Optimal nutritional status is a critical component of good health at any age but requires particular attention in the older age group. A variety of age-related morbidities and dysfunctions may interfere with the maintenance of good nutritional status. Older adults are at risk, as a population group, of compromised ability to acquire and prepare nutritious meals on a day-by-day basis. They are also at increased risk of drug-induced nutritional deficiencies because of the number of prescription drugs they take. Accordingly, the detection and treatment of nutritional disorders in older persons has emerged as a major public health concern. In response, primary and secondary preventive strategies have been developed to identify malnutrition or the risk of malnutrition in older persons.

In this review, we will outline a conceptual background or nutritional screening, describe the burden of suffering associated with nutritional disorders, examine the efficacy of currently available screening tests, evaluate the evidence that persons detected early have a better clinical outcome than those detected without screening, and provide directions for research. Although a myriad of nutritional assessments or considered potential screening tests, we have limited his review to those that can be administered in an inexpensive manner in screening settings.

The value of nutrition screening as a preventive strategy contingent upon two factors: the burden of suffering from malnutrition and the potential effectiveness of preventive intervention.5 Potential effectiveness requires that two additional criteria be met: (1) the method of nutrition screening must identify malnutrition more accurately than the test used without screening (efficacy of screening) and (2) persons detected early should have a better clinical outcome than those who are detected later without screening (effectiveness of early detection).

The efficacy of screening tests is generally determined by evaluating validity, particularly sensitivity, specificity, and predictive value.6 The ideal screening test has high sensitivity (i.e., it is positive in those who have a disorder) and high specificity (i.e., it is negative in those who do not have the disorder.) Unfortunately, few tests have both high sensitivity and specificity. Most screening programs sacrifice specificity to achieve high sensitivity with the proviso that an abnormal test will usually be followed by a diagnostic test to exclude false positives.

When instruments that have multiple items (e.g., the Nutrition Screening Initiative Checklist) rather than a single test (e.g., serum albumin) are used for screening, the instrument must meet standards of reliability, particularly internal consistency (alpha reliability).7 Instruments that are used to make decisions about the care of individual patients need to be more reliable than those used for comparing populations. The performance of an instrument (e.g., anthropometrics) when administered by different observers (inter-rater reliability) may also be important. The stability of the instrument in measuring the construct in the absence of clinical change (test-retest reliability) is also a key characteristic of reliable instruments. Instability is particularly important in nutritional epidemiology when evaluating dietary intake, which may require extended assessment to detect a stable pattern.

Finally, the benefits (effectiveness) of early detection must be demonstrated. Screening tests that detect problems for which there is no effective treatment are of little or no benefit, except when public health measures may be taken to protect others from acquiring the disorder. The most convincing evidence for benefit from screening comes from randomized clinical trials, but other types of evidence, including observational studies, case-control studies, and expert testimony, have been used to support screening tests.

Focusing on nutrition screening, a series of questions must be answered to determine the current and future status of this preventive measure:

1. What is the burden of suffering from malnutrition in older persons?
2. What is the efficacy of currently available nutritional screening tests?
3. What is the evidence that persons detected early have a better clinical outcome than those who are detected without screening?

Nutrition screening is further complicated by the heterogeneity of the health status of the older population and the impact of both acute and chronic illness on nutritional assessment.

A precise definition of malnutrition is problematic because it includes a variety of conditions reflecting over- or undernutrition of protein, energy, or nutrient status. In addition, the stage at which malnutrition is identified may have more or less clinical meaning. To illustrate, Figure 1 provides a schema based on a conceptual model of core indicators of nutritional state developed for the American
In this slightly modified model, four stages in the sequence of malnutrition are defined, beginning with (1) risk factors, then progressing to (2) inadequate intake relative to nutritional needs, (3) preclinical symptoms, anthropometric changes, and biochemical markers, and, finally, (4) measurable health outcomes. However, the process along the four stages is not predictably linear. Persons who meet criteria for concern at any of the first three stages may or may not progress to the next stage. At what point in the process is a person defined as being malnourished? Additionally, a risk factor at stage 1 (e.g., a chronic disease) could predict an outcome at stage 4 (e.g., mortality) some years later, but this relationship may be mediated by factors other than nutrition.

Moreover, the variability of time-frame and trajectory along this pathway must be considered. For some nutrients, the time from dietary deficit (stage 2) to health outcomes (stage 4) may take decades whereas for others it may be a matter of weeks. For example, insufficient calcium and vitamin D intake may take 20 years or more to result in bone insufficiently osteoporotic to fracture, but several weeks of protein-calorie malnutrition may lead to pressure sores.

