Acute Management of Nutritional Demands after Spinal Cord Injury

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Abstract

A systematic review of the literature was performed to address pertinent clinical questions regarding nutritional management in the setting of acute spinal cord injury (SCI). Specific metabolic challenges are present following spinal cord injury. The acute stage is characterized by a reduction in metabolic activity, as well as a negative nitrogen balance that cannot be corrected, even with aggressive nutritional support. Metabolic demands need to be accurately monitored to avoid overfeeding. Enteral feeding is the optimal route following SCI. When oral feeding is not possible, nasogastric, followed by nasojejunal, then by percutaneous endoscopic gastrostomy, if necessary, is suggested.

Key words: spinal cord injury; nutrition; metabolism

Introduction

AWARENESS OF THE IMPORTANCE of appropriate nutritional support for spinal cord injury (SCI) patients dates back to the era of Hippocrates (Laven et al., 1989). However, considerable variability still exists in the nutritional management of SCI. The body of literature on nutrition in the acute stage remains limited, and providing optimal nutritional support following SCI continues to be a complex challenge. Unlike most trauma patients, who undergo a period of hypermetabolism (Frankenfield, 2006), in the acute phase post-injury patients with SCI undergo metabolic changes, including reduced basal energy expenditure, coupled with increased nitrogen excretion (Dvorak et al., 2004; Kaufman et al., 1985; Kearns et al., 1992; Laven et al., 1989; Rodriguez et al., 1991, 1997). Patients also suffer anorexia and weight loss, as well as depletion of biochemical nutritional markers (Kaufman et al., 1985; Kearns et al., 1992; Laven et al., 1989).

A systematic review was undertaken to determine the optimal nutritional approach for patients in the acute stage of SCI. Three clinically-relevant questions regarding nutritional management of patients following acute SCI were used to guide this systematic review:

1. Is there evidence of metabolic abnormalities that warrant specific nutritional protocols following SCI?
2. What methods for evaluating metabolic demands are most applicable to SCI patients?

3. What is the optimal route for administration of nutritional requirements following SCI?

Methods

Search strategy

A primary literature search was performed using PubMed for articles that address nutritional status and SCI. The following terms were used in the search: "dietary," "nutrition," "nutrient or food," "vitamins," "dietary supplements," and "diet." These terms were paired with the following: "SCI," "spinal cord injuries," and "spinal cord injury," as well as the MeSH term "Spinal Cord Injuries." The search was limited to articles written in the English language and involving human subjects. Articles excluded were: any dealing with chronic SCI (rehabilitation site or >3 weeks post-injury); any single-case report (case series were allowed); any review article more than 20 years old; and those with a mixed trauma population where the majority of patients were not those with SCI. Current reviews were read and further articles were identified.

Article review process

Relevant articles from the literature search were rated by two independent reviewers according to Downs and Black scoring (Downs and Black, 1998). Any variance in the scoring between the two reviewers was addressed by a third

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reviewer. Data were presented to the Spinal Cord Injury Solutions Network (Acute Practice Network), and subjected to a modified Delphi review process to establish an expert consensus to address the guiding questions.

Results

In all, 506 articles were returned by the search. Abstracts were screened, and 13 met inclusion/exclusion criteria. The relevant articles were then rated according to Downs and Black criteria (Table 1).

Question 1: Is there evidence of metabolic abnormalities that warrant specific nutritional protocols following SCI?

Several studies have demonstrated that there are specific metabolic abnormalities that affect the acute stage of SCI. There is an obligatory negative nitrogen balance (NB) in these patients in spite of aggressive nutritional support (Kaufman et al., 1985; Laven et al., 1989; Rodriguez et al., 1991; Rodriguez et al., 1997). This negative NB persists for up to 2 months post-injury (Rodriguez et al., 1991). Some patients do demonstrate a positive NB in the first week post-injury; however, this is thought to be a delay in protein losses rather than a true incorporation of protein into body stores (Rodriguez et al., 1997). Patients show nutritional depletion based on several measures: anthropometric, biochemical, and NB (Kaufman et al., 1985; Kearns et al., 1992). Poor appetite is common among patients with acute SCI; average oral intake has been reported at 848 kcal (Kaufman et al., 1985; Laven et al., 1989). Significant weight loss is observed between 2 and 4 weeks post-injury (Kearns et al., 1992; Laven et al., 1989). Plasma levels of biochemical indicators, such as albumin, transferrin, creatinine, carotene, folate, and ascorbate, have been shown to decline post-injury (Kaufman et al., 1985; Kearns et al., 1992; Laven et al., 1989).

