Nutritional Support in the Critical Care Setting (Part 2)*

Rolando Berger, M.D., F.C.C.P.;† and Linas Adams, M.D.;‡

Oral and Tube Feeding

Oral feeding should be attempted first, if possible. Otherwise, if the GI tract is functional, tube feeding is easier, safer, and less expensive than parenteral nutrition.284–286 Enteral feeding may also allow better nutrient utilization.287–289 Help maintain mucosal integrity, and decrease the incidence of stress-induced hemorrhagic gastritis.282

Modern feeding tubes are made of nonreactive materials (e.g., polyurethane), have weighted tips to facilitate insertion, are less traumatic and more comfortable to the patient because of their small diameter, and may be safer than larger tubes.285–287 Representative examples include the Corpack Silk Nasogastric Feeding Tube (Corpack Co, about $10.50 each), the Kangaroo Enteral Feeding Tube (Sherwood Medical, about $11 each), and the Entriflex and Dobhoff Feeding Tubes (Biosearch Medical Products, about $12 and $16 each, respectively). Generally, a nasogastric or nasoenteral tube is adequate for a few weeks. If prolonged (> five weeks) or permanent support is necessary, a gastrostomy or jejunostomy is usually a better choice, especially since newer tubes can be placed percutaneously with simultaneous endoscopic visualization, thus avoiding a surgical procedure.285–287

An example of a decision-tree to help select the best type of nutritional support for a given patient is shown in Figure 1.

Formulas

Although there are several others, we favor the following classification of enteral feeding formulas.288

Polymeric Formulas

These are semi-isotonic or hypertonic solutions, most of which have a relatively high carbohydrate/fat ratio, contain intact or almost intact protein, are low in residue and sodium, and are usually lactose-free. Exceptions to the latter include Meritane (Sandoz), Sustacal, and Sustagen (Mead Johnson). Different caloric yields, protein contents, and proportions of fats are available, and daily vitamin and mineral requirements are provided (Table 1). These preparations are adequate for the majority of patients and relatively inexpensive. Since they are reasonably palatable, they can also be used for oral feeding.289,290

Oligomeric Formulas

These preparations are usually hyperosmolar. They contain oligopeptides or amino acids as protein and

![Decision Tree](image)

FIGURE 1. Example of a decision tree for selecting the type of nutritional support. The choice of gastric vs enteral placement of a feeding tube is based on several factors, but an essential consideration is whether the patient is thought to be at high risk for aspiration.

*From the Veterans Administration and University of Kentucky Medical Centers, Lexington.
†Director, Medical Intensive Care Unit, VAMC; Associate Professor of Medicine, Division of Pulmonary and Critical Care Medicine.
‡Staff Physicians, Gastroenterology Section; Assistant Professor of Medicine, Division of Nutritional and Digestive Diseases.
Part 1 appeared in the July, 1989 issue of Chest. Reprint requests: Dr. Berger, VA Medical Center 111H, Lexington, KY 40502

372 Nutritional Support in Critical Care (Berger, Adams)
oligosaccharides or disaccharides as carbohydrates, and thus are easier to digest. Oligomeric formulas also contain all essential vitamins and minerals, but they taste bad and are more expensive than a nutrient-equivalent polymeric preparation. Their main use is during periods of digestive insufficiency, eg, after GI surgery or ileus, or for patients with special requirements, eg, hepatic or renal failure (Table 1).

**Modular Formulas**

For patients with very unusual requirements, "dietary modules" can be used to prepare custom-made feedings or to supplement a fixed-ratio preparation. Complete modular feeding, however, is expensive, requires expertise, and is seldom necessary. Examples of nutrition modules include: Polycose (Ross Laboratories), Sumacal (Sherwood Medical), and Moducal (Mead Johnson) for carbohydrates; Microlipid (Sherwood Medical) for fats; Casec (Mead Johnson), Propac (Sherwood Medical), and ProMed (Ross Laboratories) for proteins; and Nutrisource (Sandoz) for a complete line of modular feedings, including modules containing electrolytes, vitamins, and trace elements.

Regardless of type, proper administration of tube feeding is essential. Generally, continuous infusion is better tolerated than intermittent administration, may allow better nutrient utilization, and may decrease the risk of aspiration. Optimal continuous infusion, however, requires a feeding pump (eg, Kangaroo-330, Sherwood Medical, $400 to $500/ea) and so is more expensive. Further, to minimize the risk of aspiration, the patient should be kept sitting, semisitting, or with the head up at 30° and in the lateral decubitus position. This is impractical or impossible in some cases.