**BURDEN OF SUFFERING**

Depending on the definition used, the prevalence of malnutrition in older persons is generally high. If defined as a decrease in nutrient reserves, an estimated 0 to 15% of ambulatory outpatients, 35 to 65% of patients hospitalized for acute illness, and 25 to 60% of institutionalized older persons are malnourished. Other definitions yield different estimates. One study reviewing an academic outpatient practice identified slightly more than 3% of persons 60 years of age or older as having body weight less than 45.4 kg (100 lbs), and almost 60% of these had severe malnutrition (below the fifth percentile of age- and sex-specific norms) as defined by National Health and Nutrition Examination Survey (NHANES) criteria. In a national household survey, Ryan et al. found that 37 to 40% of older (65-74 years and 75 years and older) men and women reported energy intakes less than two-thirds the Recommended Dietary Allowance (RDA). Prevalence rates for nutrient intakes below two-thirds the RDA exceeded 33% for vitamin E, calcium, and zinc in all subgroups; many subgroups had prevalence rates exceeding 33% for vitamins A and B₆ and for magnesium. High rates of dietary inadequacy of vitamin A and calcium have also been found in community-dwelling older New England residents. It should be noted, however, that Recommended Dietary Allowances should not used as a criterion standard for assessing individual nutritional adequacy; rather, they are a population standard. Moreover, RDAs do not acknowledge different nutrient requirements for persons over 65 years of age compared with younger persons.

The prevalence of malnutrition is considerably higher in hospitalized patients than in community-based samples. A Department of Veterans Affairs (DVA) case series defined malnutrition as meeting two of the following four measures: (weight/height per cent < 90% of normal, mid-arm muscle circumference < 90% of normal, albumin < 3.5 g/dL and transferrin < 200 mg/dL; 61% of patients 65 years of age or older met this criterion compared with 28% of those younger than 65 years. More recently, a Norwegian case series identified 55% of medical inpatients aged 70 years of older who were admitted to a medical ward as having weight/height ratios less than 90% of the expected values.

A summary of 14 surveys of nutritional status conducted among chronically institutionalized older persons concluded that only 5 to 18% of residents had energy intakes below the RDA, but up to 30% consumed less than 0.8 g protein/kg body weight per day and 15 to 60% had substandard mid-arm muscle circumference, serum albumin, or both. It also estimated that the prevalence of inadequate mineral and micronutrient intake was 20% or higher for iron, vitamins C and D, riboflavin, and pyridoxine. In a study conducted in one Canadian nursing home, a rating system based on seven anthropometric measurements identified severe undernutrition in 18% of residents, moderate undernutrition in 27%, and mild/moderate overnutrition in 18%. Data from 26 DVA nursing homes indicated that 12% of residents had body weight less than 80% of standard, and 28% had albumin levels less than 3.5 g/dL.

The health consequences of malnutrition may be profound, particularly in hospital settings. Several markers of malnutrition in older hospitalized persons, including low body mass index, low serum albumin, and in-hospital-acquired hypercholesterolemia, have been associated with increased length of stay, complications, readmissions, and mortality. Data from the Framingham Heart Study suggest a U-shaped relationship between body mass index (BMI) and mortality in older persons. A recent analysis of NHANES follow-up data indicates similar relations between BMI and self-reported functional status. Body...
weight has also been associated with length of stay and medical care charges in older persons who were admitted for elective total knee and total hip replacement surgery. The prevalence of overweight increases with age between the ages of 22 to 55 years, but then stabilizes in women and declines in men. The percentage of overweight (BMI > 27.8 for men and 27.3 for women) persons in the 65 to 74-year-old age range remains considerable, however, at about 25% in men and about 40% in women. Older black and poor women have higher rates of overweight.

A substantial body of evidence links overweight to hypertension, hypercholesterolemia, heart disease, insulin resistance and diabetes, cholelithiasis, respiratory impairment, gout, and arthritis. However, the relationship between obesity and occurrence rates of specific diseases or overall mortality in persons older than age 65 has received limited study. There is some evidence that the obesity-associated relative risk of disease occurrence is less in older than in younger persons. In addition, overweight is newly emerging as a protective factor for hip fracture (independent of its relation to bone density); thus, perhaps unique to the geriatric population, benefits versus risks of weight reduction should be analyzed.

In addition to these more global markers of malnutrition, there are also diseases that are related to specific nutrient deficiencies. For many of these, relationships are just beginning to be defined. However, the roles of calcium and vitamin D in osteoporosis and osteomalacia are clear, and the burden of suffering from these conditions has been well characterized.

Some vitamin deficiencies (e.g., thiamine, riboflavin, and niacin) are associated with health consequences but the frequencies of these deficiencies in the population do not justify screening. However, screening for vitamin deficiency may be of benefit in selected subpopulations (e.g., testing for vitamin B12 deficiency in those with prior gastric surgery). Because of physiologic changes, some nutritional requirements appear to be less important with aging. For example, iron needs are lower in older than in younger women because of the postmenopausal cessation of menstrual blood loss. Vitamin A requirements are lower in older compared with younger adults as a result of substantially lower rates of clearance of the vitamin and generally adequate liver stores. Therefore, older persons may be at increased risk of toxicity if excessive vitamin supplements are taken.