Question 2: What methods for evaluating metabolic demands are most applicable in SCI patients?

Biochemical and anthropometric testing may be useful in the assessment of metabolic demands (Dvorak et al., 2004; Kaufman et al., 1985; Laven et al., 1989). Predictive equations, such as the Harris-Benedict equation, have been used to determine a patient's predicted energy expenditure (PEE) in order to set a caloric target. Activity and stress factors are used to improve the equation's accuracy for specific clinical situations. However, there is variation within the SCI literature with respect to the value assigned by different studies to both the stress and activity factors. One study reviewed omitted the activity factor (Kolpek et al., 1989), while others used 1.1 (Barco et al., 2002; Kaufman et al., 1985), or 1.2 (Rodriguez et al., 1991, 1997). The stress factor, which is more consistently used, ranges from 1.2 to as high as 1.6 in some studies (Kaufman et al., 1985; Rodriguez et al., 1991, 1997). However, serial metabolic cart measurements (indirect calorimetry) reveal that basing patient nutritional management upon these higher stress and activity factors may result in overfeeding of patients (Rodriguez et al., 1997). Barco and colleagues incorporated an activity factor of 1.1 and a stress factor of 1.2, and found a strong correlation between measured and predicted energy expenditures (Barco et al., 2002). This study examined

a relatively homogeneous population of only ventilator-dependent C1- to C7-level injuries; however, studies of chronic SCI patients suggest that the level of injury plays a significant role in the caloric requirements of this population (Mollinger et al., 1985). This may further complicate equation-based prediction of nutritional needs; similarly, the completeness of the injury may play a role in metabolic responses (Rodriguez et al., 1997).

Question 3: What is the optimal route for administration for nutritional requirements following SCI?

Dysphagia is a common issue following SCI, particularly with higher-level injuries (Abel et al., 2004; Wolf and Meiners, 2003). Poor appetite, dysgeusia, and dysosmia can also present a challenge post-injury (Laven et al., 1989). Percutaneous endoscopic gastrostomy (PEG) insertion may provide a safe alternative with low complication rates in patients unable to tolerate an oral diet. In their case series, Frost and colleagues reported two complications among 11 patients who received a PEG: one incidence of aspiration, and one patient who needed a jejunostomy due to poor absorption (Frost et al., 1995).

An organized nutritional protocol (supplemental parenteral nutrition to meet defined energy requirements is initiated if not tolerating an enteral diet) significantly decreases the likelihood of upper GI bleeding, and allows patients to reach total energy requirements nearly threefold faster (Kuric et al., 1989). Although enteral feeding has historically been delayed in SCI patients secondary to concerns about ileus and other complications, studies have found that feeding these patients within the first 72 h is safe (Dvorak et al., 2004; Rowan et al., 2004).

Discussion

Unlike other trauma patients, such as those with traumatic brain injury, burns, or multi-trauma, patients with SCI do not demonstrate hypermetabolism following injury (Kearns et al., 1992; Kolpek et al., 1989; Rodriguez et al., 1991, 1997). Although these patients exhibit a negative NB, this negative balance is obligatory, and attempts to correct it by increasing caloric intake may result in overfeeding. Overfeeding carries its own risks, including hypercapnia, hyperglycemia, uremia, and hypertriglyceridemia (Todd et al., 2008), and should be avoided. Nutritional requirements have traditionally been estimated through the use of the Harris-Benedict equation; however, it can be difficult to accurately estimate the needs of any one individual through equations alone (da Rocha et al., 2006), and no predictive equation has been established for this patient population. One study of ventilator-dependent patients (Barco et al., 2002) did find a close correlation between predicted and measured energy expenditure using low activity and stress factors; however, the authors still recommend serial metabolic monitoring, when available, to account for variability between individuals (Barco et al., 2002). Likewise, Young and associates used indirect calorimetry on four acute, ventilated quadriplegic patients and found that measured energy expenditure was 97 % of the expenditure predicted by the Harris-Benedict equation, without inclusion of an injury activity factor (Young et al., 1987). However, indirect calorimetry may provide a more accurate reflection of the patient's caloric requirements, particularly in a more heterogeneous SCI population, and could prevent overfeeding in