---

**Table 1—Composition of Common Tube-feeding Formulas**

<table>
<thead>
<tr>
<th>Formula</th>
<th>Calories, kcal/L</th>
<th>Fat, g/L</th>
<th>Carbohydrates, g/L</th>
<th>Protein, g/L</th>
<th>Osmolality, mOsm/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole milk</td>
<td>724</td>
<td>41</td>
<td>49</td>
<td>33</td>
<td>277</td>
</tr>
<tr>
<td>Eggsoy</td>
<td>1,160</td>
<td>33</td>
<td>146</td>
<td>58</td>
<td>480</td>
</tr>
<tr>
<td>Complete regular</td>
<td>1,071</td>
<td>43</td>
<td>128</td>
<td>43</td>
<td>405</td>
</tr>
<tr>
<td>Vitaneed formula</td>
<td>1,000</td>
<td>40</td>
<td>125</td>
<td>35</td>
<td>310</td>
</tr>
<tr>
<td>Standard polymeric feeding formulas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure</td>
<td>1,057</td>
<td>37</td>
<td>144</td>
<td>37</td>
<td>450</td>
</tr>
<tr>
<td>Ensure-Plus</td>
<td>1,497</td>
<td>53</td>
<td>200</td>
<td>55</td>
<td>600</td>
</tr>
<tr>
<td>Ensure-Plus HN*</td>
<td>1,502</td>
<td>50</td>
<td>200</td>
<td>63</td>
<td>650</td>
</tr>
<tr>
<td>Isocal</td>
<td>1,060</td>
<td>44</td>
<td>132</td>
<td>34</td>
<td>300</td>
</tr>
<tr>
<td>Isocal HCN*</td>
<td>2,019</td>
<td>91</td>
<td>225</td>
<td>75</td>
<td>660</td>
</tr>
<tr>
<td>Magnacal</td>
<td>2,000</td>
<td>80</td>
<td>250</td>
<td>70</td>
<td>590</td>
</tr>
<tr>
<td>Meritene</td>
<td>970</td>
<td>30</td>
<td>115</td>
<td>60</td>
<td>560</td>
</tr>
<tr>
<td>Osmolite</td>
<td>1,061</td>
<td>37</td>
<td>145</td>
<td>37</td>
<td>300</td>
</tr>
<tr>
<td>Sustacal</td>
<td>1,011</td>
<td>23</td>
<td>140</td>
<td>61</td>
<td>630</td>
</tr>
<tr>
<td>Sustacal HC*</td>
<td>1,526</td>
<td>58</td>
<td>190</td>
<td>61</td>
<td>650</td>
</tr>
<tr>
<td>Trasavorb</td>
<td>1,060</td>
<td>37</td>
<td>144</td>
<td>37</td>
<td>468</td>
</tr>
<tr>
<td>Oligomeric and low-residue formulas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexical</td>
<td>1,006</td>
<td>34</td>
<td>153</td>
<td>22</td>
<td>550</td>
</tr>
<tr>
<td>Precision Isotonic</td>
<td>982</td>
<td>30</td>
<td>144</td>
<td>29</td>
<td>300</td>
</tr>
<tr>
<td>Precision LR*</td>
<td>1,110</td>
<td>1.6</td>
<td>248</td>
<td>26</td>
<td>530</td>
</tr>
<tr>
<td>Precision HN*</td>
<td>1,052</td>
<td>1.3</td>
<td>216</td>
<td>44</td>
<td>525</td>
</tr>
<tr>
<td>Other oligomeric or predigested formulas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vivonex Standard</td>
<td>1,017</td>
<td>1.5</td>
<td>231</td>
<td>20</td>
<td>550</td>
</tr>
<tr>
<td>Vivonex TEN*</td>
<td>1,000</td>
<td>2.8</td>
<td>206</td>
<td>38</td>
<td>630</td>
</tr>
<tr>
<td>Vivonex High Nitrogen</td>
<td>1,033</td>
<td>1</td>
<td>210</td>
<td>46</td>
<td>810</td>
</tr>
<tr>
<td>Pulmocare</td>
<td>1,500</td>
<td>92</td>
<td>106</td>
<td>63</td>
<td>490</td>
</tr>
<tr>
<td>Amin-aid</td>
<td>1,954</td>
<td>46</td>
<td>366</td>
<td>19</td>
<td>700</td>
</tr>
<tr>
<td>Hepatic-Aid II</td>
<td>1,172</td>
<td>36</td>
<td>168</td>
<td>44</td>
<td>560</td>
</tr>
<tr>
<td>Trasavorb Hepatic</td>
<td>1,084</td>
<td>14</td>
<td>213</td>
<td>28</td>
<td>690</td>
</tr>
<tr>
<td>Trasavorb Renal</td>
<td>1,335</td>
<td>18</td>
<td>271</td>
<td>23</td>
<td>590</td>
</tr>
<tr>
<td>Trauma-aid HBC*</td>
<td>1,000</td>
<td>12</td>
<td>166</td>
<td>56</td>
<td>760</td>
</tr>
<tr>
<td>Stresstain</td>
<td>1,212</td>
<td>26</td>
<td>170</td>
<td>70</td>
<td>910</td>
</tr>
<tr>
<td>Criticare HN*</td>
<td>1,067</td>
<td>3</td>
<td>222</td>
<td>38</td>
<td>650</td>
</tr>
<tr>
<td>Reshilan</td>
<td>1,000</td>
<td>39</td>
<td>131</td>
<td>32</td>
<td>300</td>
</tr>
<tr>
<td>Reshilan HN*</td>
<td>1,330</td>
<td>52</td>
<td>158</td>
<td>58</td>
<td>490</td>
</tr>
</tbody>
</table>