Efficacy of Currently Available Screening Tests

As mentioned above, we have limited this review to those measures that can be administered in an inexpensive manner in screening settings. Thus, we will focus on short questionnaires (either self-administered or interviewer-administered), subjective assessment by health professionals, short measures of food intake (both whole diet and nutrient-specific), anthropometric measures, specific biochemical tests, and multi-method techniques. Some of the instruments reviewed were developed and used for diagnostic rather than for screening uses but can also be considered potential screening methods.

Our approach will follow the stages along the pathway described in Figure 1, recognizing that many instruments do not focus on a single stage. Tables 1 and 2 summarize current multi-item nutrition screening tools and provide data on their validity and reliability.

Stage 1 - Risk Factors

The most important risk factors for poor dietary quality include low income, social isolation, and illness. The assessment of food security (defined as stable, sustainable access in socially acceptable ways to enough food of sufficient quality to lead a healthy life) is emerging as a central concern in nutritional assessment and surveillance. Indicators to assess hunger or food insufficiency have been developed and validated. In addition, the NHANES III survey incorporated a series of questions designed to study food insufficiency, defined as inadequate amount of food intake attributable to lack of money or resources. Currently, however, most food security information is limited to that collected by consumer advocacy groups, which tends to be anecdotal and qualitative.

An assessment kit designed in the United Kingdom for use by social workers to detect nutritional neediness among the homebound utilizes 10 risk factors: fewer than eight main meals a week; less than one-half pint of milk/day; little or no fruit and vegetable intake; wastage of food even if supplied; long periods of the day without food; depression or loneliness; unexpected weight change or loss; shopping difficulties; low income; and disabilities (including alcoholism).

Risk factors include chronic diseases that can affect appetite and interfere with the ability to chew, digest, or absorb food. Chronic diseases may also affect nutrition through medication-nutrient interactions.

Stage 2 - Nutritional Intake

There are four major methods for measuring dietary intake of energy and nutrients. These are diet recall, diet record, diet history, and food frequency questionnaire. Important features of each method are summarized in Table 3.

Diet Recall

A diet recall is performed by asking subjects to recollect the foods they have ingested during a given time frame, usually 24 hours; thus, it measures current dietary intake. Memory-related measurement error can occur. Respondent burden is modest; most individuals require about 20 minutes to complete a 24-hour or previous day diet recall. However, data entry can be time consuming, and, in general, best results are obtained when nutritionists perform this task. For the purpose of estimating mean nutrient intake for a group, the 24-hour recall appears to perform as well as actual food weighing or longer periods of dietary recording.

However, intra-individual (day-to-day and other time-related) variation in diet makes a single 24-hour recall inappropriate for estimation of an individual’s customary intake. The number of 24-hour recalls or records required to approximate the average value derived from all the recalls or records varies greatly, depending on the dietary component measured. For example, the number of days necessary to estimate calcium has ranged between seven and eleven; the number of days necessary to estimate cholesterol intake ranges between 28 and 45 days.

Food Records

Food records are more burdensome for subjects than recalls. During a specified time frame, subjects record all the
Table 1. Current Multi-Item Nutrition Screening Tools

<table>
<thead>
<tr>
<th>Name of Tool</th>
<th>Purpose of Tool</th>
<th>How Administered</th>
<th>Number of Items</th>
<th>Validation Population</th>
<th>Use in Other Populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulatory Patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSI checklist(^3)</td>
<td>Encourage at-risk to seek help</td>
<td>Self/caregiver</td>
<td>10 items</td>
<td>New England Medicare Beneficiaries 96% white</td>
<td>No data</td>
</tr>
<tr>
<td>NRI(^7)</td>
<td>Screen for risk of developing interview nutritionally-related disability who could benefit from intervention</td>
<td>Face-to-face</td>
<td>16 items</td>
<td>St. Louis community-dwelling elderly Veterans</td>
<td>1. St. Louis Outpatient 2. Houston community-dwelling elderly</td>
</tr>
<tr>
<td>Hospitalized Patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGA(^8)</td>
<td>To assess nutritional status</td>
<td>Trained professionals</td>
<td>11 items</td>
<td>Hospitalized persons all ages</td>
<td>1. Veterans screened for TPN</td>
</tr>
<tr>
<td>HPI(^7)</td>
<td>To predict sepsis and mortality</td>
<td>Clinical and biochemical tests</td>
<td>4 items</td>
<td>Hospitalized nutrition support team consults</td>
<td>No data</td>
</tr>
<tr>
<td>PNI(^7)</td>
<td>To predict operative morbidity and mortality</td>
<td>Anthropometric, biochemical, and immunologic tests</td>
<td>4 items</td>
<td>Hospitalized nutrition support team consults</td>
<td>1. Adult surgical patients</td>
</tr>
<tr>
<td>NRI(^7)</td>
<td>To predict serious operative complications</td>
<td>Anthropometric and biochemical tests</td>
<td>3 items</td>
<td>Randomized clinical trial of TPN</td>
<td></td>
</tr>
<tr>
<td>Nursing Home Patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRI(^3)</td>
<td>To predict 1-year mortality</td>
<td>Biochemical tests</td>
<td>2 items</td>
<td>Nursing home residents</td>
<td>No data</td>
</tr>
</tbody>
</table>