TABLE 1. RESULTS OF THE LITERATURE SEARCH

Authors	Title	Study type	Downs and Black score	Methods	Outcome	Notes
Rodriguez et al., 1991	Obligatory negative nitrogen balance following SCI	Experimental non-randomized controlled trial	14	Cervical and thoracic level SCI. Nutritional needs calculated: PEE = BEE $\times$ 1.2 (activity factor) $\times$ 1.6 (stress factor for trauma). Protein based on 2 g protein/kg ideal body weight. Total nutritional support instituted within 72h of admission. Changes in nutrient delivery were based on nitrogen balances and metabolic cart measurements.	No SCI patient was able to achieve and maintain positive NB during the 7-week period following injury. Two SCI patients had positive NB in the early post-injury period (+3 on day 4 negative NB at weeks 2 and 3. Increases in caloric and protein intakes above needs were attempted in all 10 patients to ensure that negative NB was not due to unaccounted-for hypermetabolic states. After the third week, NB became progressively less negative, until positive (average) NB was achieved at 2 months post-injury. Positive NB was reached in the control group by week 3 in 17/20 patients.	Case report within article: 22 year old with traumatic brain injury (TBI), blunt rupture thoracic aorta, and lumbar spine fracture (no neurological deficit). Aggressive nutritional support and positive NB. Suffered SCI during surgery to stabilize lumbar spine; developed negative NB in spite of increases in previously adequate amounts of protein and calories.
Frost et al., 1995	The role of percutaneous endoscopic gastrostomy in spinal cord injured patients	Observational	24	PEG inserted, complication rates determined.	No serious complications. Gastrostomy occasionally became blocked and required flushing with water. One patient aspirated and required a jejunal tube. Another patient needed jejunal tube due to poor absorption. No inflammation at PEG site (checked daily). Two patients died; cause of death unrelated to gastrostomy. Median time of PEG feeding was 11.5 weeks. Median time PEG <i>in situ</i> 15.6 weeks.	
Kuric et al., 1989	Nutritional support: A prophylaxis against stress bleeding after spinal cord injury	Observational	25	Paraplegic and tetraplegic SCI. Group 1 (first 15 months of study): started on oral diet "when clinically ready." Group 2 (subsequent months): nutrition protocol if unable to tolerate oral diet by hospital day 4, central line inserted. TPN started on day 5: 25% glucose, 4.25% amino acid @ 50 mL/h up to 125 mL/h within 24-48 h, intralipid 20% 3 times per week. If oral or NG could not be instituted by day 17, or patient required surgery for other reasons and appeared unable to tolerate feeding in the near future, jejunostomy was placed. Both groups: cimetidine, NG suction, hourly pH with gastric acid neutralization if pH < 5.0. Calories = BEE $\times$ activity factor (not specified) $\times$ 1.35 (skeletal trauma factor).	5/66 patients in group 1 developed severe acute ulceration versus 2/100 group 2 patients ($p < 0.05$). All 7 who developed severe acute ulceration had cervical injury with major neurological deficit. Group 1 reached total energy requirements (TER) at 15.5 $\pm$ 11.48 days; group 2 reached TER at 4.6 $\pm$ 5.6 days. Group 1 was on cimetidine 14.0 $\pm$ 8.83 days; group 2 for 11.0 $\pm$ 10.00 days. Group 1 needed antacid therapy 16.0 $\pm$ 10.63 days; group 2 needed antacid 6.0 $\pm$ 3.96 days ($p < 0.05$). Group 1 needed NG suction 13.4 $\pm$ 8.6 days; group 2 needed NG suction 3.3 $\pm$ 4.00 days ($p < 0.05$).	

