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A.S.P.E.N. Clinical Guidelines: Nutrition Support of Hospitalized Adult Patients With Obesity

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Abstract

Background: Due to the high prevalence of obesity in adults, nutrition support clinicians are encountering greater numbers of obese patients who require nutrition support during hospitalization. The purpose of this clinical guideline is to serve as a framework for the nutrition support care of adult patients with obesity. *Method:* A systematic review of the best available evidence to answer a series of questions regarding management of nutrition support in patients with obesity was undertaken and evaluated using concepts adopted from the Grading of Recommendations, Assessment, Development and Evaluation working group. A consensus process, that includes consideration of the strength of the evidence together with the risks and benefits to the patient, was used to develop the clinical guideline recommendations prior to multiple levels of external and internal review and approval by the A.S.P.E.N. Board of Directors. *Questions:* (1) Do clinical outcomes vary across levels of obesity in critically ill or hospitalized non–intensive care unit (ICU) patients? (2) How should energy requirements be determined in obese critically ill or hospitalized non-ICU patients? (3) Are clinical outcomes improved with hypocaloric, high protein diets in hospitalized patients? (4) In obese patients who have had a malabsorptive or restrictive surgical procedure, what micronutrients should be evaluated? (*JPEN J Parenter Enteral Nutr*. XXXX;XX:XX-XX)

Keywords

adult; life cycle; calorimetry; nutrition; assessment; outcomes; research/quality; support practice; obesity

Background

As of June 2013, the American Medical Association recognized obesity as a disease that requires medical treatment.[1,2] Based on the National Health and Nutrition Examination Survey 2009-2010, the prevalence of obesity in the United States is 35.5% in adult men, 35.8% in adult women, including 4.4% and 8.2% respectively with body mass index (BMI) ≥ 40 kg/m^2.[3] Thus, nutrition support clinicians are likely to care for obese patients, particularly during hospital admissions. While nutrition support clinicians care for patients across a broad range of clinical settings, the bulk of publications available for this clinical guideline have come from hospitalized patients. Furthermore, since the clinical acuity of patients admitted to intensive care units (ICUs) is much higher than those who are not critically ill, for this guideline most recommendations have been made separately for these 2 groups of obese hospitalized patients when data were available.

Bariatric surgery is a common treatment for patients who have severe obesity, with estimates of approximately 200,000 adults treated with bariatric surgery annually in the United States.[4] Since these procedures are designed to limit the patient's nutrient intake as a strategy to promote significant and durable weight loss, patients treated with these procedures may require nutrition care. Thus, the purpose of this clinical guideline is to guide clinicians on the nutrition support care of hospitalized adult patients who have obesity.

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The A.S.P.E.N. Clinical Guidelines Editorial Board guided the development of and review of these guidelines using the GRADE system. The A.S.P.E.N. Board of Directors approved the guidelines on June 26, 2013.

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Method

The American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) is an organization comprised of healthcare professionals representing the disciplines of medicine, nursing, pharmacy, dietetics, and nutrition science. The mission of A.S.P.E.N. is to improve patient care by advancing the science and practice of clinical nutrition and metabolism. A.S.P.E.N. vigorously works to support quality patient care, education, and research in the fields of nutrition and metabolic support in all healthcare settings. These clinical guidelines were developed under the guidance of the A.S.P.E.N. Board of Directors. Promotion of safe and effective patient care by nutrition support practitioners is a critical role of the A.S.P.E.N. organization. A.S.P.E.N. has been publishing clinical guidelines since 1986.[5-15]

These A.S.P.E.N. clinical guidelines are based on general conclusions of health professionals who, in developing such guidelines, have balanced potential benefits to be derived from a particular mode of medical therapy against certain risks inherent with such therapy. However, the professional judgment of the attending health professional is the primary component of quality medical care. Because guidelines cannot account for every variation in circumstances, the practitioner must always exercise professional judgment in their application. These clinical guidelines are intended to supplement, but not replace, professional training and judgment.

A.S.P.E.N. clinical guidelines has adopted concepts of the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) working group.[16-19] A full description of the methodology has been published.[20] Briefly, specific clinical questions where nutrition support is a relevant mode of therapy are developed and key clinical outcomes are identified. A rigorous search of the published literature is conducted, each included study assessed for research quality, tables of findings developed, the body of evidence for the question evaluated and graded. Randomized controlled clinical trials are initially graded as strong evidence, but may be downgraded in quality based on study limitations. Controlled observational studies are initially graded as weak evidence, but may be graded down further based on study limitations or upgraded based on study design strengths. In a consensus process, the authors make recommendations for clinical practice that are based on the evidence review assessed against consideration of the risks and benefits to patients. Recommendations are graded as strong when the evidence is strong and/or the risk vs benefit analysis is strong. Weak recommendations may be based on weaker evidence and/or weaker trade-offs to the patient. When limited research is available to answer a question, the recommendation is for further research to be conducted.

The guideline authors represent a range of academic and clinical expertise (medicine, dietetics, nursing, pharmacy). The external and internal expert reviewers, including the A.S.P.E.N. Board of Directors, have a similar breadth of professional expertise. This clinical guideline is planned for revision in 2018.

The questions are summarized in Table 1. With the assistance of a reference librarian a search was conducted in PubMed, EMBASE, and CINAHL on August 1, 2012, and updated May 2, 2013, using inclusion criteria of adult subjects, English language, randomized controlled trials, observational studies, and publications over the past 10 years. Search terms "obesity," "clinical outcomes," "mortality," "infection," "parenteral nutrition," and "enteral nutrition" were applied in various combinations for questions 1-3. For question 1, 31 articles met the inclusion criteria. For question 2, 9 articles that described measures in hospitalized or clinical populations of obese patients and that reported data with accuracy and bias rates were included. For question 3, the time limitation was relaxed to obtain all published information on the topic, yielding 8 articles. For question 4, search terms of "copper," "zinc," "iron," "selenium," "vitamin deficiency," "nutrient deficiency," "gastric bypass," "biliopancreatic diversion," "vitamin D," and "bariatric surgery" were used in various combinations with a time limitation of the past 10 years, which yielded 22 articles.

Results

Question 1: Do Clinical Outcomes Vary Across Levels of Obesity in Critically Ill or Hospitalized Non-ICU Patients? (Tables 2-3)

Recommendation

1a. Critically ill patients with obesity experience more complications than patients with optimal BMI levels. Nutrition assessment and development of a nutrition support plan is recommended within 48 hours of ICU admission (strong).

Evidence Grade: Low.

1b. All hospitalized patients, regardless of BMI, should be screened for nutrition risk within 48 hours of admission, with nutrition assessment for patients who are considered at risk (strong).

Evidence Grade: Low.

Rationale. Clinical outcomes in patients with obesity may be impacted by numerous factors, including comorbid conditions, associated metabolic changes and any modifications in clinical care (including nutrition support) that are made on behalf of the obese patient. The available studies comparing outcomes of mortality, length of stay (LOS), and complications in obese ICU and non-ICU patients are limited by their retrospective database evaluation,[21-35] by a relatively small number of obese subjects,[24-28,36-41] or by overall small sample size.[22,24-28,31,34,39-43] In particular, mortality outcomes are varied, depending on these factors. To address concerns about limitations in statistical power for the outcome of mortality, we considered the evidence from 8 studies with more than 300 obese subjects. One found increased mortality in obese trauma patients,[21] 5 reported reduced mortality in mixed ICU types,[23,35,42,44,45] and 3 reported no difference in mortality.[29,32,46] LOS in the ICU was not

Table 1. Nutrition Support Clinical Guideline Recommendations in Adult Patients With Obesity.

Question	Recommendation	Recommendation Grade and Evidence Quality
1. Do clinical outcomes vary across levels of obesity in critically ill or hospitalized non-ICU patients?	1a. Critically ill patients with obesity experience more complications than patients with optimal BMI levels. Nutrition assessment and development of a nutrition support plan is recommended within 48 hours of ICU admission.	Recommendation: Strong Evidence: Low
	1b. All hospitalized patients, regardless of BMI, should be screened for nutrition risk within 48 hours of admission, with nutrition assessment for patients who are considered at risk.	Recommendation: Strong Evidence: Low
2. How should energy requirements be determined in obese critically ill or hospitalized non-ICU patients?	2a. In the critically ill obese patient, if indirect calorimetry is unavailable, energy requirements should be based on the Penn State University 2010 predictive equation, or the modified Penn State equation if the patient is over the age of 60 years.	Recommendation: Strong Evidence: High
	2b. In the hospitalized obese patient, if indirect calorimetry is unavailable and the Penn State University equations cannot be used, energy requirements may be based on the Mifflin–St Jeor equation using actual body weight.	Recommendation: Weak Evidence: Moderate
3. Are clinical outcomes improved with hypocaloric, high protein diets in hospitalized patients with obesity?	3a. Clinical outcomes are at least equivalent in patients supported with high protein, hypocaloric feeding to those supported with high protein, eucaloric feeding. A trial of hypocaloric, high protein feeding is suggested in patients who do not have severe renal or hepatic dysfunction. Hypocaloric feeding may be started with 50%-70% of estimated energy needs or < 14 kcal/kg actual weight. High protein feeding may be started with 1.2 g/kg actual weight or 2-2.5 g/kg ideal body weight, with adjustment of goal protein intake by the results of nitrogen balance studies.	Recommendation: Weak Evidence: Low
	3b. Hypocaloric, low protein feedings are associated with unfavorable outcomes. Clinical vigilance for adequate protein provision is suggested in patients who do not have severe renal or hepatic dysfunction.	Recommendation: Weak Evidence: Low
4. In obese patients who have had a malabsorptive or restrictive surgical procedure, what micronutrients should be evaluated?	4. Patients who have undergone sleeve gastrectomy, gastric bypass, or biliopancreatic diversion ± duodenal switch have increased risk of nutrient deficiency. In acutely ill hospitalized patients with history of these procedures, evaluation for evidence of depletion of iron, copper, zinc, selenium, thiamine, folate, and vitamins B_{12} and D is suggested as well as repletion of deficiency states.	Recommendation: Weak Evidence: Low

ICU, intensive care unit.

significantly different in obese than nonobese subjects in the single large study reporting this outcome.[45] Studies with more than 300 obese patients reported more complications in obese than nonobese patients,[25,47] as did 3 smaller studies in trauma patients.[33,37,48] One large study in patients admitted to the medical ICU observed no difference in complications in obese than nonobese patients.[32] These complications may impact adjunctive nutrition care and thus support our consensus that an early nutrition assessment (as for all critically ill patients) and care plan is indicated.

In the hospitalized, non–critically ill obese patient, 2 studies had more than 300 obese patients. One of these in surgical patients reported lower mortality and hospital LOS,[30] while a study of patients with myocardial infarction reported higher mortality and no difference in complications.[49] Further research is very likely to change our assessment of the outcomes associated with obesity in non-ICU patients. However, all patients should be screened for nutrition risk, and those who are at risk further assessed for nutrition status and potential development of a nutrition support care plan.[15]

Clearly, more prospective, adequately powered outcomes research is needed to clarify the risks associated with varying levels of obesity in hospitalized ICU and non-ICU patients. Studies that include measures of inflammation, body composition (with a focus on lean body mass), and micronutrient status

Table 2. Evidence Summary Question 1: Do Clinical Outcomes Vary Across Levels of Obesity in Critically Ill or Hospitalized Patients?.