*Approximate caloric density and nutrient composition are given. All commercial formulations provide the daily requirements of vitamins and minerals in a mean volume of 1,800 ml; range, 950-3,000 ml. (Source: product information insert; references 15,95, and 254). HN = high nitrogen, HC-high calorie, HCN = high calorie, high nitrogen, LR = low residue, TEN = total enteral nutrition, HBC = high branch chain.
Intermittent administration of feedings, every 3 to 6 h, each over 30 to 60 min, is a reasonable alternative to continuous infusion. This approach is less expensive, more convenient, and better simulates a normal feeding pattern, but the incidence of intolerance and complications may be higher. Thus, using small boluses and a slow infusion rate is recommended, as well as keeping the patient in a head-up position for 1 to 2 h after each feeding.

Tube feeding is usually started with 25 to 50 ml of formula diluted to ½ or ¾ strength. If tolerated, the formula’s concentration is gradually increased before increasing the volume or rate of feeding. If preferred, the volume or rate of infusion can be increased first, especially if a duodenal or jejunal tube is being used. In either case, supplemental oral intake, if possible, should be encouraged. Finally, prolonged (days) or frequent interruptions of tube feedings must be avoided. If this is not possible, supplemental parenteral nutrition should probably be considered (Fig 1) to avoid building a larger nutritional deficit.

**Complications**

Unfortunately, gastric or enteral tube-feeding is not free of many types of complications.

**Mechanical Complications**

These include knotting or clogging of the tube, improper tube placement (most commonly in the bronchial tree), epistaxis, nasopharyngeal erosions and discomfort, sinusitis, otitis, gagging, esophageal reflux and esophagitis, tracheoesophageal fistulas, and ruptured esophageal varices. Gastrostomy or jejunostomy tubes, on the other hand, can cause pyloric or intestinal obstruction. Finally, nasogastric or nasoenteral tubes are not recommended for patients with known or suspected cribiform plate fracture because of the risk of tube placement within the cranial vault. Of course, in any patient tube feedings should not be started until proper tube placement is confirmed.

**Nausea and Vomiting**

Nausea and vomiting occur in 10 to 20 percent of all orally or tube-fed patients. Common causes include the formula’s odor, consistency, or taste; a fast rate of infusion; large volumes; fat or lactose intolerance; hyperosmolality; and delayed gastric emptying. The management of most of these problems is self-evident. Metoclopramide (Reglan, A.H. Robins) can be used to treat delayed gastric emptying or to facilitate the transpyloric passage of a feeding tube.