NSI = Nutrition Screening Initiative.
NRI = Nutritional Risk Index.
SGA = Subjective Global Assessment.
HPI = Hospital Prognostic Index.
PNI = Prognostic Nutritional Index.
NRI = Nutrition Risk Index.
MRI = Mortality Risk Index.
TPN = Total Parenteral Nutrition.

Food they eat; the amounts can be estimated or weighed by the subjects. Respondent burden is high, and although the recording should be done contemporaneously, many subjects complete the record at the end of the day, leading to potential memory-related error. Similar to diet recall, data entry requires expertise and is fairly time consuming.

Individual food records suffer the same shortcomings as individual 24-hour recalls, as a result of the instability of daily diet. However, the 7-day food record has been used often as a criterion standard against which diet history and food frequencies are judged. In several such validation studies of food frequencies, a systematic difference in caloric intake has been reported, with the energy intake according to the records being lower than diet history or food frequency questionnaires.\(^{13,44}\)

Diet History

Diet histories are performed by interviewers and consist of open-ended questions that attempt to ascertain the subjects' usual intake of food. They require at least an hour to complete and highly trained personnel to administer. Advantages include the ability to assist the subjects in considering seasonal variations in food and to account for ethnic foods not generally included on standard survey instruments. Diet histories are impractical as screening tools. However, they are sometimes used as criterion standards to validate other methods of diet assessment.

Food Frequency Questionnaires

Food frequency questionnaires (FFQ) attempt to estimate the customary dietary intake over a specified period of time (e.g., 1 year). Subjects report on their usual frequency and portion size of various foods from a predetermined list. Food frequency questionnaires that measure the complete diet may include more than 100 items and take up to an hour to complete.\(^{45,46}\)

Limited FFQs, intended to measure the usual intake of certain nutrients such as calcium, vitamin A, and vitamin E.
Table 2. Reliability and Validity of Current Multi-Item Nutrition Screening Tools

<table>
<thead>
<tr>
<th>Name of Tool</th>
<th>Type of Validity</th>
<th>Ability to Identify Risk — Sensitivity/Specificity/Reliability</th>
<th>Performance in Other Populations</th>
<th>Studies of Benefit/Efficacy</th>
<th>Studies of Cost-Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ambulatory Patients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSI Checklist(^{55})</td>
<td>Criterion (single 24 dietary recall)</td>
<td>Sens 36% Spec 85% PPV 38%</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td></td>
<td>Construct (perceived health)</td>
<td>Sens 46% Spec 85% PPV 56%</td>
<td>Not reported</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>NR(^{57})</td>
<td>Construct</td>
<td>Alpha (0.47–0.60)</td>
<td></td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Hospitalized Patients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGA(^{79})</td>
<td>Criterion ss (nutrition-associated complications)</td>
<td>Sens 82% Spec 72%</td>
<td>Preoperative veterans in TPN trial</td>
<td>Reduced major noninfectious complications (RR 0.54)</td>
<td>No data</td>
</tr>
<tr>
<td>HP(^{75})</td>
<td>Criterion (sepsis and mortality)</td>
<td>Sens 74% Spec 66%</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>PNI(^{78})</td>
<td>Criterion (mortality)</td>
<td>Sens 93% Spec 44%</td>
<td>Similar findings</td>
<td>High risk patients had lower complications, sepsis and mortality when given TPN in nonrandomized setting</td>
<td>No data</td>
</tr>
<tr>
<td>(^{79})</td>
<td>Criterion (major noninfectious complications)</td>
<td>See text</td>
<td>Preoperative veterans in TPN trial</td>
<td>Reduced major noninfectious complications (RR 0.12)</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Nursing Home Patients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRI(^{13})</td>
<td>Criterion</td>
<td>See text</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
</tbody>
</table>

NSI = Nutrition Screening Initiative.
NR = Nutritional Risk Index.
SGA = Subjective Global Assessment.
HP = Hospital Prognostic Index.
PNI = Prognostic Nutritional Index.
NR\(^{1}\) = Nutrition Risk Index.
MR = Morbidity Risk Index.
TPN = Total Parenteral Nutrition.
RR = Relative Risk.