(continued)

TABLE 1. CONTINUED

Authors	Title	Study type	Downs and Black score	Methods	Outcome	Notes
Laven et al., 1989	Nutritional status during the acute stage of SCI	Observational	23	Nutritional status of acute tetraplegic and paraplegic SCI patients examined using anthropometric measures, nutritional assays (energy and protein intake), biochemical assays (vitamin and nutrient levels), grip strength, and incidence of secondary medical complications.	57% report poor appetite 2 weeks after injury; declined to 29% after 8 weeks. 14% report dysgeusia and 22% report dysosmia 2 weeks after injury. Significant weight loss (-4.37 ± 9.45 ; $p < 0.05$) occurred between 2 and 4 weeks. Weight loss also occurred between 4 and 8 weeks post-injury but was not significant (-0.86 ± 4.42 ; $p > 0.05$). Mean values for plasma albumin, carotene, folate, and ascorbate, as well as erythrocyte folate, were lowest 2 weeks after injury and improved thereafter. Vitamin B ₁₂ was unusually high at 2 weeks but declined substantially thereafter. Other nutrient levels remained constant over time. Complications in the first 2 weeks: bacteriuria (35%), pleurisy (10%), pneumonia (6%), post-operative wound infections (6%), septicemia (4%), and decubitus ulcers (2%). Complications between 2 and 4 weeks: bacteriuria (54%), pneumonia (8%), pleurisy (4%), post-operative wound infections (4%), septicemia (4%), decubitus ulcers (4%), pleurisy (2%), and septicemia (2%). Between 4 and 8 weeks 4% developed pneumonia. No consistent associations between incidence of specific secondary complications and measures of nutritional status. Low plasma folate associated with less hand grip strength (36.3 ± 10.1 kg versus 48.9 ± 8.8 kg; $p = 0.027$). Plasma folate level not associated with maximal inspiratory pressure or maximal expiratory pressure. Creatinine levels not correlated with estimates of protein intake.	Study suggests 1500 kcal/d may be sufficient to prevent nutrition-related complications.
Dvorak et al., 2004	Early versus late enteral feeding in patients with acute cervical SCI	Randomized controlled trial	37	Tetraplegic (C2 to T1 level). Early group: NG feeding initiated within first 72 h post-injury; late group NG feeding initiated more than 120 h after injury. For both groups energy requirements were calculated using the Harris-Benedict equation. Dietitian estimated stress factor based on patient's condition; varied up to 1.5. Protein requirements estimated and	Early group: mean 2.4 ± 1.5 infections; late group 1.7 ± 1.1 infections. Most were pulmonary infections (10 per group). Transferrin level was mean 137 ± 44 mg/dL in early group, 145 ± 38 mg/dL in late group on day 5. Day 14 transferrin level 178 ± 28 mg/dL in late group; 39 feeding complications early group, 59 late group. Duration of ventilation in early group was	

varied from 1.0–1.3 g/kg protein.

Tetraplegic and paraplegic patients. Nutritional support: 2 g protein/kg ideal body weight. Calories PEE = BEE $\times$ 1.2 (bedrest) $\times$ 1.6 (trauma); instituted within 48 h of admission; TPN converted to tube feeding as early as patient gut function allowed.

762.8 $\pm$ 846.3 h; in late group was 502.1 $\pm$ 347.3 h. Length of stay in early group was 53.0 $\pm$ 34.4 days; in late group was 37.9 $\pm$ 14.6 days.

First week 5 patients had negative NB; 4 had positive NB; 1 had balance of 0.0. Second week: 7 had negative NB; 1 had positive NB. Third week: 9 had negative NB; 0 had positive NB. Fourth week: 2 had negative NB; 1 had positive NB. During weeks 1 and 2, the measured energy expenditure was lower than the PEE in the majority of patients. A single patient with motor complete myelopathy demonstrated similar metabolic response to trauma as did those with complete myelopathies. Patient with motor incomplete myelopathy manifested a "quite different" metabolic response (positive NB except for week 3). Average daily calorie intake was 848 kcal (38% of expected needs). NB was negative to a greater extent than expected and persisted for 10 days. Initial assessment (within 4 days of admission): 1 normal, 3 mild depletion, 2 moderate depletion, 2 severe depletion. Second assessment (within 4 days from 10th day of admission): 1 had mild, 3 had moderate, 3 had severe depletion. 3 patients did not change categories between assessments, 2 declined 1 category, and 2 declined 2 categories. Albumin, transferrin, and creatinine height index declined between assessments (3.4 $\pm$ 0.5 to 2.9 $\pm$ 0.4, 229 $\pm$ 37 to 190 $\pm$ 71, 106 $\pm$ 19 to 95 $\pm$ 24, respectively); total lymphocyte count rose (1096 $\pm$ 474 to 1533 $\pm$ 856). 82% were commenced on enteral feeding; enteral feeding was commenced on day 2 (median), and patients were fed a median of 7.7 days during their ICU stay; 25 were commenced on NG and 2 were later converted to NJ; 2 were commenced on NJ due to