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
ICU patients					
Nelson et al, 2012[89]	Retrospective record review Small sample 90 obese patients	Single center trauma database of admissions 1996-present with Injury Severity Score ≥ 16 ● BMI ≤ 18.5 kg/m^2, n = 30 ● BMI = 18.5-24.9, n = 603 ● BMI 25.0-29.9, n = 361 ● BMI ≥ 30, n = 90 Total N = 1084	Compare resuscitation, treatment, and short-term outcomes by BMI group	**Mortality:** ● BMI ≥ 30 vs normal BMI, OR 2.52 (95% CI, 1.3-4.9) **Mortality on day 0:** ● BMI ≥ 30 vs normal BMI, 8.9% vs 2.8%, *P* = .023 Uncontrolled hemorrhage most common cause	
Abhyankar et al, 2012[44]	Retrospective record review Large sample 5287 obese patients	Admissions to single hospital MICU, SICU, or CCU, 2001-2008 ● BMI ≤ 18.5 kg/m^2, n = 786 ● BMI = 18.5-24.9, n = 5463 ● BMI 25.0-29.9, n = 5276 ● BMI 30-39.9, n = 4168 ● BMI ≥ 40, n = 1119 Total N = 16,812	Examine BMI vs 30-day and 1-year mortality	**30-day Mortality:** ● BMI ≤ 18.5 kg/m^2, OR 1.41 (95% CI, 1.13-1.76) ● BMI = 18.5-24.9, reference group ● BMI 25.0-29.9, OR 0.81 (95% CI, 0.7-0.93) ● BMI ≥ 30, OR 0.74 (95% CI, 0.64-0.86) **1-year Mortality:** ● BMI ≤ 18.5 kg/m^2, OR 1.51 (95% CI, 1.18-1.94) ● BMI = 18.5-24.9, reference group ● BMI 25.0-29.9, OR 0.68 (95% CI, 0.59-0.79) ● BMI ≥ 30, OR 0.57 (95% CI, 0.49-0.67) ● BMI ≥ 40 kg/m2, OR 0.70 (95% CI, 0.54-0.90)	Lower mortality in obese than normal weight patients
Hoffmann et al, 2012[21]	Retrospective record review 760 obese subjects Multivariate analysis adjusted for age, new injury severity score, head injury, Glasgow Coma Scale, base excess, coagulation, severe bleeding, cardiac arrest	Trauma patients with Injury Severity Score > 16, years 2004-2008 in German Society for Trauma Registry ● BMI ≤ 20 kg/m^2, n = 269 ● BMI = 20-24.9, n = 2617 ● BMI 25.0-29.9, n = 2120 ● BMI ≥ 30, n = 760 Total N = 5766	Determine whether low or high BMI is linked with worse outcomes	**Hospital Mortality:** ● BMI 25.0-29.9 vs normal BMI, OR = 0.99, (95%, CI = 0.76-1.29) ● BMI ≥ 30 vs normal BMI, OR 1.6 (95% CI, 1.1-2.3, *P* = .009) **Time to Death:** ● BMI 25.0-29.9 vs normal BMI, 16.6 vs 10.1 days, *P* < .001 ● BMI ≥ 30 vs normal BMI, 16.6 vs 10.1 days, *P* < .001	Mortality increased, and time to death longer
Westerly et al, 2011[22]	Retrospective record review Diagnostic similarity 545 obese patients No adjustment for comorbidities or acuity	Admissions to single hospital 2000-2008 Quartiles of BMI ≥ 40: ● BMI 40-47.5 kg/m2, n = 127 ● BMI 47.6-54.6, n = 151 ● BMI 54.7-65, n = 147 ● BMI > 65, n = 120 Total N = 545	Evaluate outcomes of hospitalized morbidly obese patients	Across quartiles of BMI > 40, mortality was not different. Hospital LOS increased, *P* < .001 Tracheostomy increased, *P* = .001	
Hutagalung et al, 2011[23]	Retrospective record review HR adjusted for acuity measures 2245 obese patients Loss of 24% due to no height/weight	German surgical ICU patients, 2004-2009 ● BMI ≤ 18.5 kg/m^2, n = 186 ● BMI 18.6-24.9, n = 2633 ● BMI 25.0-29.9, n = 4093 ● BMI 30-39.9, n = 2066 ● BMI ≥ 40, n = 179 Total N = 9935	Assess impact of obesity on 60-day hospital mortality	**60-day Mortality:** ● BMI 25.0-29.9 vs normal BMI, HR (lower HR in study indicates lower risk) 0.86 (95% CI, 0.74-0.99, *P* = .047) ● BMI = 30-39.9 vs normal BMI, HR 0.83 (95% CI, 0.69-0.99, *P* = .047) ● BMI ≥ 40 vs normal BMI, HR 1.14 (95% CI,0.74-1.74)	BMI 30-39.9 with lower mortality than normal BMI

(continued)

Table 2. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Evans et al, 2011[24]	Retrospective record review 154 obese patients, no power calculation Limited statistical analysis	US Level I Trauma Center registry, patients over age 45 years ● BMI < 18.5 kg/m^2, n = 22 ● BMI 18.6-24.9, n = 145 ● BMI 25.0-29.9, n = 140 ● BMI ≥ 30, n = 154 Total N = 461	Assess impact of BMI on trauma outcomes, complications, injury distribution, n = 461	**90-day Mortality:** ● No statistically significant differences across BMI groups in complications, ICU or hospital LOS, mortality or discharge to home	
Martino et al, 2011[45]	Multicenter international prospective observation study Large sample Data analysis adjusted for age, gender, APACHE II score, diagnosis category, geographic region, hospital type, ICU type, product of age and APACHE II score	Adults in 1 of 355 ICUs for more than 72 hours in 2007-2009 ● BMI < 18.5 kg/m^2, n = 423 ● BMI 18.5-24.9, n = 3490 ● BMI 25-29.9, n = 2604 ● BMI 30-39.9, n = 1772 ● BMI 40-49.9, n = 348 ● BMI 50-59.9, n = 118 ● BMI ≥ 60, n = 58 Total N = 8813	Evaluate outcomes of severe obesity (BMI ≥ 40 kg/m^2)	**60-day Mortality:** ● BMI 25-29.9 vs normal BMI, OR 0.81 (95% CI, 0.71-0.91), $P < .001$ ● BMI 30-39.9 vs normal BMI, OR 0.74 (95% CI, 0.64-0.84, $P < .001$) ● BMI ≥ 40 vs normal BMI, OR 0.87 (95% CI, 0.69-1.09) **Ventilator Days:** ● BMI 25-29.9 vs normal BMI, HR (low hazard ratio in this study indicates higher risk) 0.97 (95% CI, 0.9-1.05) ● BMI 30-39.9 vs normal BMI, HR 0.85 (95% CI, 0.78-0.93, $P < .001$) ● BMI ≥ 40 vs normal BMI, HR 0.86 (95% CI, 0.77-0.97, $P < .05$) **ICU LOS:** ● BMI 25-29.9 vs normal BMI, HR 0.95 (95% CI, 0.88-1.03) ● BMI 30-39.9 vs normal BMI, HR 0.86 (95% CI, 0.79-0.94, $P < .001$) ● BMI ≥ 40 vs normal BMI, HR 0.82 (95% CI, 0.72-0.93, $P < .05$) **Hospital LOS:** ● BMI 25-29.9 vs normal BMI, HR 0.98 (95% CI, 0.91-1.05) ● BMI 30-39.9 vs normal BMI, HR 0.96 (95% CI, 0.89-1.04) ● BMI ≥ 40 vs normal BMI, HR 0.91 (95% CI, 0.80-1.04)	Obese patients (BMI 30-39.9) with lower mortality; all obese patients with longer ventilator intubation and ICU LOS
Serrano et al, 2010[25]	Retrospective record review 314 obese patients OR adjusted for potential confounders	Admissions to level I trauma center 2008 ● BMI 18.5-24.9, n = 382 ● BMI 25-29.9, n = 328 ● BMI 30-39.9, n = 250 ● BMI ≥ 40, n = 64 Total N = 1024	Evaluate the importance of obesity as an independent risk factor for nosocomial infection in trauma patients	**Infection:** ● BMI 30-39.9 vs normal BMI, OR 4.69 (95% CI, 2.18-10.1) ● BMI ≥ 40 vs normal BMI, OR 5.91 (95% CI, 2.18-16.0) Most common types were pulmonary and wound infections	Obesity is independent risk factor for infection after trauma

(continued)

Table 2. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Wurzinger et al, 2010[26]	Retrospective record review 66 obese patients, no power calculation	● BMI ≤ 18.5 kg/m^2, n = 15 ● BMI 18.5-24.9, n = 125 ● BMI 25-29.9, n = 95 ● BMI 30-39.9, n = 66 Total N = 301	Evaluate impact of BMI on mortality in patients with septic shock	In adjusted model, no difference in mortality by obesity SAPS II predicts mortality	
Duchesne et al, 2009[48]	Retrospective record review Very small sample 52 obese patients	All patients in Level I trauma center 2003-2006, total sample 12,759 patients Those with damage control laparotomy: ● BMI ≤ 18.5-29.9 kg/m^2, n = 52 ● BMI 30-39.9, n = 38 ● BMI ≥ 40, n = 15 Total N = 105	Examine prevalence of surgical site infections in obese vs nonobese patients	**Surgical Site Infections:** ● Prevalence ratio in BMI ≥ 40 vs nonobese 4.42 (95% CI, 1.74-11.2) **Intraabdominal Abscess:** ● Prevalence ratio in BMI ≥ 40 vs nonobese 1.76 (95% CI, 0.73-4.28) **Acute Renal Injury:** ● Prevalence ratio in BMI 30-39.9 vs nonobese 2.07(95% CI, 1.9-4.7) ● Prevalence ratio in BMI ≥ 40 vs nonobese 3.07 (95% CI, 1.34-7.03) **Multisystem Organ Failure:** ● Prevalence ratio in BMI 30-39.9 vs nonobese 1.74 (95% CI, 1.14-2.66) ● Prevalence ratio in BMI ≥ 40 vs nonobese 1.82 (95% CI, 1.14-2.90) Prevalence ratios adjusted for age, gender, type of injury, blood pressure and base deficit **Days on Ventilator:** ● Nonobese vs obese vs severely obese, 9.8 ± 7 vs 14 ± 7 vs 24 ± 8, *P* = .0001 **Hospital LOS:** ● Nonobese vs obese vs severely obese, 14 ± 8 vs 14 ± 11 vs 27 ± 9, *P* = .0001	
Dossett et al, 2009[47]	Prospective cohort observation OR adjusted for age, sex, APACHE II score 686 obese patients	Patients in ICU > 48 hr ● BMI ≤ 18.5 kg/m^2, n = 640 ● BMI 18.5-24.9, n = 672 ● BMI 25-29.9, n = 615 ● BMI 30-39.9, n = 494 ● BMI ≥ 40, n = 192 Total N = 2037	Describe relationship between BMI and site-specific ICU-acquired infection risk	● **Catheter-related Bloodstream Infection Risk:** ● BMI 30-39.9 vs normal BMI, OR 1.9 (95% CI, 1.2-2.9) ● BMI ≥ 40 vs normal BMI, OR 3.2 (95% CI, 1.9-5.3)	May be due to provider reluctance to pull established lines in patients with difficult venous access
Pieracci et al, 2008[27]	Retrospective record review BMI distribution of patients in ICU > 4 days not clear 232 obese patients	Patients admitted to ICU > 4 days ● BMI ≤ 18.5 kg/m^2, n = 53 ● BMI 18.5-24.9, n = 376 ● BMI 25-29.9, n = 285 ● BMI 30-39.9, n = 188 ● BMI ≥ 40, n = 44 Total N = 946	Test hypothesis that BMI is associated with mortality from surgical critical illness	ROC analysis suggests BMI predicts mortality at level of chance alone Age and APACHE III were strongest predictors in all models, BMI was not significant	