Stage 3 - Clinical Indices, Anthropometric Measures, and Biochemical Measures

**Self-Report Brief Screening Instruments**

Nutrition Screening Initiative (NSI) The American Academy of Family Physicians, the American Dietetic Association, and the National Council on Aging, Inc. have developed a tiered approach to nutrition screening. The first tier consists of a checklist for older Americans and/or their caregivers to complete. The checklist includes some items that are in Stages 1–3 in the schema displayed in Figure 1.

Based on review by the NSI's technical review committee, a checklist score of 6 was selected for identifying older persons at high nutritional risk. An estimated 24% of all Medicare beneficiaries would fall into this high-risk group. In a validation study, those at high risk were more likely to have been hospitalized overnight during the past year. Using the cut-point of 6 to predict inadequate nutrient intake (three...
### Table 3. Current Methods of Dietary Assessment

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Measurement Caveats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall (current)</td>
<td>List (from memory) foods eaten during a given period of time, usually 24 hours or multiples thereof</td>
<td>Age, SES, health status, can affect reliability. Within-person variation in single 24-hour measures. Multiple-day recall required to assess individual intake. Current illness may affect recall and may cause recall period to be unrepresentative.</td>
</tr>
<tr>
<td>Records (current)</td>
<td>Record foods concurrently during a given period of time, usually 24 hours or multiples thereof</td>
<td>Respondent burden. Recording diet may induce behavior change. Multiple days according to nutrient. Respondent burden.</td>
</tr>
<tr>
<td>History (current or past)</td>
<td>Open ended questions, about usual food intakes</td>
<td>Requires highly trained personnel. Recall error/&quot;appropriate answers&quot;. Requires integration of day to day variation by participant in order to judge usual intake.</td>
</tr>
<tr>
<td>Food frequency (current or past)</td>
<td>Frequency of intake of foods from a standard list of food items list can vary in length, depending on purpose of measurement</td>
<td>If major food item not included, may lead to inaccuracy. Recall error/&quot;appropriate answers&quot;. Relative validity is nutrient dependent.</td>
</tr>
</tbody>
</table>

SES = Socioeconomic status.

or more nutrients below 75% of RDA) on a single 24-hour recall, the sensitivity, specificity, and positive predictive value of the NSI Checklist were 36%, 85%, and 38%; using the same cut-point, the comparable test characteristics to predict perceived fair or poor health status were 46%, 85%, and 56%.

The NSI checklist has been criticized for poor test characteristics, retaining items that were not significantly associated with outcomes of interest and using outcomes that are neither well-defined pathologic states nor have proven treatments. In addition, by relying on a single 24-hour recall as criterion validity, the methodology of the validation study assumes that stability in diet is much greater in older persons than has been demonstrated in the general population.

Those who are identified at risk of poor nutritional status based on the checklist are eligible for level I or level II screening. Level I screening is designed for any setting in which older Americans come into contact with professionals in the health care and social service system. Included at this level screen are height and weight (and calculated BMI) as well as questions about 10-pound weight gain or loss within 6 months, eating habits, living environment, and functional status. Level II screening is designed to obtain more diagnostic information in clinical settings. Included are anthropometric measurements (BMI, mid-arm circumference, mid-arm muscle circumference, triceps skinfold); laboratory data (serum albumin and cholesterol); and information on therapeutic drug use, clinical problems that might affect eating, eating habits, living environment, functional status, and cognitive and affective status.

**Nutritional Risk Index (NRI)** The NRI was derived in part from items contained in the NHANES I survey. The instrument is comprised of 16 items that tap into five dimensions for nutritional risk: mechanics of food intake, prescribed dietary restrictions, morbid conditions affecting food intake, discomfort associated with the outcomes of food intake, and significant changes in dietary habits. Alpha reliability of the instrument ranges from 0.51 to 0.60, levels of internal consistency such that it would be unacceptable even for studies at the population level. The relations between NRI and other measures of nutritional adequacy were not consistent across the three validation studies. Finally, the construction and validation of the instrument does not follow a conceptual model that allows differentiation of whether the nutritional deficiencies are a cause or effect of the associated health outcomes.