**Aspiration**

Partly because of differences in patient population and/or study design, aspiration has been reported to occur in 1 to 40 percent of patients who are orally or tube fed. Time-honored recommendations to prevent it include feeding patients sitting or semisitting, keeping the endotracheal cuff inflated, measuring gastric residuals periodically, feeding by continuous infusion, and feeding beyond the pylorus. If recurrent “silent” aspirations are suspected, the tracheal aspirates can be tested for glucose, or methylene blue can be added to the feedings as a marker.

**Diarrhea**

Diarrhea develops in 10 to 25 percent of enterally fed patients. Although hypertonic feedings can cause osmotic diarrhea, the volume and rate of infusion are at least as important as the solution’s osmolality. Another potential cause of diarrhea, bacterial contamination, can be easily prevented by a few simple measures: (1) Wash hands before handling the feeding system. (2) Use clean equipment to prepare and mix feedings. (3) Change bag and tubing at least once a day. (4) Keep the “hanging time” of individual bags to under 6 h. (5) Keep prepared bags refrigerated until ready to use. Of course, hypocalbuminemia, changes in intestinal flora, and drug side effects are also common causes of GI problems in the ICU setting.

Most cases of feeding-induced diarrhea can be managed by eliminating or reducing problem nutrients (fats, lactose, gluten), by maintaining a reasonable osmolality and infusion rate, and/or by increasing the proportion of fats. Beyond these dietary manipulations, administering pectin is often sufficient, although very large doses may be needed in rare cases. Of course, fluid and electrolyte balance must be maintained throughout. If needed, other drugs can be used: diphenoxylate hydrochloride (Lomotil; Searle), camphorated opium (Paregoric, Roxane Laboratories) and loperamide (Imodium, Janssen). For antimicrobial-induced diarrhea pectin and cholestyramine (Questran, Bristol) may be preferred, but it must be remembered that cholestyramine interferes with the absorption of many medications, fats, and vitamins A, D, and K. Finally, in one study psyllium hydrophilic mucilloid (Metamucil, Proctor and Gamble) was effective in controlling diarrhea at an average dose of 7 g/L of feeding, but individual doses varied widely. Feeding formulas that include dietary fiber have become available, eg, Enrich and Jevity (Ross Laboratories).

**Metabolic Complications**

These include nutrient intolerance, and fluid and electrolyte imbalance. Close monitoring will identify these problems, but to prevent dehydration and hypokalemia additional free water should be given to patients receiving minimal or no IV fluids, especially...
if they have large insensible losses or are fed a mixture with relatively high sodium content.

**Nutritional Noncompliance**

Nutritional compliance must be monitored, since in a previous study patients were found to receive, on average, only 70 to 85 percent of the prescribed nutrients for a variety of reasons. For example, with continuous infusion, gastric residuals of 100 to 150 ml are not rare, but they have little clinical significance if the patient has normal bowel sounds and is not distended, in pain, regurgitating, or vomiting. However, finding such "high" gastric residuals often leads to frequent and unnecessary interruptions and/or manipulations of the feeding system. Thus, we agree with Bartlett's opinion that an occasional check of the gastric residual (eg, once preshift), is adequate for the clinically stable patient receiving continuous tube feeding.

**Drug Administration**

The subject of drug compatibility with feeding formulations has been reviewed recently, and pertinent examples include the decreased absorption of phenytoin (Dilantin, Parke-Davis) with continuous feeding and the decreased efficacy of warfarin (Coumadin, DuPont) with vitamin K-containing formulations. Useful general recommendations for administering drugs through a feeding tube include: (a) the tube should be flushed first with 30 ml of water; (b) if several drugs are needed, they should be given separately, flushing the tube after each one; (c) liquid formulations are best, and for some drugs it is possible to give parenteral preparations by the enteral route; (d) all tablets should be crushed to a fine powder, except those which are entericoated or sustained release; (e) hyperosmolar or irritant medications should be diluted.

**Parenteral Feeding**

Peripheral and central parenteral nutrition are similar, but the volume and concentration of nutrients that can be given through a small vein is somewhat limited. Thus, peripheral nutrition is not optimal for long-term maintenance or for meeting large nutritional needs (Fig 1), but it is well suited for short-term maintenance or for supplementing limited oral intake. Thus, it is not uncommon to administer IV lipids peripherally to seriously ill malnourished patients receiving oral or tube feedings, to deliver a higher proportion of fats without risking GI intolerance. However, there are no controlled studies definitely establishing the risk/benefit and cost/benefit ratio of routinely using this approach. Supplementing the oral/enteral diet of patients with poor intake or fat intolerance, however, is justified.