(continued)

Table 2. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Sakr et al, 2008[46]	Prospective observational cohort 505 obese patients Adjusted model	Multicenter study of epidemiology of sepsis in European countries, n = 198 ICUs ● BMI ≤ 18.5 kg/m^2, n = 120 ● BMI 18.5-24.9, n = 1206 ● BMI 25-29.9, n = 1047 ● BMI 30-39.9, n = 424 ● BMI ≥ 40, n = 81 Total N = 2878	Investigate impact of obesity on morbidity and mortality in European sepsis in acutely ill patients study	BMI does not impact mortality or LOS **ICU-acquired Infection:** ● Obese vs optimal weight, 10.1% vs 9%, $P < .05$ ● Severely obese vs optimal weight, 12.3% vs 9.0%, $P < .01$	
Frat et al, 2008[36]	Prospective case-control observation 82 obese patients Prognostic similarity	Patients matched for age, gender, center and SAPS II score ● BMI < 30, n = 124 ● BMI ≥ 35, n = 82 Total N = 206	Evaluate influence of severe obesity on morbidity and mortality in mechanically ventilated patients	Only difference in morbidity was more frequent difficulty with tracheal intubation and postextubation stridor in obese No difference in mortality	
Morris et al, 2007[28]	Retrospective record review 165 obese patients OR adjusted for age, APACHE score, admission source, chronic health points, etiology of ALI	All ICU patients with ALI and BMI in 1999-2000 ● BMI < 18.5 kg/m^2, n = 28 ● BMI 18.5-24.9, n = 179 ● BMI 25-29.9, n = 150 ● BMI 30-39, n = 125 ● BMI ≥ 40, n = 40 Total N = 825	Evaluate the association between BMI and outcomes in patients with ALI	**Mortality:** ● Not different by BMI group **Discharge Disposition:** ● To rehabilitation center BMI ≥ 40 vs normal BMI, OR 6.0 (95% CI, 1.8-20.2) To skilled nursing facility BMI ≥ 40 vs normal BMI, OR 4.3 (95% CI, 1.5-12.5)	
Newell et al, 2007[37]	Retrospective record review 264 obese patients, no power statement No adjustment of OR	Consecutive admissions to trauma center with Injury Severity Score ≥ 16 and blunt trauma in 2001-2005 ● BMI missing n = 357 ● BMI < 18.5 kg/m^2, n = 61 ● BMI 18.5-24.9, n = 554 ● BMI 25-29.9, n = 529 ● BMI 30-39, n = 271 ● BMI ≥ 40, n = 93 Total N = 2108	Evaluate clinical outcomes in blunt trauma patients stratified by BMI	**Mortality:** BMI ≥ 40 vs normal BMI, OR 0.81 (95% CI, 0.35-1.86) **Complications in BMI 30-39.9 vs normal BMI:** ● Acute respiratory failure, OR 1.8 (95% CI, 1.3-2.4) ● Pneumonia, OR 1.7 (95% CI, 1.2-2.4) ● UTI, OR 1.8 (95% CI, 1.2-2.9) **Complications in BMI ≥ 40 vs normal BMI:** ● ARDS, OR 3.68 (95% CI, 1.2-10.9) ● Acute respiratory failure, OR 2.79 (95% CI, 1.6-4.8) ● Acute renal failure, OR 13.5 (95% CI, 2.4-76.4) ● MSOF, OR 2.6 (95% CI, 1.09-6.4) ● Pneumonia, OR 2.5 (95% CI, 1.5-4.3) ● UTI, OR 2.3 (95% CI, 1.2-4.4) ● DVT, OR 4.1 (95% CI, 1.3-13.5) Decubitus ulcer, OR 2.8 (95% CI, 1.4-5.8)	Complications higher in severely obese than obese than normal BMI patients

(continued)

Table 2. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Nasraway et al, 2006[90]	Retrospective record review 96 obese patients model adjusted for age, gender, acuity, renal failure, diabetes, vasopressor use, mechanical ventilation	Consecutive admissions to surgical ICU 1998-2001 ● BMI ≤ 18.5 kg/m^2, n = 70 ● BMI 18.5-24.9, n = 529 ● BMI 25-29.9, n = 408 ● BMI 30-39.9, n = 272 ● BMI ≥ 40, n = 94 Total N = 1373 Patients who stayed in ICU ≥ 4 d ● BMI ≤ 18.5 kg/m^2, n = 26 ● BMI 18.5-24.9, n = 164 ● BMI 25-29.9, n = 119 ● BMI 30-39.9, n = 74 ● BMI ≥ 40, n = 24 Total N = 406	Determine whether BMI ≥ 40 is independent risk factor for death in ICU patients	Mortality, ICU LOS and hospital LOS not different in entire group of admissions	
Peake et al, 2006[38]	Prospective cohort observation 125 obese patients Model included age, APACHE II score, albumin Charlson comorbidity index	Patients admitted to medical-surgical ICU in 2001 ● BMI < 18.5 kg/m^2, n = 24 ● BMI 18.5-24.9, n = 129 ● BMI 25-29.9, n = 151 ● BMI 30-34.9, n = 75 ● BMI ≥ 35, n = 54 Total N = 433	Evaluate effect of BMI on 30-day and 12-month survival	Increasing BMI associated with decreasing mortality TR > 1 is increased survival time: ● 30-day TR for BMI = 1.85 (95% CI, 1.05, 3.26) 12-month TR for BMI = 1.03 (95% CI, 1.005, 1.063)	
Duane et al, 2006[39]	Retrospective record review 115 obese patients, no power statement	Blunt trauma patients admitted 2004-2005 ● BMI < 30, n = 338 ● BMI ≥ 30, n = 115 Total N = 453	Determine effect of obesity on morbidity and mortality in ICU and non-ICU population of blunt trauma patients	No difference in mortality or morbidity measures	
Alban et al, 2006[40]	Retrospective record review 135 obese patients, no power statement	Patients admitted to trauma ICU, 1999-2002 Nonobese, n = 783 Obese, n = 135 Total, n = 928	Compare outcomes of obese vs nonobese patients after trauma	**Mortality:** ● Obese vs nonobese, OR 0.8 (95% CI, 0.3-1.8) ● Age > 55 y, OR 3.5 (95% CI, 1.8-6.6) ● ISS > 20, OR 8.9 (95% CI, 4.2-18.8) ● APACHE II > 20, OR 12.0 (95% CI,4.7-30.6) ● Blunt vs penetrating injury, OR 2.0 (95% CI, 1.1-3.9)	Severity of illness more predictive than obesity
O'Brien et al, 2006[42]	Retrospective record review 457 obese patients Mortality adjusted for age, gender, race, SAPS II, team model, condition on admission, patient origin, diagnosis of skin or subcutaneous tissue disease, preexisting illness, use of pressors, ICU complications, number of preexisting diseases	Critically ill adults from 106 ICUs in 84 hospitals in acute lung injury IMPACT study ● BMI < 18.5 kg/m2, n = 88 ● BMI 18.5-24.9, n = 544 ● BMI 25-29.9, n = 399 ● BMI 30-39.9, n = 326 ● BMI ≥ 40, n = 131 Total N = 1488	Determine association between BMI and hospital mortality	**Hospital Mortality:** ● BMI 30-39.9 vs normal BMI, OR 0.67 (95% CI, 0.46-0.97) ● BMI ≥ 40 vs normal BMI, OR 0.78 (95% CI, 0.44-1.38) **Unadjusted Differences in Care:** ● BMI ≥ 40 vs normal BMI ● Heparin prophylaxis in 57% vs 44% ● Tracheostomy, 26% vs 17% ● Specialty bed, 29% vs 15%	

(continued)

Table 2. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Aldawood et al, 2006[35]	Retrospective record review 540 obese patients Unadjusted OR	Critically ill adults from single ICU in Saudi Arabia, 2001-2004 ● BMI < 18.5kg/m^2, n = 140 ● BMI 18.5-24.9, n = 631 ● BMI 25-29.9, n = 524 ● BMI 30-34.9, n = 312 ● BMI 35-39.9, n = 135 ● BMI ≥ 40, n = 93 Total N = 1835	Examine impact of obesity on hospital and ICU mortality, LOS, duration of mechanical ventilation	**Hospital Mortality:** ● BMI ≥ 40 vs normal BMI, OR 0.51 (95% CI, 0.28-0.92, *P* = .025) Also predicted by chronic respiratory illness, age, medical vs surgical admission	Lowest mortality for BMI ≥ 40
Ray et al, 2005[32]	Retrospective record review 550 obese patients No adjustment for acuity	Medical ICU admissions 1997-2001 ● BMI < 20 kg/m2, n = 350 ● BMI 20-24.9, n = 663 ● BMI 25-29.9, n = 585 ● BMI 30-39.9, n = 396 ● BMI ≥ 40, n = 154 Total N = 2148	Examine the effect of BMI on ICU outcome	**ICU Mortality:** APACHE II score predicts (*P* < .001) but BMI does not (*P* = .588) **Hospital Mortality:** APACHE II score predicts (*P* < .001) but BMI does not (*P* = .469) **Complications:** No difference by BMI group	Acuity score predicts mortality better than BMI
Winkelman et al, 2005[41]	Prospective cohort observation Small sample	Critically ill patients with severe obesity BMI ≥ 40, n = 43	Describe resources used by nurses to care of patients with severe obesity	**Most common equipment:** Specialty bed or mattress Large BP cuff Large commodes Large wheelchairs Assist of 2 to reposition patient Special skin care treatment	Nurses should anticipate these needs to avoid poor outcomes
Brown et al, 2005[33]	Retrospective record review 283 obese patients OR adjusted but factors used not reported	Trauma and ICU database ● BMI < 30, n = 870 ● BMI ≥ 30, n = 283 Total N = 1153	Evaluate influence of obesity on outcomes after severe blunt trauma	Obesity independent risk factor for mortality: Adj OR 1.6 (95% CI, 1.0- 2.3, *P* = .03) ISS, GCS, hypotension on admission and age are stronger predictors Obese patients with more total complications, MSOF, ARDS, dialysis, MI	
O'Brien, 2004[34]	Retrospective record review 219 obese patients, no power statement 15% excluded due to missing variables Model not adjusted	Mechanically ventilated patients with ALI enrolled in RCT testing weaning protocols ● BMI 18.5-24.9, n = 334 ● BMI 25-29.9, n = 254 ● BMI ≥ 30, n = 219 Total N = 807	Examine association of obesity and outcome	**28-day Mortality:** ● Overweight vs normal BMI, OR 1.09 (95% CI, 0.7-1.7) ● Obese vs normal BMI, OR 1.1 (95% CI, 0.7-1.8) ● Age, OR 1.04 (95% CI, 1.03-1.06) ● APACHE III score, OR 1.02 (95% CI, 1.01-1.03) ● Pao2:Fiox ratio, OR 0.99 (95% CI, 0.99-0.99) ● Assigned higher tidal volume, OR 1.7 (95% CI, 1.2-2.4) ● Peak airway pressure, OR 1.03 (95% CI, 1.0-1.05) ● Trauma diagnosis, OR 0.32 (95% CI, 0.12-086)	Acuity factors more important than BMI as predictors of outcome