Nutritional assessment carried out within 4 days of admission and within 4 days from 10th day after admission: NB, anthropomorphic measurements (weight, skin triceps fold, arm muscle circumference); lab tests: serum albumin, serum transferrin, creatinine height index, total lymphocyte count, skin antigen testing. Patients graded as mildly depleted if any test abnormal; graded as moderately to severely depleted if tests within pre-defined range. Length of stay on respirator; infection rates measured.

Data collected regarding enteral feeding and reasons for interrupting feeding for all patients admitted to the intensive care unit (ICU) with spinal cord transection resulting in paraplegia or tetraplegia.

The metabolic response to SCI

Rodriguez et al., 1997

22

Experimental non-randomized controlled trial

Observational

19

General metabolism in patients with acute paraplegia and quadriplegia

Kaufman et al., 1985

Is early enteral feeding safe in patients who have suffered SCI?

Rowan, et al., 2004

27

Retrospective chart review

TABLE 1. CONTINUED

<i>Authors</i>	<i>Title</i>	<i>Study type</i>	<i>Downs and Black score</i>	<i>Methods</i>	<i>Outcome</i>	<i>Notes</i>
Wolf et al., 2003	Dysphagia in patients with acute cervical spine injury	Experimental non-randomized controlled trial	31	Performed fiberoptic endoscopic examination of swallowing (FEES) on patients with cervical SCI. 5 levels of respiratory/feeding treatment, depending on level of dysphagia.	<p>high gastric aspirate. 23/27 were transferred from ICU on enteral feeding. 6 patients were not started on enteral feeds: 4 on oral, 1 had ileus, and 1 transferred to another hospital. Feeds were interrupted a median of twice (range 0–20 times); most frequently for high aspirates, followed by attempts at oral diet and diagnostic procedures. 1 patient's feeding was interrupted due to ileus and failure to absorb the feeding. This patient was switched to NJ 4 days after ileus onset, and there were no further interruptions. Another patient was unable to absorb the feeding, was switched to NJ 1.5 days after NG feeding started, and similarly had no further complications. 10 (37%) of patients did not have their feeding interrupted for high gastric aspirate; 10 (37%) were interrupted only once or twice. Only 3 patients had their feeding interrupted >4 times for high aspirate.</p> <p>On admission, 21/51 had severe dysphagia (levels 1–3), 20 had mild dysphagia, 10 had none detected. One patient had subglottic stenosis of the trachea with fixed vocal cords, one had post-operative unilateral vocal cord palsy, two had luxations of arytenoid cartilage. 27/51 had repeated FEES at 4- to 6-week intervals (either because initial dysphagia level 1–3, or because proven aspiration in patient with initial dysphagia level 4). Only 3 patients retained severe dysphagia with danger of substantial aspiration (one of whom had cranial nerve palsy secondary to a brainstem lesion). No significant relationship between level of SCI and level of dysphagia at admission. At outcome, small but highly significant relationship between SCI level and dysphagia level. Age not significantly</p>	

associated with level of dysphagia. On admission, 40/51 were fed exclusively via NG or PEG. At outcome, 40/48 had exclusively oral diet, 8 had a PEG. 1 was exclusively fed via PEG, while 7 of those with PEG were partly fed orally (2 due to level 3 dysphagia; 5 had no dysphagia but oral diet had to be supplemented.) 40 patients fed exclusively via NG or PEG on admission; after therapy, 40 completely on oral diet, 8 had PEG but only 1 was completely dependent with level 2 dysphagia (remaining 7 had partly oral diet; 2 had level 3 dysphagia, 5 had no dysphagia but oral diet had to be supplemented).