In most parenteral feeding protocols, dextrose and amino acid solutions are mixed, but lipids are infused separately (Table 2). Although modern lipid emulsions can be mixed with amino acids and dextrose solutions, this approach results in more frequent clogging of the IV catheter. Vitamins and minerals are added to the dextrose/amino acid mixture because a separate rapid infusion could result in the urinary loss of some vitamins. Depending on the specific feeding protocol being used, other nutrients may also be given: vitamin K (5 to 10 mg/week), folic acid (5 mg/week or 1 mg/day), iron (eg, Imferon, Fisons; 100 mg or 2 ml/week or 1-2 mg/day) and/or vitamin B12 (1 mg every one or two weeks).

To calculate caloric densities, it must be remembered that dextrose solutions have glucose as glucose-monohydrate, and thus yield 3.4 kcal/g. Similarly, since lipid preparations also contain phospholipids and glycerol, a 10 percent emulsion of triglycerides (100 g), for example, yields 1,100 kcal/L or 1.1 kcal/ml. Finally, the caloric density of amino acids solutions is assumed to be 4 kcal/g.

Parenteral nutrition must be used judiciously, since it is very expensive, and although potentially lifesaving, the advantages of this type of nutritional

---

**Table 2—Examples of Representative Total Parenteral Nutrition Formulations**

<table>
<thead>
<tr>
<th></th>
<th>Calories, kcal/L</th>
<th>Carbohydrates, g/L</th>
<th>Amino Acids, g/L</th>
<th>Calorie/Nitrogen Ratio†</th>
<th>Osmolality, mOsm/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Michigan‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral (PFN)</td>
<td>440</td>
<td>100</td>
<td>25</td>
<td>85:1</td>
<td>880</td>
</tr>
<tr>
<td>Standard-Central</td>
<td>1,090</td>
<td>250</td>
<td>42.5</td>
<td>127:1</td>
<td>1,825</td>
</tr>
<tr>
<td>Concentrated (cardiac)</td>
<td>1,360</td>
<td>350</td>
<td>42.5</td>
<td>178:1</td>
<td>2,325</td>
</tr>
<tr>
<td>Essential AA (renal)</td>
<td>830</td>
<td>350</td>
<td>15.7</td>
<td>476:1</td>
<td>1,935</td>
</tr>
<tr>
<td>VAMC/UKMC Lexington</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral (PFN)</td>
<td>510</td>
<td>100</td>
<td>42.5</td>
<td>50:1</td>
<td>1,100</td>
</tr>
<tr>
<td>Standard-Central</td>
<td>1,020</td>
<td>250</td>
<td>42.5</td>
<td>125:1</td>
<td>1,825</td>
</tr>
</tbody>
</table>

*Caloric density based on a yield of 3.4 kcal/g for glucose monohydrate and 4 kcal/g for crystalline amino acids. PFN = peripheral parenteral nutrition; AA = amino acids; UKMC = University of Kentucky Medical Center; VAMC = Veterans Administration Medical Center.

†The total calorie/nitrogen ratio would be greater because of additional lipid administration.

‡Adapted from the parenteral and enteral nutrition manual of the University of Michigan Medical Center, 4th ed. 1986. Courtesy of Drs. Robert H. Bartlett and John R. Wesley.
support are not definitely established in all cases.\cite{92,131,132,145,151,167,209,309} Furthermore, parenteral nutrition is plagued by complications due to improper placement of the central venous catheter, infections at or through the puncture site, or metabolic derangements secondary to parenteral feeding.

