapy, methotrexate treatment and excess alcohol intake. A combination of low vitamin A, B6 and C values is known to depress the immune response. Vitamin K deficiency may occur with broad-spectrum antibiotic therapy.

There are two types of test for vitamin status: blood concentrations or the measurement of an enzyme activity in which a vitamin is a co-factor (Sauberlich, Doway and Skala, 1974). Plasma vitamin A, C, B12 and folate concentrations reflect recent dietary intake, while leucocyte ascorbic acid and red cell folate values are indices of whole body status. Vitamin B1 (thiamine) status is measured by red cell transketolase activity and vitamin B6 (pyridoxine) status by red cell aspartate transaminase activity. Four coagulation factors are vitamin K-dependent, but deficiency is usually measured by a prolonged cephalin-kaolin time and a prolonged prothrombin time.

Trace element status

The body contains approximately 40 elements present in varying amounts; those present in adults in the concentration of about 100 parts per million are the trace elements. Up to 15 trace elements are essential for optimal health (Aggett, 1979). Some trace metals form complexes with organic molecules and are involved in cell membrane function while others are involved with enzyme function. Indeed, about one-third of all enzymes are trace metal dependent. Copper is involved with cellular respiration, zinc in carbonic anhydrase function, nucleic acid and protein synthesis and the urea cycle, selenium in peroxide reduction, manganese in glycoprotein synthesis and molybdenum in sulphur metabolism.

Trace metal deficiencies are usually associated with gross malnutrition or prolonged nutritional support, especially parenteral nutrition, and circulating zinc, copper, magnesium and chromium concentrations must be measured. In some instances various clinical manifestations may give a suspicion of deficiency. Zinc depletion is associated with anaemia, dermatitis, diarrhoea, and impaired wound healing, copper with iron-resist-

Awareness that a patient may be nutritionally depleted is the key to assessment and management. A dietary history and clinical examination are of great value in indicating possible specific deficiencies. However, specific tests are of most value. No single abnormal parameter should be used in isolation to identify malnutrition, but rather a combination of at least three parameters. Those selected by the clinician obviously depend upon his understanding of their limitations and laboratory availability. In general, anthropometric measurements will indicate moderate or severe degrees of malnutrition and during a feeding regimen will show evidence of successful repletion if performed at approximately 2-week intervals (Goode et al., 1976; Shenkin and Steele, 1978).

Collins, McCarthy and Hill (1979) studied degrees of weight loss, arm circumference and arm muscle circumference with total body nitrogen content. They concluded that anthropometry was reliable, the 95% confidence limits were nitrogen ± 30 g, but the variance shown made it inappropriate as a single measurement. Similarly, anthropometry was not reliable in following changes in body protein in individual patients over a short period of time.

A frequently recommended triad for nutritional assessment has been a recent weight loss in excess of 10%, serum albumin less than 32 g litre−1 and loss of skin antigen recall. Mullen and others (1979) studied 16 nutritional parameters and concluded that only serum albumin and serum transferrin concentrations with delayed hypersensitivity reactions had a significant predictive value of morbidity and mortality after operation; patients with these reduced parameters had a 2.5-fold increase in complications, although the prognostic accuracy of delayed hypersensitivity has been disputed (Brown et al., 1980).

During nutritional support, either enteral or parenteral, it is essential to measure changes in nutritional status, circulating substrates and ions, and organ function at prescribed intervals.

Programmes for daily, twice-weekly and weekly measurements of these parameters are given in tables IV–VI.

Advances in the understanding of the consequences of malnutrition and its management by
appropriate nutritional support have been a major advance in patient care. It is surprising, therefore, that therapy has often not been preceded by measurement to allow the most appropriate regimen to be provided. The selection of the appropriate tests for assessment of nutritional status before and during management can be critical for a successful outcome. The formation of nutritional care teams is an additional source of expertise now available, which can be of particular value in the management of the complicated patient.

REFERENCES