Abel et al., 2004	Dysphagia in patients with acute SCI	Observational	29	<p>Dysphagia screening done with questionnaires and tests on tetraplegic and quadriplegic patients with clinically complete cord transection; those with suspected dysphagia followed by speech therapist and underwent dye tests (if tracheal tube) or swallowing studies. Patients were classified according to severity, phase of impaired swallowing, and dietary restrictions. Adequacy of deglutition at discharge noted. Incidence of pneumonia and duration of orotracheal intubation determined.</p>
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Duration of oral intubation significantly shorter than nasal intubation (mean 5.7 versus 14.4 days; $p = 0.015$). Duration of orotracheal intubation prior to tracheal tube placement: 10.0 days for patients without dysphagia, 16.9 days for patients with dysphagia ($p > 0.05$). Duration of orotracheal intubation for patients not being tracheostomized: 3.9 days for patients without dysphagia, 8.3 days for patients with dysphagia ($p > 0.05$). Tracheostomy closure was median 88 days (inter-quartile range 81) after tracheostomy, and median 67 days (inter-quartile range 86) after stopping mechanical ventilation. Of 33 patients with tracheostomy, 3 died, 4 remained respirator-dependent, and 1 had recurrent pulmonary aspiration requiring prolonged endotracheal suctioning. Mean time between end of mechanical ventilation and tracheostomy closure significantly longer in patients with dysphagia (106.4 days versus 188.5

(continued)

TABLE 1. CONTINUED

Authors	Title	Study type	Downs and Black score	Methods	Outcome	Notes
						<p>days; $p < 0.05$). Anterior approach to cervical spine surgery not significantly correlated with dysphagia (Pearson $\chi^2 = 0.67$; $p = 0.42$). However, there was no patient with dysphagia who had neither a tracheostomy nor anterior approach to surgery, and a forward stepwise logistical regression model suggested that the combination may increase the risk for dysphagia. Halo fixation was not associated with dysphagia. 3/4 patients with ankylosing spondylitis with rigid cervical spine needed a tracheostomy and had severe dysphagia. 31/73 patients had no pneumonia symptoms; 24/73 had one episode (22 early, 6 late); 6 had one early and one late episode; 11 had early plus multiple late episodes of pneumonia. Incidence of late or multiple episodes of pneumonia 58% for those with dysphagia versus 9% for those without (Pearson $\chi^2 = 24.5$, $df = 4$; $p < 0.01$). Dysphagia necessitated dietary restrictions in the texture of foods or solid food for 18 of 26 patients with swallowing pathology. Oral phase problems required dietary modifications more often than pharyngeal alone ($p = 0.044$). 10 pts needed PEG. 4 died, 2 due to recurrent pneumonia. At time of discharge 9/22 had resolved (all oral phase problems), 7 had persistent problems, 5 with pharyngeal phase problem and 2 with combined oral + pharyngeal; none on dietary restrictions (hypervigilant while swallowing). 6 had persistent dysphagia and discharged with PEG.</p>