**Clinician-Determined Brief Screening Instruments**

**Subjective Global Assessment (SGA)** This method relies on items from the patient history, physical examination findings, and the clinician's overall judgment of person's global nutritional status. Historical items include (1) weight loss within the previous 6 months and whether there has been any recent change (within the previous 2 weeks); (2) dietary intake relative to usual, with classifications of duration and degree of deviations; (3) presence of persistent (greater than 2 weeks) gastrointestinal symptoms; (4) functional capacity, with duration and degree of incapacity classified; and (5) an assessment of the metabolic demand of the patient's primary diagnosis. Five components of the physical examination (loss of subcutaneous fat, muscle wasting, ankle edema, sacral edema, and ascites) are subjectively graded from 0 (normal) to 3+ (severe). Finally, the overall SGA ranking (normal, mildly malnourished, significantly malnourished) is determined, again subjectively, with instructions for raters to place most of their judgment on weight loss, poor dietary intake, loss of subcutaneous tissue, and muscle wasting. The instrument has been administered by research nurses, nurse practitioners, and physicians who had substantial training in use of the instrument. Interrater reliability has been reported at 0.91. Overall SGA rankings are
most highly correlated with subjective estimates of loss of subcutaneous fat and muscle wasting.

Reports describing the validity of SGA have relied on parallelized subjects admitted electively to general surgical wards for major gastrointestinal surgery, with mean ages greater than 50 years. Mean values of albumin, ratio of actual to ideal lean body weight, ratio of actual to ideal weight, creatinine-height index, body fat to body weight ratio, and total body potassium were each associated with overall SGA ranking. In addition, complications (both septic and non-septic) were markedly increased in persons judged as severely malnourished by SGA. Compared with other methods (prognostic nutritional index, creatinine-height index, triceps skinfold, and various lab tests), SGA has demonstrated the best test characteristics and best prediction for nutrition-associated complications; furthermore, the addition of laboratory information did not substantially improve its performance.

Despite showing some promise, several aspects of SGA limit its potential use as a screening method for older persons. First, it requires a trained clinician to administer. Second, its administration requires that patients undress and be turned, resulting in administration times that are likely to be too long for mass screening, even in hospitalized patients, unless incorporated into an admission history and physical examination. Third, its validation has been conducted primarily in younger patients who were admitted for elective surgery, often gastrointestinal surgery. The latter is important because some of the components of SGA may be specific to gastrointestinal diseases rather than generic markers of malnutrition. According to the test's performance may differ substantially in situations with lower disease prevalence, such as community-dwelling older persons.

Anthropometric Measures

Anthropometric measures have long been used in assessing nutritional status, and reference values derived from older white persons have been published. Anthropometric measurements can be used in two ways to assess nutritional status, either monitoring change in a measure for an individual or comparing a person's value with reference normal (or malnourished) values. The only widely used anthropometric indices are height, weight, and the derived body mass index (BMI). Because of narrowing of vertebral disc spaces and osteoporotic vertebral fractures, measured height may not be accurate for calculation of BMI in older persons, and some situations, older persons may be unable to stand to have height measured. In these cases, knee height and total arm length and arm span have been used as proxies.

Both extremes of body mass index confer increased risk of mortality in older persons. However, there is a road range of BMI over which mortality does not vary. Objectively determined weight change has prognostic significance. In one sample of older persons admitted to a geriatric rehabilitation unit, percent of usual weight lost (derived from medical records) predicted whether complications would develop on the unit and 1-year mortality.

Other measures such as midarm circumference and skin fold thickness are poorer reliability in older compared with younger subjects, even among experienced researchers, in part because of difficulty accurately locating anatomic landmarks and also as a result of age-related changes in skin folds. With aging, a smaller proportion of total body fat is subcutaneous; therefore, skinfold thickness is less likely to indicate total body fat in older compared with younger persons. Although anthropometric measures may have some benefit in validating instruments and in describing populations, other than simple measures of weight and height (and derived BMI), the degree of training needed, poor reliability between and within observers, and the wide range of variation in healthy older persons preclude their value as screening instruments.

Biochemical Tests

There are many potential biochemical indicators of nutritional status, including measurement of the nutrient or its metabolites in blood, urine, or other biological samples; functional measures (e.g., of enzyme activity or other processes that are nutrient-dependent); and measurement of a product of the nutrient under study (e.g., hemoglobin as an indicator of iron status). Even so, there are few biochemical markers that have established associations with compromised nutritional status in the older population, and the criteria for their interpretation in this age group are generally unclear. Rarely have potential biochemical screening tests been subjected to validation studies to establish their sensitivity, specificity, or predictive value. Some (e.g., creatinine-height index, which requires 24-hour urine collection) are likely to be too cumbersome to be adopted as screening methods. We will review briefly measurements of protein nutrient and cholesterol that have been used for screening. Other tests for specific micronutrients (minerals and vitamins) are presented in Table 4 but are not discussed in this text.