(continued)

Table 2. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Garrouste-Orgeas et al, 2004[43]	Prospective cohort observation 227 obese patients	In 6 medical-surgical ICUs in France over 2 years ● BMI < 18.5, n = 189 ● BMI 18.5-24.9, n = 806 ● BMI 25-29.9, n = 476 ● BMI ≥ 30, n = 227 Total N = 1698	Examine association between BMI and mortality in adult ICU patients	**Mortality:** Obese vs normal BMI, OR 0.6 (95% CI, 0.4-0.88)	
Tremblay et al, 2003[29]	Retrospective record review 18,221 obese patients Limited information on comorbid conditions	Project Impact Critical Care Data System, all patients with BMI and at least 1 severity score ● BMI < 18.5, n = 11,479 ● BMI 18.5-24.9, n = 24,332 ● BMI 25-29.9, n = 21,867 ● BMI 30-39.9, n = 13,952 ● BMI ≥ 40, n = 4269 Total N = 75,889		**Mortality:** ● Not significantly different in obese or severely obese from nonobese **LOS:** ● Not significantly different in obese or severely obese from nonobese	
Hospitalized non-ICU patients					
Nafiu et al, 2012[30]	Retrospective record review 49,761 obese patients Model adjusted for age, anesthesia status, racial group, elective vs emergent surgery	Racial/ethnic minority surgical patients 2005-2008 from 186 centers in National Surgical Quality Improvement Program ● Overall BMI = 30.3 ± 8.9 kg/m^2 ● BMI < 18.5 kg/m^2, n = 3230 ● BMI = 18.6-24.9, n = 31,699 ● BMI 25.0-29.9, n = 34,929 ● BMI = 30-39.9, n = 34,450 ● BMI ≥ 40, n = 15,311 Total N = 119,619	Evaluate contribution of BMI to 30-day postsurgical outcome	**30-day Mortality:** ● BMI 18.6-24.9 vs BMI ≥ 40, OR 1.52 (95% CI, 1.23-1.87, *P* < .001) ● BMI 25.0-29.9 vs BMI ≥ 40, OR 1.33 (95% CI,1.08-1.65, *P* = .009) ● BMI = 30-39.9 vs BMI ≥ 40, OR 1.2 (95% CI, 0.97-1.49) **Hospital LOS:** ● BMI 18.6-24.9, 8.9 ± 14.2 d ● BMI 25.0-29., 7.3 ± 12.2, *P* < .001 vs normal BMI ● BMI = 30-39.9, 6.7 ± 11.6, *P* < .001 vs normal BMI ● BMI ≥ 40, 5.3 ± 10.5, *P* < .001 vs normal BMI ● Most perioperative outcomes in obese subjects not different than normal weight	BMI ≥ 40 with lowest mortality & hospital LOS. Authors suggest that obese patients may have less severe disease or that they are monitored vigilantly and treated conservatively
Das et al, 2011[49]	Retrospective record review OR adjusted for age, prior PAD, BP, HR, shock, ECG findings, troponin ratio, creatinine 2558 patients with severe obesity	Patients in the National Cardiovascular Data Registry with diagnosis of MI ● BMI missing in 1831 (3.5%) ● BMI ≤ 18.5 kg/m^2, n = 344 ● BMI 18.5-24.9, n = 11,785 ● BMI 25-29.9, n = 19,408 ● BMI 30-39.9, n = 15,596 ● BMI ≥ 40, n = 2558 Total N = 50,149	Evaluate impact of severe obesity on outcomes in patients with ST-segment MI	**Mortality:** ● BMI ≥ 40 vs BMI 30-35, Adjusted OR 1.64 (95% CI, 1.32-2.03) **Major Bleeding:** BMI ≥ 40 vs BMI 30-35, Adjusted OR 1.09 (95% CI, 0.94-1.26)	Mortality increased
Park et al, 2011[31]	Retrospective record review No acuity scores No adjustment for confounders 147 obese patients	Surgical patients from single hospital 1999-2009 ● BMI 18.5-24.9, n = 469 ● BMI 30-39.9, n = 108 ● BMI ≥ 40, n = 39 Total N = 626	Determine impact of obesity on perioperative and long-term clinical outcomes after open AAA repair or endovascular aneurysm repair	No difference in LOS, MI, ARF, wound infection, mortality **ICU LOS:** Obese vs normal BMI, *P* = .03	

Low HR indicates increased risk; low OR indicates reduced risk. AAA, abdominal aortic aneurysm; ALI, acute lung injury; APACHE, Acute Physiology and Chronic Health; ARDS, acute respiratory distress syndrome; ARF, acute renal failure; BMI, body mass index; BP, blood pressure; CCU, cardiac care unit; CI, confidence interval; DVT, deep vein thrombosis; GCS, Glasgow coma scale; HR, hazard ratio; ICU, intensive care unit; ISS, injury severity score; LOS, length of stay; MI, myocardial infarction; MICU, medical ICU; MSOF, multi-system organ failure; OR, odds ratio; PAD, peripheral artery disease; RCT, randomized controlled trial; ROC, receiver operator curve; SAPS, simplified acute physiology score; SICU, surgical ICU; TR, time ratio; UTI, urinary tract infection.

Table 3. GRADE Table Question 1: Do Clinical Outcomes Vary Across Levels of Obesity in Critically Ill or Hospitalized Non-ICU Patients?.

Comparison	Outcome	Quantity, Type of Evidence	Findings	Grade for Outcome	Overall Evidence GRADE
ICU patients					
Obese vs optimal BMI	Mortality (large studies)	8 OBS	1 increased[21] 5 decreased[23,35,42,44,45] 2 no difference[32,46]	Low	Low
	Hospital LOS (large studies)	4 OBS	3 increased[22,29,45] 1 no difference[46]	Low	
	Complications	6 OBS	5 increased[25,37,46-48] 1 no difference[32]	Low	
BMI ≥ 40 kg/m^2 vs optimal BMI	Mortality (large studies)	4 OBS	1 decreased[44] 3 no difference[22,23,45]	Low	
	Hospital LOS (large studies)	4 OBS	2 increased[22,29] 2 no difference[45,46]	Low	
Non-ICU patients					
Obese vs optimal BMI	Mortality	2 OBS	1 increased[49] 1 no difference[91]	Low	

ICU, intensive care unit; LOS, length of stay; OBS, observational study.

would be especially helpful. Finally, nutrition support interventions that aim to improve clinical outcomes are needed in this population.

Question 2: How Should Energy Requirements Be Determined in Obese Critically Ill or Hospitalized Non-ICU Patients? (Table 4)

Recommendation

2a. In the critically ill obese patient, if indirect calorimetry is unavailable, energy requirements should be based on the Penn State University 2010 predictive equation or the modified Penn State University equation if the patient is over the age of 60 years (strong).

Evidence Grade: High.

2b. In the hospitalized obese patient, if indirect calorimetry is unavailable and the Penn State University equations cannot be used, energy requirements may be based on the Mifflin–St Jeor equation using actual body weight (weak).

Evidence Grade: Moderate.

Rationale. Most studies recommend the use of indirect calorimetry to measure resting energy expenditure (REE); however, some patients do not meet valid testing criteria, and most facilities do not have indirect calorimeters. Avoiding energy overfeeding is an important goal; therefore either REE or use of a predictive equation to approximate REE is an essential part of nutrition assessment. In the critically ill, ventilator-dependent obese patient, the Penn State University (PSU) predictive equation most accurately predicts REE compared with others (including Harris–Benedict, Mifflin–St Jeor, Swinamer, and Ireton-Jones). Frankenfield and colleagues compared multiple predictive equations with REE in patients with BMI ≥ 30 kg/m^2 and found the PSU equation to have the highest prediction accuracy of 70% (± 10% of REE) with the least bias or the lowest likelihood of over or underestimation.[50] In another comparison study in critically ill patients with BMI ≥ 45 kg/m^2, accuracy of the PSU equation was highest at 76% (± 10% of REE) compared with other equations studied.[51] In the older critically ill obese patient (≥ 60 years) with BMI ≥ 30, a modified PSU appears to be more accurate than the original PSU.[50] When compared with the unmodified version, the modified PSU was found to have an accuracy rate of 70% (± 10% of REE) vs 58% (P = .04).[50] Further, in a case series of 7 patients (including 2 obese patients) with REE measured continuously for 7 days, the prediction error using the PSU equation was only a total of –468 ± 642 kcal (–3.7 ± 5.1%) over 1 week.[52]

The PSU equations[53] are as follows:

Younger obese patients:

- RMR (kcal/d) = MSJ(0.96) + Tmax(167) + VE(31) – 6212

Older obese patients:

- RMR (kcal/d) = MSJ(0.71) + Tmax(85) + VE(64) – 3085
- ○ Where MSJ = Mifflin–St Jeor equation (below); V_E = minute ventilation (L/minute); T_{max} = maximum temperature in prior 24 hours in degrees C

In the mixed ICU and non-ICU patients, the evidence is more difficult to assess due to several important variables. The

Table 4. Evidence Summary Question 2: How Should Energy Requirements Be Determined in Obese Critically Ill or Hospitalized Non-ICU Patients?.

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
			ICU patients		
Frankenfield et al, 2012[51]	Validation study Similar prognosis in obese group 55 obese patients	Critically ill patients at extremes of BMI BMI ≤ 21 kg/m^2, n = 56 BMI ≥ 45 kg/m^2, n = 55	Validate the PSU prediction equation and test validity of IJ, ACCP, MSJ, HB	**Accuracy within 10% REE (%):** ● PSU (76%) ● MSJ (55%) ● HB (60%) ● IJ (29%) ● ACCP (27%) **Bias in kcal/d (95% CI):** ● PSU (–33, +97) ● MSJ (–299, –82) ● HB (–105, +149) ● IJ (+283, +509) ● ACCP (–616, –403)	PSU valid in severely obese, critically ill patients
Kross et al, 2012[92]	Retrospective validation study 401 obese patients	All mechanically ventilated patients with REE between 1998-2005 ● BMI 18.5-24.9, n = 254 ● BMI 25-29.9, n = 272 ● BMI 30-34.9, n = 176 ● BMI 35-39.9, n = 84 ● BMI ≥ 40, n = 141 Total N = 925	Compare REE with HB, Owen, MSJ, IJ, ACCP	**BMI 30-34.9:** **Accuracy (%):** ● MSJ (18.8%) ● HB (34.1%) ● IJ (20.5%) ● ACCP (9.7%) ● Owen (9.7%) **Bias mean (95% CI):** ● MSJ, –177.8 (–203.9, –151.6) ● HB, –53.4 (–78.6, +10.1) ● IJ, –86.4 (–117.6, –55.2) ● ACCP, –218.7 (–245.3, –192.2) ● Owen, –205.6 (–233.1, +177.9) **BMI 35-39.9**: **Accuracy (%):** ● MSJ (18.8%) ● HB (27.4%) ● IJ (20.5%) ● ACCP (7.1%) ● Owen (14.3%) **Bias mean (95% CI)** ● MSJ, –166.6 (–209.4, –123.8) ● HB, –66.0 (–105.1, +27.3) ● IJ, –101.9 (–76.7, +23.8) ● ACCP, –243.7 (–285.5, –202.1) ● Owen, –198.9 (–240.2, –157) **BMI ≥ 40:** **Accuracy (%):** ● MSJ (33.3%) ● HB (28.4%) ● IJ (14.2%) ● ACCP (1.4%) ● Owen (20.6%) **Bias mean (95% CI):** ● MSJ, –91.8 (–119.5, –64.0) ● HB, –61.1 (–55.8, +19.5) ● IJ, –91.3 (–133.9, –48.7) ● ACCP, –243.7 (–319.1, –261.4) ● Owen, –145.2 (–174.1, –116.3)	Unable to evaluate PSU or Swinamer due to missing minute ventilation or tidal volume Equations are not adequate