Keams et al., 1992	Nutritional and metabolic response to acute spinal cord injury	Observational	25	<p>C4-T10 SCI. Initial assessment including Abbreviated Injury Scale. Weekly nutritional exams including weight were done for 4 weeks or until the flaccid phase of acute SCI began to resolve (as evidenced by return of patellar reflex); 72-h calorie intake calculated weekly; biochemical analyses done including albumin and calcium.</p>	<p>Serum albumin increased over the course of the study from 31 ± 1 to 34 g/dL ($p < 0.05$), despite negative NB. Serum calcium increased from 2.12 ± 0.1 to $2.36 \pm 0.14 \text{ mEq/L}$ ($p < 0.01$). Cumulative weight loss was $7.0 \pm 0.6 \text{ kg}$. Basal energy expenditure $1683 \pm 65 \text{ kcal/d}$. Resting energy expenditure 1523 ± 109, did not change significantly over course of study. Negative fluid balance first 2 weeks of study. Urinary calcium:creatinine ratio = upper limits of normal at baseline, but by week 3, 8 of 10 patients had hypercalciuric ratios, in spite of increases in creatinine excretion. Ratio significantly higher in quadriplegics than tetraplegics. Urinary 3-methylhistidine significantly elevated at baseline and remained elevated at week 4. Total nitrogen excretion was highest at baseline, and remained elevated throughout the study, but fell significantly ($p < 0.05$ versus week 0) at week 3. NB remained negative throughout.</p>
Barco et al., 2002	Energy expenditure assessment and validation after spinal cord injury	Experimental non-randomized controlled trial	23	<p>Ventilator-dependent SCI patients with isolated SCI evaluated. PEE determined using Harris-Benedict equation with 1.1 activity factor and 1.2 injury factor. Patients fed either enterally or parenterally; nutritional support adjusted based on indirect calorimetry measure expenditure. Urinary urea nitrogen, NB, nutrient intake, respiratory quotient, and pre-albumin levels were measured.</p>	<p>Mean measured energy expenditure was 95–100% of PEE. Predicted and measured energy expenditure were significantly correlated at each data point ($r = 0.74$–0.79; $p < 0.05$). NB was negative over all 4 study weeks. Pre-albumin improved significantly over the study period ($p < 0.001$). Mean body weight decreased by 9% over the study period (predictive equation not adjusted).</p>
Kolpek et al., 1989	Comparison of urinary urea nitrogen excretion and measured energy expenditure in spinal cord injury and nonsteroid-treated severe head trauma patients	Observational	25	<p>SCI pts receiving enteral or parenteral nutrition studied; prospectively studied; matched with TBI for sex, age, and weight. Indirect calorimetry performed biweekly where possible. Daily protein and caloric intake measured, 24-h urinary urea nitrogen collected, and NB determined. PEE was determined using the Harris-Benedict equation without an activity factor (not specified whether stress factor was used).</p>	<p>Although SCI pts were fed less than TBI pts (mean $0.8 \pm 0.07 \text{ g/kg/d}$ protein and 18.5 ± 1.3 non-protein kcal/kg/d, and mean $1.1 \pm 0.07 \text{ g/kg/d}$ protein and 26.7 ± 1.4 non-protein kcal/kg/d, respectively), they achieved total caloric balance ($177 \pm 969 \text{ kcal}$), while the TBI pts had a negative overall caloric balance ($-358 \pm 1222 \text{ kcal}$). Measured energy expenditure for SCI patients was 56% of PEE in week 1. Over the course of the 3-week study period, measured energy expenditure was 94% of PEE for SCI, but was 48% higher than PEE for TBI. Both SCI and TBI had higher-than-normal nitrogen excretion, and both were in negative NB over the study period.</p>

BEE, basal energy expenditure; PEE, predicted energy expenditure; SCI, spinal cord injury; NB, nitrogen balance; PEG, percutaneous endoscopic gastrostomy; TPN, total parenteral nutrition; NG, nasogastric; Nf, nasojejunal; PEDro, Physiotherapy Evidence Database (de Morton, 2009).

many cases by allowing adjustments of intake based on measured energy expenditure rather than predicted energy expenditure (Dvorak et al., 2004; Rodriguez et al., 1997). This technology holds promise but further study is required.

Although the optimal route of nutritional support has not been studied specifically in SCI patients, several studies of trauma populations have shown that enteral feeding is preferable to the parenteral route, as it produces a lower incidence of infectious complications and hyperglycemia (Gramlich et al., 2004; Kudsk et al., 1992). The preferred initial route for enteral feeding in critically ill patients is nasogastric (NG); patients who do not tolerate NG feeding as evidenced by either by vomiting or by high residual volumes (250 ml more than the amount delivered since the last gastric aspirate) should proceed to the nasojejunal (NJ) route (Davies et al., 2002). If the patient requires gastric feeding tube placement, percutaneous endoscopic gastrostomy (PEG) is the preferred method for trauma patients (Dwyer et al., 2002).

Systematic review recommended answers to clinical questions

Is there evidence of metabolic abnormalities that warrant specific nutritional protocols following SCI?

- Multiple studies document metabolic abnormalities following SCI, including an obligatory negative nitrogen balance.
- These patients have unique requirements mandating the development of specific treatment protocols.
- (*Recommendation strong, data moderate.*)

What methods for evaluating metabolic demands are most applicable in SCI patients?

- The use of indirect calorimetry to calculate measured energy expenditure will most accurately predict the patient's caloric needs.
- (*Recommendation weak, data weak.*)

What is the optimal route for administration for nutritional requirements following SCI?

- Enteral feeding is the optimal route for administration of nutritional requirements following SCI. When oral feeding is not possible, NG, followed by NJ, followed by PEG, if necessary, would be suggested. If enteral feeds do not meet the metabolic demands within 5 days of injury, total parenteral nutrition should be started to ensure adequate caloric intake.
- (*Recommendation strong, data weak.*)

Author Disclosure Statement

No competing financial interests exist.

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