**Complications**

**Pneumothorax**

Complications from catheter insertion have been reported to occur in 1 to 15 percent of patients,\cite{270-272} mainly depending on the expertise of the operator.\cite{273-275} Pneumothorax is the most common complication (5 percent incidence) and is more likely to occur on the left side because the left pleural dome is higher. Other risk factors include mechanical ventilation, positive airway pressure, cachexia, obesity, and chest deformities. Late development of a pneumothorax\cite{276} can occur and may be suggested by the new onset of scapular or supravaculicular pain. Although a small asymptomatic pneumothorax could be observed or aspirated, because of the risk of tension pneumothorax, a closed-tube thoracostomy is often preferred, especially if mechanical ventilation is being used.\cite{277}

**Arterial Puncture**

Accidental puncture of a subclavian or carotid artery is not rare but often requires only digital pressure over the puncture site. However, significant bleeding can occur, especially in patients with coagulation abnormalities, including platelet dysfunction due to uremia, severe jaundice, or antiplatelet drugs. Rarely, surgical exploration and repair of a lacerated vessel may be necessary, or a "late" arteriovenous fistula or pseudoaneurysm may develop.\cite{278} Accidental injuries to the thoracic duct may result in a chylothorax and, obviously, this is the more common with attempts at venous cannulation done on the left side.

**Wrong Catheter Placement**

The most common type is directing a subclavian catheter into the neck, and this may be suggested by ipsilateral neck, auricular, or mandibular pain during catheter manipulation. This problem is more common on the right side because of the abrupt descent of the vena cava from the point of junction of the right subclavian vein. Potentially more serious is advancing the catheter into the cardiac chambers or a suprahepatic vein. Careful insertion technique, the use of shorter catheters, and an immediate postinsertion radiographic check will avoid or detect these problems. Of course, IV infusion should never be started until proper catheter position has been confirmed. A more dangerous complication is the perforation of a vessel and advancement of the catheter into the neck tissues, pleural space, mediastinum, or pericardium, resulting in a large hematoma, upper airway obstruction, hydro or hemo-pneumothorax, or pericardial tamponade.\cite{279}

**Phlebitis and Thrombosis**

Superficial phlebitis often occurs with peripheral parenteral nutrition because of the sclerosing effect of hypertonic dextrose and amino acid solutions. Thrombosis of a central vein (usually subclavian vein) is relatively rare but may be more likely to occur in patients with a "short" partial thromboplastin time or with low levels of antithrombin III.\cite{280,281} Adding heparin to the feeding solution (3,000 to 6,000 units/L) can prevent this complication.\cite{282}

**Infection**

Both bacterial and fungal infections are associated with parenteral feeding, occurring in 3 to 7 percent of patients.\cite{283,284} The most common organisms are *Staphylococcus aureus* and *Candida albicans*, respectively. Most cases are due to failure to preserve the sterility of the administration system, and only a few to contaminated solutions or a metastatic infection from a distant site.\cite{277,284,285} Thus, strict adherence to a protocol that ensures sterility during insertion, manipulation, and dressing changes, and using the feeding catheter exclusively for this purpose, are the two most important preventive measures,\cite{277,287} keeping premixed feeding solutions refrigerated or in a dark, cool place,\cite{288} and using an occlusive dressing, probably better if with a topical antiseptic or antimicrobial.\cite{289,290}

A particularly troublesome problem is the occurrence of unexplained fever in a patient receiving total parenteral nutrition, meaning that there is no known infectious source, the insertion site looks normal, and there are no positive blood cultures yet. Since the routine removal of the central catheter under these circumstances is unnecessary in over 75 percent of the cases,\cite{291,292} the approach described by Benotti and Bistrian\cite{293} is a reasonable compromise. When fever is first noted, blood cultures are obtained and the catheter is changed over a guide wire through the same insertion site.\cite{293,294,295} The removed catheter, and probably also the insertion site, should then be Gram stained and cultured.\cite{296} If the catheter is sterile and either the blood cultures are negative or an unrelated source of bacteremia is identified, a new insertion site is not needed.

**Hyperglycemia**

Hyperglycemia is often seen when nondiabetic critically ill patients are first given parenteral nutrition. The reasons for this response include: persistent gluconeogenesis, blunted insulin response, decreased tissue sensitivity to insulin, impaired peripheral utili-
zation of glucose, or phosphate or chromium deficiency, which further diminish tissue sensitivity to insulin. This type of hyperglycemia is usually transient and responds well to insulin, reduction of caloric intake, or substitution of some carbohydrates by a calorie-equivalent amount of fats. The late development of hyperglycemia in a stable patient, however, often heralds a new infection or complication.

**Hypoglycemia**

Hypoglycemia results from either a decreased or uneven infusion rate or, rarely, excessive insulin administration. Because parenteral feeding eventually induces relative hyperinsulinemia in most patients, discontinuation must be gradual (over 72 to 96 h) to avoid “rebound” hypoglycemia. For the same reason, a peripheral infusion of 10 or 20 percent dextrose should be started immediately if the central feeding infusion is suddenly stopped.