(continued)

Table 4. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Frankenfield, 2011[53]	Validation study Included archived data in analysis, unclear prognostic similarity Precise measurement protocol	Obese, older ICU patients, n = 50 Age 70 ± 7 y BMI 38.4 ± 7.2 kg/m^2 Data from previous studies: n = 79	Test the validity of a modified PSU equation against Deltatrac REE measures	**Accuracy:** ● Modified PSU = 70% ● Original PSU = 66% **Bias (95% CI):** ● Modified PSU (–120, –12) kcal/d ● Original PSU (–90, + 25) kcal/d	Both PSU equations include both body size and metabolic factors (temperature, minute ventilation)
Frankenfield et al, 2009[50]	Validation study Similar prognosis	REE measures in 202 critically ill patients in 2006-2007: Obese young: n = 47 Obese elderly: n = 51	Compare REE measured by Deltatrac calorimeter with estimates by HB, MSJ, ACCP, Swinamer, IJ, PSU, Brandi, and Faisy equations	**Accuracy:** **Young Obese:** ● PSU (66%) ● MSJ (21%) ● HB (45%) ● IJ (49%) ● ACCP (53%) **Elderly Obese:** ● PSU (46%) ● MSJ (35%) ● HB (35%) ● IJ (51%) ● ACCP (12%) **Bias (95% CI):** **Young Obese:** ● PSU (–249, –31) ● MSJ (–544, –316) ● HB (–368, +89) ● IJ (–249, –31) ● ACCP (358, 874) **Elderly Obese:** ● PSU (–51, +133) ● MSJ (–440, –215) ● HB (–357, –126) ● IJ (–174, +31) ● ACCP (457, 749)	PSU equation unbiased and precise across all age and weight groups

(continued)

Table 4. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Alves et al, 2009[93]	Validation study Dissimilar prognosis	Overweight or obese ICU patients Mean BMI 36.41 ± 9.03 kg/m^2 Fasting, n = 42 Stable feeding, n = 29	Compare REE measured by Deltatrac calorimeter with estimates by HB, IJ equations, and 21 kcal/kg of actual, average, and adjusted body weight	**Accuracy (Concordance Correlation Coefficient):** **Fasted measures:** ● HB actual weight (0.767) ● IJ actual weight (0.452) ● 21 kcal/kg actual weight (0.446) **Fed measures:** ● HB actual weight (0.829) ● IJ actual weight (0.641) ● 21 kcal/kg actual weight (0.490) **Bias:** **Fasted measures:** ● HB actual weight –81.3 (–726.1, +563.4) ● IJ actual weight –644.2 (–1369.8, +81.4) ● 21 kcal/kg actual weight –413.3 (–1527.7, +701) **Fed measures:** ● HB actual weight –63.7 (–658.3, +530.8) ● IJ actual weight 461.9 (–172.7, +1096.5) ● 21 kcal/kg actual weight +315.9 (–924.5, +1555.7) Use of adjusted body weight produced less accurate estimates	REE should be measured Bias with best equation could result in change in body weight if applied to energy delivery
Anderegg et al, 2009[55]	Validation study Dissimilar prognosis Different measuring devices Small sample	Hospitalized adult patients with BMI 38.2 ± 8 kg/m^2 Ventilated, n = 27 Spontaneously breathing, n = 9 Total N = 36	Identify which of 4 predictive equations gave estimates within 10% of measured energy expenditure by Deltatrac (ventilated) or Medgem (spontaneously breathing).	**Accuracy:** ● HB actual weight (38.9%) ● MSJ (19.4%) ● IJ ventilator (38.9%) ● 21 kcal/kg actual weight (41.5%) **Bias (mean ± SD):** ● HB 110.1 ± 478.3 ● MSJ 215.8 ± 470.7 ● IJ 152.3 ± 399.1 ● 21 kcal/kg actual weight –271 ± 641.7 **Mean REE:** ● Ventilated 20.4 ± 5.1 kcal/kg/d ● Spontaneously breathing, 15.5 ± .9 kcal/kg/d	Indirect calorimetry should be employed to measure energy expenditure in obese hospitalized patients
Boullata et al, 2007[54]	Retrospective record validation study Dissimilar prognosis Unclear how many obese patients are ventilator vs canopy measures	All patients with an REE in 1991, n = 395 Ventilator measures, n = 141 Canopy measures, n = 254 Obese, n = 51	Evaluate the accuracy of 7 predictive equations against measured REE in hospitalized patients, including the critically ill and obese	**Accuracy:** ● HB actual weight (62%) ● IJ (32%) **Bias:** ● HB +47 (–440, +534)	Data collection predates current level of obesity

(continued)

Table 4. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Dobratz et al, 2007[57]	Validation study Similar prognosis Small sample	Female pre–bariatric surgery patients, n = 14 BMI 49.8 ± 6.2, (range 41.3-65.3) kg/m^2	Identify which of 12 prediction equations is most accurate relative to measured REE using Deltatrac calorimeter	**Accuracy:** ● MSJ (86%) ● HB actual weight (69%) **Bias (mean difference):** ● MSJ –48 ± 191 kcal ● HB actual weight –89 ± 187 kcal/day Use of adjusted body weight with HB equation made the underestimate worse Error for all predictive equations (including MSJ) ≥ 250 kcal	Small sample Clinically stable prior to bariatric surgery Prediction error might result in change in body weight if applied to energy delivery
Frankenfield et al, 2003[56]	Validation study	Healthy volunteers and bariatric surgery patients in a hospital setting All canopy measures, BMI range up to 96.8 kg/m^2 Nonobese, n = 83 BMI 30-39.9, n = 20 BMI ≥ 40, n = 27	Evaluate equations for predicting resting metabolic rate against measured values in obese and nonobese people	**Accuracy of MSJ:** ● BMI 30-39.9 (70%), 10% underestimates, 20% overestimates ● BMI ≥ 40 (70%), 7% underestimates, 23% overestimates **Accuracy of HB:** ● BMI 30-39.9 (50%), 40% underestimates, 10% overestimates BMI ≥ 40 (74%), 22% underestimates, 4% overestimates	

Bias is the 95% CI of difference between estimated and measured REE; precision is the percentage of measures ± 10% REE. ACCP, American College of Chest Physicians; CI, confidence interval; HB, Harris–Benedict; ICU, intensive care unit; IJ, Ireton-Jones; MSJ, Mifflin–St Jeor; PSU, Penn State University; REE, resting energy expenditure.

5 studies reviewed compared multiple predictive equations (Harris–Benedict, Schofield, Mifflin–St Jeor, and others) with REE but did not include all the same predictive equations in each. All included very small samples of obese patients, 1 reported on data collected in 1991,[54] and 1 used measures from 2 different calorimeter devices.[55] Accuracy (± 10% of REE) varied among the equations studied with Mifflin–St Jeor (MSJ) demonstrating the highest accuracy at 70%[56]-86%[57] compared with 50% for Harris–Benedict with adjusted weight[55] and 50%,[56] 62%[54]-69%[57] for Harris–Benedict using actual weight. In addition, significant bias[55] and prediction errors[54,57] were measured that could result in undesired weight changes when applied to specific patients. The error for MSJ, however, was lower than that demonstrated with Harris–Benedict using actual weight.[56,57]

The MSJ[58] equations are as follows:

- Men (kcal/day) = 5 + 10 × Weight (kg) + 6.25 × Ht(cm) – 5 × Age(y)
- Women (kcal/day) = –161 + 10 × Weight (kg) + 6.25 × Ht(cm) – 5 × Age(y)

Whether provision of energy requirements based on REE provides superior clinical outcomes in hospitalized patients to those with energy needs estimated by a predictive equation has not yet been evaluated in patients with obese or optimal BMI.

Question 3: Are Clinical Outcomes Improved With Hypocaloric, High Protein Diets in Hospitalized Patients With Obesity? (Tables 5-6)

Recommendation

3a. Clinical outcomes are at least equivalent in patients supported with high protein hypocaloric feeding to those supported with high protein eucaloric feeding. A trial of hypocaloric high protein feeding is suggested in patients who do not have severe renal or hepatic dysfunction (weak). Hypocaloric feeding may be started with 50%-70% of estimated energy requirements or < 14 kcal/kg actual weight. High protein feeding may be started with 1.2 g/kg actual weight or 2-2.5 g/kg ideal body weight, with adjustment of goal protein intake by the results of nitrogen balance studies.

Evidence Grade: Low.

3b. Hypocaloric low protein feedings are associated with unfavorable outcomes. Clinical vigilance for adequate protein provision is suggested in patients who do not have severe renal or hepatic dysfunction (weak).

Evidence Grade: Low.

Rationale. Insulin resistance, glucose intolerance, hyperlipidemia, nonalcoholic fatty liver disease, and hypoventilation syndrome are more prevalent in patients with obesity than nonobese patients.[59] As a result, the hospitalized patient with obesity is susceptible to experiencing complications associated with overfeeding. Because of these concerns, hypocaloric, high protein regimens have been designed by clinicians in an effort to minimize potential overfeeding complications while simultaneously achieving net protein anabolism.

Hypocaloric feeding is defined as providing a caloric intake less than measuredor estimated energy expenditure whereas eucaloric feeding is intended to provide a caloric intake sufficient to meet caloric needs as assessed by measured energy expenditure. Hypercaloric feeding is the provision of a caloric intake greater than caloric requirements. Hypocaloric, high protein feeding is often mistaken for permissive underfeeding. Permissive underfeeding allows for both protein and caloric deficits whereas the intent of hypocaloric, high protein diets is to provide only a calorie deficit while ensuring adequate protein intake.