Protein Nutrient

The most commonly used biochemical indicators of protein status are serum proteins that are synthesized in the liver. Serum albumin is the best studied serum protein. It has been shown to have prognostic value for subsequent mortality and morbidity but has several limitations. A relatively large extracellular pool provides a buffer in the acute states of deprivation; thus, albumin is a better indicator of chronic protein status and generally does not fall unless undernutrition is moderately severe and prolonged or accompanied by trauma, sepsis, or significant infection. The latter events alone (without protein deprivation) also cause a fall in serum albumin, leading some to suggest that low serum albumin levels in acute care settings should be regarded more as a negative acute-phase reactant than a direct measure of protein status. Because serum albumin does not fall quickly in protein deprivation, it may be a useful indicator for chronic moderate to severe undernutrition.

Several studies have associated low serum albumin in hospitalized older persons (measured at various times during the hospitalization) with in-hospital complications, longer hospital stays, more frequent readmissions, in-hospital mortality, and mortality at 90 days and 1 year. When considering mortality, the lower the albumin level, the higher the risk of death.

Proteins with shorter half-lives and smaller body pools, such as retinol-binding protein and thyroxine-binding prealbumin, may be better suited to monitor nutritional status during acute illness and convalescence. In a study of hip fracture, patients who had complications did not show improvement in prealbumin (or albumin) during their hospitalization, whereas those without complications did. Among nursing home residents who were hospitalized, severe hypop-
Table 4. Micronutrients and Biochemical Measurement Methods

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Measurement Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>Plasma zinc and metallothionein</td>
<td>Low levels of both indicate depleted zinc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low zinc and high metallothionein indicates zinc redistribution$^{2,33}$</td>
</tr>
<tr>
<td>Thiamine</td>
<td>Erythrocyte transketolase activity with and without thiamine pyrophosphate</td>
<td>Functional enzyme activity test expressed as ratio</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>Erythrocyte glutathione reductase activity with and without flavin adenine dinucleotide (FAD)</td>
<td>Functional enzyme activity test expressed as ratio</td>
</tr>
<tr>
<td>Niacin</td>
<td>Urine N'-methylnicotinamide and N'-methyl-2-pyridone-5-carboxylamide</td>
<td>The ratio of the two falls in niacin deficiency$^{84}$</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>Serum 25(OH)D</td>
<td>Reflects both dietary and sunlight-induced vitamin D</td>
</tr>
<tr>
<td></td>
<td>Serum 1.25 (OH)$_2$D</td>
<td>Detects disorders in converting hydroxy to active dihydroxy form$^{85}$</td>
</tr>
<tr>
<td>Vitamin B$_{12}$</td>
<td>Serum B$_{12}$ levels</td>
<td>May be insensitive in detecting clinically important neuro psychiatric changes</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>Serum and urine methylmalonic acid</td>
<td>Responds to changes in dietary intake within a period of 7 to 10 days</td>
</tr>
<tr>
<td></td>
<td>Plasma pyridoxal 5'-phosphate (PLP)</td>
<td>Activity and/or stimulation of enzymes may provide longer term measure$^{86}$</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>Pyridoxine-dependent erythrocyte transaminases</td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Plasma or leukocyte C levels</td>
<td>Not sensitive to dietary intake or body stores of vitamin E</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Serum and tissue tocopherol</td>
<td>Serum levels are sensitive to acute dietary intake$^{87}$; total body stores are better assessed by erythrocyte levels$^{88}$</td>
</tr>
<tr>
<td>Folate</td>
<td>Serum and erythrocyte folate levels</td>
<td></td>
</tr>
</tbody>
</table>

realalbuminemia predicted extended hospitalization, but not mortality.$^{72}$

Serum Cholesterol

Recently, low or falling serum cholesterol has been explored as a nutritional marker. In a study at a DVA Nursing home, a variety of demographic and nutrition-related variables were used to predict 1-year mortality; in multivariate analysis, only serum cholesterol and hematocrit remained significantly significant. The authors reported a "mortality risk index" using the equation: 0.1 (cholesterol) + (hematocrit) < 60 with specificity of 83% and sensitivity of 99%. In a case-control study of older persons with normal cholesterol levels (≥160 mg/dL) on admission to the hospital, those whose cholesterol fell to ≤120 mg/dL during hospitalization (9% of admissions among persons ≥65 years) had more infectious and noninfectious complications, and length of stay was 3 times as long; mortality was higher, though not significantly, in the acquired hypocholesterolemia group.$^{14}$ It is unclear whether the fall in cholesterol occurs early enough in the course of malnutrition to allow restorative steps to be successful.

Multi-Method Techniques

Several instruments have been derived by analyzing data obtained by administering large batteries of questions, anthropometric measures, dietary intake measures, and laboratory values and then examining bivariate associations and multivariable models or determining test characteristics. These studies have been conducted in selected subpopulations of hospitalized persons. For example, in a study of veterans admitted to a geriatric rehabilitation unit, nine items entered into a logistic regression analysis that predicted in-hospital complications with an accuracy of 71 to 76%.$^{76}$

Prognostic Nutritional Index The prognostic nutritional index (PNI) was derived using stepwise regression and discriminant analysis methods from a set of 161 patients who had nutritional assessment on admission before major elective general surgery. PNI is reported as the risk (0–100, with 100 being highest risk) of developing a complication, based on an equation that includes albumin, triceps skinfold, serum transferrin, and curaneous delayed hypersensitivity to mumps, streptokinase-streptodornase, or Candida. PNI scores have been trichotomized into high risk, intermediate risk, and low risk. Thirty-three percent of high risk patients died during the hospitalization compared with 3% who were at low risk. Sepsis, major sepsis, and all complications were similarly significantly increased in those at high risk.$^{77}$ Using a cut-point of ≥50, sensitivity of the PNI was 86% and specificity was 69% for in-hospital mortality; using a cut-point of >40, the values are 93% and 44%, respectively.$^{78}$

Hospital Prognostic Index The hospital prognostic index (HPI) was derived from medical and surgical hospitalized persons (mean age 59) who received consultations for metabolic and nutritional support. Discriminant function equations were generated to predict subsequent sepsis and in hospital mortality. Cancer diagnosis and serum transferrin level were predictive of subsequent sepsis (sensitivity of the equation was 65% and specificity was 61%). Serum albumin level, cutaneous delayed hypersensitivity response, concurrent sepsis, and cancer were predictive of in-hospital mortality (sensitivity 74%, specificity 66%).$^{79}$
Evidence that persons detected early have a better clinical outcome than those detected without screening

Hospitalized Patients

A DVA cooperative study randomized 459 malnourished veterans (99% male, mean age 63) undergoing laparotomy or noncardiac surgery to perioperative total parenteral nutrition (TPN) or usual care. Subjects were eligible if they met either or both of two criteria: (1) a score of 100 or less on the Nutrition Risk Index (NRI) calculated as (1.159) (serum albumin) + 0.417 (current weight/ideal weight) (100) or (2) any two of the following: a current weight that was 95% of ideal weight or less, a serum albumin of 3.5 g/dL or less, or a serum prealbumin level of 186 mg/dL or less. Subgroup analysis was performed classifying subjects by SGA and NRI. Total complication rates at 30 days were similar in both groups, but major infectious complication rates were higher in those receiving TPN. However, the marked increase in infectious complications was confined to those who were borderline or mildly malnourished by SGA assessment. Among those who were severely malnourished by SGA or NRI, the frequency of infectious complications did not differ by treatment group, and major noninfectious complications were reduced.

Another clinical trial of parenteral nutrition identified and randomized persons undergoing surgery for gastrointestinal cancer as being malnourished if they had lost more than 10% of their previous weight, had serum albumin below 3.5 g/dL, and had negative responses to five skin tests. Those assigned to the intervention group had significantly fewer complications and a lower mortality rate.

In a nonrandomized study, middle-aged persons at high risk based on a Prognostic Nutritional Index score of >50 who received parenteral nutrition perioperatively had fewer complications and episodes of major sepsis and less mortality compared with a control group.

Conclusions and Directions for Future Research

Despite the availability and current usage of nutritional screening instruments and methods in ambulatory, hospital, and nursing home populations of older persons, no test (or instrument) has yet been demonstrated to have test characteristics sufficient to justify its use in screening. Many current nutritional screening instruments tap into several stages long the pathway from risk factors to health outcomes, but each one appears to be stage-specific. Data linking malnutrition identified at earlier stages to subsequent adverse health outcomes are few and usually have not considered their factors (e.g., diseases) that may contribute to these outcomes, nor is there good evidence that these outcomes are nutritionally mediated. Furthermore, there is only scanty evidence to suggest that persons identified early as being nutritionally at-risk will benefit from intervention. The best strategy supporting intervention come from epidemiological, short, and case-series studies that define adverse consequences of those who are at-risk.

The complexity of issues inherent in assessment of nutritional status in older persons and the uncertainty of the efficacy of interventions to prevent or correct malnutrition, the development of adequate nutritional status screeners, and this population will be difficult, at best. However, the goal of attempting to develop nutritional screening should be pursued even if the perfect screening instrument is never achieved. The benefits of further investigation leading to identifying predictors of adverse health outcomes will provide information that will benefit populations and will help elucidate mechanisms by which malnutrition confers adverse outcomes. Moreover, perhaps instruments can be developed that, when combined with other health status variables, can provide valuable prognostic information for both health care providers and patients.

Note added in proof: A recent randomized clinical trial of nutritional supplementation (360 kcal and one-third of the RDA of vitamins and minerals) failed to show improvement in muscle strength, whole body fat-free mass, and mobility.

Acknowledgments

The authors would like to thank Drs. Vay Liang W. Go and Andrew J. Silver for reviewing a draft of the manuscript.

References