Four comparative studies[59-62] and 2 case series[63,64] examined the use of hypocaloric, high protein nutrition therapy for hospitalized patients with obesity. The hypocaloric, high protein diets contained average intakes ranging from 90 g to 140 g of protein and 900 kcals to 1300 kcals daily (Table 4). Significantly improved clinical outcomes, as evidenced by decreased LOS in the ICU, decreased duration of antibiotic therapy, and a trend toward decreased days of mechanical ventilation, were suggested in a single small observational study examining hypocaloric, high protein diets vs eucaloric, high protein diets for critically ill trauma patients with obesity.[61] Positive clinical outcomes were also noted for use of hypocaloric, high protein feeding in 2 observational case series of surgical patients with obesity.[63,64] In the only randomized controlled trial that examined clinical outcomes,[59] no difference in mortality or length of hospital stay was found for hospitalized patients with obesity who received hypocaloric high protein feeding when compared with eucaloric high protein diets. All 3 comparative studies[59-61] indicated that nutrition outcomes, such as nitrogen balance and serum protein response, were similar between eucaloric and hypocaloric feeding in the presence of adequate protein intake. However, 1 large observational study indicated a worsened 60-day mortality rate when a hypocaloric diet was combined with a low protein intake (average daily caloric and protein intakes of 1000 kcals and 46 g, respectively) and given to hospitalized patients with Class II (BMI 35-39.9 kg/m^2) obesity.[65]

The current literature, which includes a total of 163 patients supported with hypocaloric, high protein regimens, indicates that clinical outcomes for hospitalized patients with obesity are at least equivalent, if not improved, by the provision of hypocaloric feeding when adequate protein intake is given to achieve net protein anabolism. A large randomized controlled trial is warranted to ascertain whether hypocaloric, high protein nutrition therapy offers a significant therapeutic advantage over eucaloric or hypercaloric feeding with respect to clinical outcomes and avoidance of complications from overfeeding for hospitalized patients with obesity.

Table 5. Evidence Summary Question 3: Are Clinical Outcomes Improved With Hypocaloric, High Protein Diets in Hospitalized Patients?.

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Dickerson et al, 2013[62]	Retrospective cohort observation	Admissions to trauma center, 2009-2011 with BMI ≥ 30 kg/m^2 BMI = 35 ± 6 kg/m^2 Weight = 105 ± 26 kg Age 18-59 years, n = 41 Age ≥ 60 years, n = 33	Examine whether older, critically ill trauma patients who are obese achieve nitrogen equilibrium and obtain similar clinical outcomes to younger obese patients during hypocaloric, high protein therapy	**Daily Nutrient Delivery:** ● Younger: 18 kcal/kg ideal weight, protein 1.9 g/kg ideal weight ● Older: 21 kcal/kg ideal weight, protein 2.1 g/kg ideal weight ($P < .05$) **ICU LOS:** 28 ± 17 vs 30 ± 13 days in younger vs older **Hospital LOS:** 45 ± 30 vs 34 ± 14 days in younger vs older, $P = .065$ **Sepsis:** 83% vs 76% in younger vs older, $P = .041$ **Pneumonia:** 39% vs 48% in younger vs older **Antibiotic days adjusted for mortality:** 10 ± 3 vs 8 ± 4 days in younger vs older, $P = .041$	
Hamilton et al, 2011[63]	Retrospective record review No control Small sample	Bariatric surgery patients admitted for initiation of home PN to treat bowel obstruction or leak/fistula, 2000-2008 with follow-up data from home Baseline BMI = 39.8 (IQR 36.1, 48.1) Baseline weight = 113 kg (IQR 94.5, 134) N = 23	Evaluate effect of hypocaloric PN on weight loss, albumin level, PN complications	**Daily Nutrient Delivery:** ● Energy 13.6 kcal/kg actual body weight ● Protein 132.6 ± 6.6 g, 1.2 ± 0.3 g/kg body weight **Weight Loss:** ● –7.0 ± 5.1% in 1.5 months **Complications:** ● Readmission 52.5%	

(continued)

Table 5. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Alberda et al, 2009[65]	Prospective cohort observation Some differences in cardiovascular dx at admission, similar APACHE II score OR adjusted for nutrition days, BMI, age, admission category, dx, APACHE II score 728 obese subjects, but < 200 in each of BMI 35-39.9 and > 40 groups	Adult patients admitted to 1 of 167 ICUs in 37 countries ● BMI < 20 kg/m^2, n = 289 ● BMI 20-24.9, n = 937 ● BMI 25-29.9, n = 818 ● BMI 30-34.9, n = 395 ● BMI 35-39.9, n = 162 ● BMI ≥ 40, n = 171 Total N = 2772	Examine the relationship between amount of energy and protein provided to clinical outcomes, and the impact of preillness BMI on outcomes	**Daily Energy Intake:** ● BMI < 20 kg/m^2, 994 ± 469 kcal; 19.7 ± 9.6 kcal/kg ● BMI 20-24.9, 1024 ± 490; 15.7 ± 7.5 kcal/kg actual weight ● BMI 25-29.9, 1074 ± 536; 13.6 ± 6.7 kcal/kg ● BMI 30-34.9, 1008 ± 534 kcal; 11.2 ± 4.9 kcal/kg ● BMI 35-39.9, 1009 ± 532 kcal; 9.8 ± 5.1 kcal/kg ● BMI ≥ 40, 1048 ± 531 kcal; 8.1 ± 4.4 kcal/kg **Daily Protein Intake:** ● BMI < 20 kg/m^2, 44.7 ± 23.4 g; 0.9 ± 0.5 g/kg ● BMI 20-24.9, 46.7 ± 25.9 g; 0.7 ± 0.4 g/kg ● BMI 25-29.9,47.5 ± 28.3 g; 0.6 ± 0.3 g/kg ● BMI 30-34.9,47.9 ± 28.3 g; 0.5 ± 0.3 g/kg ● BMI 35-39.9,45.8 ± 29.2 g; 0.4 ± 0.3 g/kg ● BMI ≥ 40, 50.3 ± 33.3 g; 0.4 ± 0.3 g/kg **60-day Mortality Per 1000 kcal/day Increase in Energy Intake:** ● BMI < 20 kg/m^2, OR 0.52 (95% CI, 0.29-0.95, *P* = .03) ● BMI 20-24.9, OR 0.62 (95% CI, 0.44-0.88, *P* = .007) ● BMI 25-29.9, OR 1.05 (95% CI, 0.75-1.49) ● BMI 30-34.9, OR 1.04 (95% CI, 0.64-1.68) ● BMI 35-39.9, OR 0.36 (95% CI, 0.16-0.80, *P* = .012) ● BMI ≥ 40, OR 0.63 (95% CI, 0.32-1.24) **60-day Mortality per 30 g Increase in Protein Intake:** ● BMI < 20 kg/m^2, OR 0.60 (95% CI, 0.41-0.87, *P* = .007) ● BMI 20-24.9, OR 0.81 (95% CI, 0.66-0.99, *P* = .036) ● BMI 25-29.9, OR 0.97 (95% CI, 0.79-1.19) ● BMI 30-34.9, OR 1.04 (95% CI, 0.79-1.37) ● BMI 35-39.9, OR 0.62 (95% CI, 0.39-0.98, *P* = .039) ● BMI ≥ 40, OR 0.72 (95% CI, 0.51-1.03)	Energy and protein targets for patients with obesity go down as BMI increases (20.2 kcal/kg and 1.0 g/kg; 17.9 kcal/kg and 0.9 g/kg, 15.0 kcal/kg and 0.8 g/kg; and for BMI 30-34.9, 35-39.9, ≥ 40 respectively) Increased energy and protein intake may be important for patients with BMI 35-39.9, not significantly so for BMI ≥ 40

(continued)

Table 5. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Choban et al, 2005[66]	Retrospective record review	Obese adult patients from 2 sites BMI 30-39.9 kg/m^2, n = 48 BMI ≥ 40 kg/m^2, n = 22	Evaluate protein requirements, using nitrogen balance, in hospitalized patients with obesity	**Protein Requirement:** **ICU Patients:** ● BMI 30-39.9 kg/m^2, 1.9 g/kg ideal body weight/day ● BMI ≥ 40 kg/m^2, 2.5 g/kg ideal body weight/day **Non-ICU Patients:** ● BMI 30-39.9 kg/m^2, 1.7 g/kg ideal body weight/day ● BMI ≥ 40 kg/m^2, 1.8 g/kg ideal body weight/day	
Dickerson et al, 2002[61]	Retrospective record review Similar prognosis Small sample	Obese adult patients with > 7 days enteral tube feeding in surgical ICU Baseline BMI 41.3 ± 4.7 kg/m^2 and weight 118 ± 41 kg in hypocaloric, 36 ± 12.4 kg/m^2 and weight 102 ± 36 kg in eucaloric group Hypocaloric as energy intake < 20 kcal/kg adjusted body weight and protein intake 2 g/kg ideal body weight, n = 28 Eucaloric as energy intake ≥ 20 kcal/kg adjusted body weight and protein 2 g/kg ideal body weight, n = 12 Total N = 40	Evaluate nutrition and clinical efficacy of eucaloric vs hypocaloric enteral feeding Daily feeding plan: ● Both groups with protein 2 g/kg ideal body weight (1.2 g/kg actual weight) ● Eucaloric goal 25-30 total kcal/kg adjusted body weight; actual intake 18.5-25.9 kcal/kg current body weight and 0.8-1.2 g protein/kg current body weight Hypocaloric goal < 20 kcal/kg adjusted body weight; actual intake 13.4-19.2 kcal/kg current body weight and 0.7-0.9 g protein/kg current body weight	**Actual intake**: ● Hypocaloric vs Eucaloric: 1285 ± 325 kcal, 90 ± 24 g protein vs 1841 ± 482 kcal, 111 ± 32 g protein daily **Length of ICU Stay:** ● Hypocaloric vs Eucaloric, 18.6 ± 9.9 vs 28.5 ± 16.1 days, $P < .03$ **Ventilator Days:** ● Hypocaloric vs Eucaloric, 15.9 ± 10.8 vs 23.7 ± 16.6 days, $P = .09$) **Duration Antibiotic Therapy:** ● Hypocaloric vs Eucaloric, 16.6 ± 11.7 vs 27.4 ± 17.3 days, $P = .03$) **Nutrition Measures:** ● No difference in nitrogen balance, change in prealbumin or albumin	
Choban et al, 1997[59]	RCT Balanced prognosis Blinded delivery of PN Indirect outcomes	Obese adult patients referred for PN, BMI 35 (range 26-46.5) kg/m^2 Hypocaloric high protein PN, n = 16 Eucaloric high protein PN, n = 14 Total N = 30	Evaluate efficacy of hypocaloric vs eucaloric PN with protein 2 gm/kg ideal body weight Daily feeding plan: ● Eucaloric goal with kcal/nitrogen 150:1, actual intake 1936 ± 198 kcal and 108 ± 14 g protein (1.2 g/kg actual weight, 2 g/kg ideal weight) Hypocaloric goal with kcal/nitrogen 75:1, actual intake 1293 ± 299 kcal and 120 ± 27 g protein	**Daily Nutrient Delivery:** ● Hypocaloric 1293 ± 298 nonprotein kcal, 120 ± 27 g protein ● Eucaloric 1936 ± 198 nonprotein kcal, 108 ± 14 g protein **Change in body weight** ● Hypocaloric vs Eucaloric: 0 ± 6.8 kg vs 2.7 ± 7kg **Change in Albumin:** ● Hypocaloric vs Eucaloric: –1 ± 2 g/L vs –2 ± 2 g/L **Nitrogen Balance:** ● Hypocaloric vs Eucaloric, 4.0 ± 4.2 vs 3.6 ± 41. g nitrogen	

(continued)

Table 5. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Burge et al, 1994[60]	RCT Unblinded PN delivery Indirect outcomes Small sample	Obese patients referred for PN BMI = 33 ± 5.5 kg/m^2 Weight 77-114 kg Hypocaloric high protein PN, n = 9 vs Eucaloric high protein PN, n = 7 Total N = 16	Evaluate impact of hypocaloric PN on nitrogen balance Daily feeding plan: ● Eucaloric goal with kcal at 100% REE, kcal/nitrogen 150:1, actual intake, actual intake 2492 ± 298 kcal (25 kcal/kg actual weight) and 130 ± 15 g protein (1.2 g/kg or 2 g/kg ideal weight) Hypocaloric goal with 50% REE and kcal/nitrogen 75:1, actual intake 1285 ± 374 kcal (14 kcal/kg actual weight) and 111 ± 32 g protein (1.3 g/kg actual weight, 2 g/kg ideal weight)	**Daily Nutrient Delivery:** ● Hypocaloric 585 ± 170 nonprotein kcal, 110.9 ± 32 g protein ● Eucaloric 1972 ± 235 nonprotein kcal, 130 ± 15.5 g protein **Change in body weight** ● Hypocaloric vs Eucaloric: –4.1 ± 6. kg vs –7.4 ± 8.4kg (~4.5% vs7.3%) **Nitrogen Balance:** ● Hypocaloric vs Eucaloric, 1.3 ± 3.62 vs2.83 ± 6.9 g	
Dickerson et al, 1986[64]	Prospective cohort Uncontrolled Balanced prognosis Small sample	Obese, stressed surgical patients requiring PN Baseline weight 127 ± 60 kg (range 90-302 kg) N = 13	Evaluate efficacy of hypocaloric, high-protein feeding **Daily Nutrient Delivery:** ● Nonprotein kcal 881 ± 393 (51% REE) ● Protein 129 g or 2.1 ± 0.6 g/kg ideal body weight or 1.2 ± 0.5 g/kg actual weight, 2.1 g/kg ideal weight	**Nitrogen Balance:** ● +2.4 g/day **Weight Loss:** ● 2.3 ± 2.7 kg/week **Wound Healing:** ● All fistulas or dehiscence healed by 35.8 ± 18.1 days **Adverse Events in Single Patients:** ● Ketonuria ● Mild skin rash that responded to zinc and lipid intake ● Acute renal failure due to antibiotic therapy ● Readmission for recurrent anastomotic leak	

APACHE, Acute Physiology and Chronic Health Evaluation; BMI, body mass index; ICU, intensive care unit; IQR, interquartile range; LOS, length of stay; OR, odds ratio; PN, parenteral nutrition; RCT, randomized controlled trial.

Table 6. GRADE Table Question 3: Are Clinical Outcomes Improved With Hypocaloric, High Protein Diets in Hospitalized Patients?

Comparison	Outcome	Quantity, Type Evidence	Finding	Final GRADE	Overall Evidence GRADE
Hypocaloric/high protein vs eucaloric/high protein	LOS	1 OBS	1 decreased[61]	Low	Low
	Nitrogen Balance	1 RCT, 3 OBS	4 no difference[59-62]	Low	
	Weight Loss	1 RCT, 1 OBS	2 no difference[59,60]	Low	

LOS, length of stay; OBS, observational study; RCT, randomized controlled trial.

Data to support this recommendation are in Table 3, where protein intake of 1.2 g/kg actual body weight (2 g/kg ideal body weight) daily was given to patients in 5 observational studies[59-62,64] with hypocaloric or eucaloric energy intake. An additional study compared protein requirements based on nitrogen balance studies separately for ICU and non-ICU patients. The ICU patients required 2-2.5 g/kg/day and the non-ICU patients 1.8-1.9 g/kg/d to approach nitrogen equilibrium with the higher requirements for those with BMI > 40 kg/m^2.[66] These studies included patients up to 302 kg and BMI 50.6 kg/m^2, however most subjects were considerably below these levels. Data have not been found to establish reasonable nitrogen intake goals for patients beyond these limits. Nitrogen balance was similar at this level of protein intake whether energy intake was hypocaloric or eucaloric. These initial recommendations should be adjusted using nitrogen balance studies, with a goal of nitrogen equilibrium if possible (–4 to +4 g nitrogen/kg/d).[61] While older studies may have suggested increase in albumin or prealbumin concentration as a goal for protein intake, a more recent appreciation of the strong impact of inflammation on these measures makes them unreliable as a marker of nutrition state in most ill, hospitalized patients.

Question 4: In Obese Patients Who Have Had Malabsorptive or Restrictive Surgical Procedures for Weight Loss, What Micronutrients Should Be Evaluated? (Tables 7-8)

Recommendation

Patients who have undergone sleeve gastrectomy, gastric bypass, or biliopancreatic diversion ± duodenal switch have increased risk of nutrient deficiency. In acutely ill hospitalized patients with history of these procedures, evaluation for evidence of depletion of iron, copper, zinc, selenium, thiamine, folate, and vitamins B_{12}, and D is suggested as well as repletion of deficiency states. (weak).

Evidence Grade: Low.

Rationale. Bariatric surgical procedures that change the capacity of the stomach facilitate weight reduction by restriction, that is, increasing satiety and reducing caloric intake. Procedures that shorten small bowel absorptive capacity result in malabsorption of protein, energy and micronutrients to varying degrees depending on construction of the anatomy. Biliopancreatic diversion ± duodenal switch (BPD ± DS) and Roux-en-Y gastric bypass (RYGB) combine these mechanisms. Micronutrient deficiency may well be a comorbidity of severe obesity in that it appears to increase in prevalence as the degree of obesity increases in populations who have had no prior bariatric surgery. This has been documented for alpha & beta carotene, beta cryptoxanthin, lutein/zeaxanthin, lycopene, total carotenoids, iron, selenium, vitamins A, C, D, B_6, B_{12}, and folic acid.[67-69]

Twenty-one observational studies and 2 RCTs have investigated a variety of micronutrients. These have compared serum levels in cohorts of patients treated with different procedures and have included RYGB, sleeve gastrectomy (SG), BPD ± DS, and adjustable gastric band procedures. The duration of follow-up was generally short, with 16 studies covering 1-3 years,[69-82] 3 studies 4-5 years[83-85] and 1 study 7 years.[86] The study of longest duration documented no deficiency states in patients with restrictive procedures but no malabsorptive component; however, the others have documented an increased risk of deficiency of iron, copper, zinc, selenium, thiamine, folate, and Vitamins B_{12} and D as compared with preoperative populations.

The proclivity of restrictive or malabsorptive procedures to exacerbate or create micronutrient deficiency states has been acknowledged by recommendations for supplementation published by the American Society for Metabolic and Bariatric Surgery and the Obesity Society.[87] For all bariatric surgery patients, a daily multiple vitamin/mineral supplement is recommended with 2 daily doses for patients with SG, RYGB, and BPD. For all patients, at least 3000 IU vitamin D daily is recommended to achieve serum 25-hydroxyvitamin D levels > 30 ng/mL; 2 mg copper daily; iron 45-60 mg from diet and supplements; and vitamin B_{12} should be given as needed to maintain normal serum levels. All patients except those with BPD should take 1200-1500 mg calcium citrate daily. Evaluation of folic acid, iron and 25-hydroxyvitamin D should be done annually. Copper, zinc, selenium, and thiamine should be monitored when patients have specific findings to suggest deficiency. As with other chronic or home medications, these vitamin supplements should be continued or resumed in hospitalized patients.

Table 7. Evidence Summary Question 4: In Obese Patients Who Have Had a Malabsorptive or Restrictive Surgical Procedure, What Micronutrients Should Be Evaluated?.

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Beckman et al, 2013[79]	Prospective cohort observation Small sample	Women with RYGB, N = 20	Describe serum 25(OH)D changes and determine if FM loss and vitamin D intake are associated with changes in serum levels at 12 months after RYGB	25(OH)D increased by 10 ± 2 ng/mL by 12 months 3 patients still had 25(OH)D < 20 ng/mL Weight, FM, BMI, and %EWL changes were associated with 25(OH)D change	
Aasheim et al, 2012[94]	Prospective nonrandomized trial Small sample	RYGB, n = 29 Lifestyle management, n = 24	Assess change in vitamin status in patients taking vitamin supplements 1 year after RYGB vs lifestyle management controls	All vitamins similar between RYGB and control patients except vitamin A lower in RYGB	
Damms-Machado, 2012[69]	Retrospective record review Similar population Small sample	SG, N = 54	Describe nutrient deficiencies before and 1, 3, 6, and 12 months after SG	At least 51% had a micronutrient deficiency preoperatively: ● Vitamin D (83%) ● Iron (29%) ● Vitamin B6 (11%) ● Vitamin B12 (9%) ● Folate (6%) ● Potassium (7%) By 12 months after SG, prevalence of deficiencies of the following nutrients increased: ● Vitamin B_6 (17%) ● Vitamin B_{12} (17%) ● Folate (14%)	Reduction in gastric acidity may be implicated postoperatively with vitamins B6, B12; folate deficiency may be due to food choices of patients
Gletsu-Miller, 2012[95]	Retrospective record review with Prospective cohort observation Small sample	RYGB, N = 136	Describe number of RYGB patients with copper deficiency and associated hematological and neurological Complaints over 12 months.	Prevalence of copper deficiency, 9.6% Incidence of copper deficiency, 18.8% Concomitant complications include anemia, leukopenia, and various neuromuscular abnormalities.	
Kehagias et al, 2011[76]	RCT of surgical procedure ITT analysis 5% attrition Small sample	Randomized to RYGB, N = 30 or SG, N = 30	Describe perioperative safety and 3-year results after RYGB or SG	**Preoperative nutrient deficiencies:** RYGB vs SG, not significantly different **3 years postoperatively:** Vitamin B_{12} deficiency in 7/29 (24%) in RYGB vs 1/28 (3.5%) in SG	

(continued)

Table 7. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Leivonen et al, 2011[75]	Retrospective record review Small sample	Patients over age 60 years treated with SG, N = 12 vs patients < age 59 years, N = 43	Evaluate differences in recovery, weight loss, and vitamin status 12 months after SG in younger vs older patients	**Vitamin deficiencies:** ● Not significantly different	
de Luis et al, 2011[85]	Retrospective record review No information on supplement adherence	BPD patients at baseline and 4 years postoperatively N = 65	Evaluate influence of BPD on copper and zinc levels	**Prevalence of copper deficiency:** ● Preoperative, 67.8% ● 6 months, 76.9% ● 12 months, 76.9% ● 24 months, 87.7% ● 36 months, 87.7% ● 48 months, 90.7% **Prevalence of zinc deficiency:** ● Preoperative, 73.8% ● 6 months, 73.8% ● 12 months, 86.1% ● 24 months, 86.1% ● 36 months, 90.7% ● 48 months, 90.7%	Deficiency prevalence increases over time
Alasfar et al, 2011[68]	Controlled cohort observation No information on trace element intake or supplement use	Bariatric surgery patients, N = 66, BMI = 45.3 Nonobese controls, N = 44, BMI = 25.9	Compare serum trace element (copper, zinc, selenium, magnesium) concentrations in preoperative bariatric surgery vs nonobese control subjects	Selenium concentration significantly lower in obese patients, $P < .001$	
Balsa et al, 2011[83]	Cohort observation No information on trace element supplement use	RYGB, N = 52 BPD, N = 89	Compare prevalence of copper and zinc deficiency in RYGB vs BPD patients	**Prevalence of copper deficiency, RYGB vs BPD:** ● Preoperative, 0% vs 0% ● 6 months, 0% vs 17% ● 12 months, 2% vs 13% ● 24 months, 0% vs 24% ● 48 months, 2% vs 22% ● 60 months, 2% vs 13% **Prevalence of zinc deficiency, RYGB vs BPD:** ● Preoperative,12% vs 12% ● 6 months, 6% vs 69% ● 12 months, 2% vs70% ● 24 months, 6% vs 74% ● 48 months, 15% vs 46% ● 60 months, 21% vs 45%	Copper and zinc deficiencies more common with BPD than RYGB, more prevalent over time

(continued)

Table 7. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Rosa et al, 2011[96]	Prospective bioavailability studies Small sample	RYGB, N = 9	Describe iron and zinc plasma response to a tolerance test before and 3 months after RYGB.	Lower plasma zinc response ($P < .01$) and delayed response to iron intake after RYGB The total plasma iron concentration area over 4 hours was not different after surgery ($P > .05$) 24-hour urinary iron and zinc excretion did not change	
Gehrer et al, 2010[77]	Retrospective record review	2004-2006 RYGB, N = 86, SG, N = 50	Assess frequency of pre- and 3-year postoperative vitamin deficiencies and the success rate of their treatment	**Preoperative and postoperative deficiencies:** ● Vitamin B_{12} in RYGB (58%) vs SG (18%), $P < .0001$ ● Vitamin D in RYGB (52%) vs SG (32%), $P < .01$ All deficiencies treatable	
Schouten et al, 2010[86]	RCT of laparoscopic band vs open VBG, cohort observation Diagnostic similarity Small sample may lack statistical power	Original study N = 100 2 and 7-years postsurgical data obtained from 91 (91%) with a mean follow-up of 84 months laparoscopic AGB N = 48 VBG N = 43	Describe the long-term results of restrictive bariatric procedures including weight loss, long-term complications, comorbidities, reoperations, and vitamin status	No significant differences in levels of iron, zinc, folic acid or thiamine, vitamin B_6, or B_{12} between laparoscopic AGB and VGB groups No vitamin deficiencies were present 7 years after restrictive bariatric surgical procedures	
Signori et al, 2010[80]	Retrospective record review	RYGB patients, N = 123 Recommended to take 1200-2000 IU vitamin D daily	Compare vitamin D status preoperatively vs 12 months post-RYGB	25-OH D (ng/mL) 22.7 ± 9.9 vs 29.7 ± 14.1, preop vs 12 months post-RYGB, $P < .001$	
Salle et al, 2010[78]	Retrospective record review	Bariatric surgery patients in Angers, France RYGB, N = 266 SG, N = 33 BPD-DS, N = 25	Describe zinc and nutrition status before and 6, 12 and 24 months after RYGB, SG, DS	Preoperative: Zinc deficiency (9%) 24 months postoperatively: ● RYGB (35%) ● SG (18%) at 12 months ● BPD-DS(92%) Iron deficiency: ● RYGB (38%) ● SG (25%) at 12 months ● BPD-DS(58%)	

(continued)

Table 7. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Goldner et al, 2009[81]	RCT dose-response trial Small sample	Patients with RYGB and daily vitamin D supplements 800 IU, N = 13 2000 IU, N = 13 5000 IU, N = 15	Dose-response trial to define dose of vitamin D supplement needed after RYGB	**Preoperative serum 25(OH) D**: ● 19.1 ± 9.9 vs 15.0 ± 9.3 vs22.9 ± 10.3 nmol/L in 800 vs 2000 vs 5000 IU groups, $P = .01$ **12 months post-RYGB:** ● 27.5 ± 31.0 (n = 9), 800 IU ● 60.2 ± 37.4 (n = 9), 2000 IU ● 66.1 ± 42.2 (n = 10), 5000 IU No hypercalcemia	Recommended to start all patients at 2000 IU/day
Coupaye et al, 2009[72]	Prospective cohort Difference in BMI by treatment group Small sample, may lack statistical power No adjustment for inflammation or BMI group difference	Single center 70 consecutive patients who had undergone bariatric surgery AGB: N = 49, BMI 43 RYGB: N = 21, BMI 49	Compare the vitamin and nutrition status before and 1 year after bariatric surgery in patients receiving systematized nutrition care	Deficiencies of thiamine, vitamin C, and iron in 38%, 47% and 43% of ABG patients preoperatively, not significantly worsened at 1 year In RYGB patients deficiencies of thiamine, iron, vitamin C were in 25%, 57%, and 47% preoperatively, with improvement in thiamine and vitamin C deficiencies at 1 year (12%* $P < .05$, 37%, 10% * $P < .05$ respectively) CRP and fibrinogen improved in both groups by 1 year	Vitamin supplements improved postoperative outcomes in RYGB patients
Carlin et al, 2009[82]	RCT Small sample	Compare supplementation in female RYGB patients with 50,000 IU vitamin D weekly, N = 30 vs No vitamin D supplementation, N = 30 Both received 800 IU vitamin D and 1500 mg calcium daily	Evaluate the effectiveness of 50,000 IU vitamin D weekly to replenish vitamin D stores 1 year after RYGB	**Baseline 25-hydroxyvitamin D:** ● 19.7 ± 8.5 vs 18.5 ± 9.4 ng/mL, intervention vs control **12 Month 25-hydroxyvitamin D:** ● 37.8 ± 15.6 vs 15.2 ± 7.5 ng/mL, intervention vs control ($P < .001$) ● Less decline in bone mineral density in treatment More frequent resolution of hypertension in treatment	

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Table 7. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Toh et al, 2009[97]	Retrospective record review Prognostic similarity Small sample No adjustment for supplement adherence rates, interaction of weight loss with vitamin status	Preoperative: n = 232 Postoperative: n = 148; RYGB = 103; SG = 46	Describe prevalence of nutrient deficiencies in patients who present for bariatric surgery, compare with 12-month postoperative levels	Preoperatively ● Low 25-OH vitamin D in 57% ● Low iron in 15.7% ● High CRP in 58.5% Postoperatively, ● Low 25-OH vitamin D reduced to 30% in RYGB, 43% in SG patients ● Low iron unchanged ● High CRP improved to 13% and 17% in RYGB and SG patients ● Vitamin B_{12} increased from 1% to 11% in RYGB ● Low RBC folate increased in RYGB from 1% to 12%	Increased B_{12} and folate deficiencies with RYGB suggest lack of adherence with supplements
Gasteyger et al, 2008[74]	Retrospective record review Small sample Adherence with vitamin supplements not evaluated	Single center Adult patients at 2 year follow-up after RYGB N = 137 (110 women; 27 men) Length of Roux limb: 100cm for BMI ≤ 48. 0 and 150 cm for BMI < 48.0 All patients received a multivitamin supplement 1-6 months after RYGB Supplementation with specific nutrients prescribed for values that fell below the reference range	Assess type, frequency, and pattern of the development of nutrition deficiencies over the first 24 months after RYGB, to determine the amount of supplements prescribed and to evaluate the cost of treatment.	**Patients requiring supplementation:** ● 3 months, 34% ● 6 months, 59% ● 24 months, 98% **Most frequent supplements:** ● Vitamin B_{12}, iron, calcium/vitamin D in 60% ● Folate in 40% ● Vitamin B_6, zinc, magnesium in 15% **Mean supplements per patient:** ● 24 months, 2.9 ± 1.4 ● Cost/year US$417.96	Nutrition deficiencies are common post RYGB despite multivitamin supplementation
Madan et al, 2006[71]	Retrospective record review Small sample Incomplete data	All patients undergoing laparascopic RYGB by 1 surgeon during a 6 month period. N = 100 Only about 30 patients with all vitamin levels at 12 months	Describe preoperative and 1-year post-RYGB vitamin and trace mineral levels	**Deficiencies, preoperative vs postoperative:** ● Vitamin A, 7% vs 16% ● Vitamin B 12.5% vs 0% ● Vitamin D, 40% vs 19% ($P < .05$) ● Zinc, 28% vs 36% ● Iron, 14% & 6% ● Selenium, 58% & 3% ($P < .001$) ● Folate, 2% vs 8%	Did not report thiamine levels

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Table 7. (continued)

Study	Study Design, Quality	Population, Setting, n	Study Objective	Results	Comments
Clements et al, 2006[70]	Retrospective record review	All patients with laparoscopic RYGB, 2002-2004 (N = 493) with 1- and 2-year follow-up, N = 141	Evaluate prevalence of vitamin deficiency after RYGB	**Vitamin Deficiencies:** ● A (11%) ● C (34.6%) ● D (7%) ● Thiamine (18.3%) ● Riboflavin (13.6%) ● B_6 (17.6%) ● B_{12} (3.6%) No difference year 1 vs year 2 postoperatively	
Skroubis et al, 2002[84]	Retrospective record review No data on adherence rates No data on baseline comorbid conditions Unclear data on number of subjects at each time point	University medical center in Greece N = 174 RYGB, N = 79 (BMI 45.6 ± 4.9) BPD, N = 95 (BMI 57.2 ± 6.1)	Compare nutrition complications and effectiveness of micronutrient supplementation after RYGB and BPD All patients received a multivitamin and mineral supplement and 2 g of calcium	**Iron deficiency:** ● Low iron and ferritin levels increased with both surgical procedures over time **Vitamin B_{12} deficiency:** ● Increased with both surgical procedures from preop to 4 years postop with RYGB 33%, BPD 22% Negligible incidence of hypoalbuminemia	

AGB, adjustable gastric banding; BMI, body mass index; BPD, biliopancreatic diversion; CRP, C-reactive protein; DS, duodenal switch; EWL, excess weight loss; FM, fat mass; ITT, itention to treat analysis; IU, international unit; RCT, randomized controlled trial; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; VBG, vertical-banded gastroplasty; 25(OH)D = 25-hydroxyvitamin D.

Table 8. GRADE Table Question 4: In Obese Patients Who Have Had a Malabsorptive Surgical Procedure, What Micronutrients Should Be Evaluated?

Comparison	Outcome/Nutrient Deficiency	Quantity, Type Evidence	Finding	Final GRADE	Overall Evidence GRADE
Preoperative to postoperative RYGB or BPD	Copper	3 OBS	Increased[83,85,95]	Low	Low
	Zinc	3 OBS	Increased[83,85]	Low	
	Iron	3 OBS	Increased[84,97]	Very low	
	Selenium	1 OBS		Low	
	Thiamine	1 OBS	Increased[72]	Low	
	Folic acid	1 OBS	Increased[97]	Low	
	Vitamin B_{12}	2 OBS	Increased[84,97]	Low	
	Vitamin D	5 OBS, 2 RCT	Increased with supplements decreased[97]	Low	

BPD = biliopancreatic diversion; OBS = observational study; RCT, randomized controlled trial; RYGB = Roux-en-Y gastric bypass.

Compliance with supplement ingestion has been variable, with BPD ± DS 55%, RYGB 25%.[88] Patient follow-up with bariatric surgical programs, and hence routine surveillance of nutrition parameters, tends to diminish with time duration after the surgical procedure. The severity and prevalence of deficiency appears to increase with the interval of time after the procedure as well as with the degree of malabsorption induced by the procedure. Data evaluating micronutrient status in patients in the decades following bariatric surgical intervention are not available.

A.S.P.E.N. Board of Directors Providing Final Approval

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