**Hyperlipidemia**

Usually triglyceride levels peak 4 h after IV infusion and are back to baseline in 6 to 8 h, but their clearance may be impaired in patients with liver disease or multiple-organ failure. Excessive or rapid infusion of lipids results in transient hyperlipidemia, which may interfere with some laboratory tests. Intravenous lipids may also worsen pulmonary function in some patients, but this is not well established and its clinical significance, if any, is unclear. In any case, confusing heparin (60 units/kg) will prevent transient hyperlipidemia and continuous rather than discontinuous IV administration of fat emulsions may be better in some cases. Finally, if lipids account for most or all of the daily calories, dilutional anemia and hyponatremia can develop due to increased endogenous production of water.

**Hepatic Dysfunction**

Abnormal liver function tests and fatty liver infiltration often develop with parenteral nutrition, especially if carbohydrate based, but almost never with enteral feeding. Fortunately, most cases are mild, self-limited, and require only a lower caloric intake or an increase in the proportion of fats. However, the administration of IV lipids has also been associated with liver function abnormalities. Severe and refractory cases should alert the clinician to the possibility of an unrelated cause of liver dysfunction, eg, sepsis, hepatitis, obstruction, or drug toxicity.

**Acid-Base Disturbances**

Hyperchloremia can develop from amino acid metabolism, but the resulting acidosis is usually mild, and most amino acid preparations contain acetate as buffer. Additional acetate can be given by using potassium and sodium acetate instead of chloride for the daily replacement of these electrolytes. Conversely, metabolic alkalosis can be seen with diuretic use, nasogastric suction, or corticosteroid therapy, if the concomitant replacement of chloride ions is inadequate. If sodium and potassium intake must be strictly restricted, significant hypochloremic alkalosis (pH >7.55 to 7.6) could rarely require the IV administration of hydrochloric acid.

**Electrolyte Imbalance**

Usually, sodium, potassium, chloride, and bicarbonate abnormalities are promptly detected and corrected in the ICU. The same may not be true of magnesium, calcium, and phosphorus. Hypophosphatemia is often seen when first starting parenteral nutrition after a period of semistarvation because of the additive effect of poor prior intake, increased glucose phosphorylation, and augmented intracellular transport of phosphates (which, with potassium, magnesium, and nitrogen, are the main components of lean tissue). Plasma phosphate levels below 0.5 to 0.3 mmole/L (1.5 to 1.0 mg/dl) can cause hemolysis, rhabdomyolysis, and may induce respiratory failure or hamper weaning attempts owing to impaired performance of respiratory muscles. Further, this abnormal muscle metabolism may persist for several days after adequate replacement. Other effects of hypophosphatemia include arrhythmias, decreased myocardial contractility, 2,3-DPG deficiency, seizures, diminished tissue sensitivity to insulin, abnormal calcium and magnesium metabolism, decreased sensitivity to vasoactive drugs, and generalized tissue hypoxia and ATP deficiency.

**Miscellaneous Complications**

- Hyperosmolar states with excessive osmotic diuresis.
- Specific vitamin or trace element deficiencies.
- Precipitation of ventilatory failure or impairment of the weaning process because of excessive carbohydrate administration to patients with decreased ventilatory reserve.
- Air embolism due to accidental disconnection of the central IV line or, rarely, to the removal of the catheter.

Finally, some rare or minor types of lipid-induced toxicity have been reported, including the following:
- Fever, chills, nausea, vomiting, and/or chest or back pain during the initial minutes of an IV lipid infusion. Thus, it is recommended to start the infusion at no more than 60 ml/h, gradually increasing it after 15 to 30 min to a maximum of 100 to 125 ml/h (4 to 5 h to infuse 500 ml).
- Abnormal platelet function and hypercoagulability.
• Anemia developing after prolonged use of IV lipids, specifically soybean oil emulsion (Intralipid, Traveneol Laboratories).

• Allergic reactions, including wheezing, urticaria, skin wheals, and erythema.

• A “fat overload syndrome,” which may include hyperlipidemia, hepatosplenomegaly, abnormal liver function tests, thrombocytopenia, prolonged prothrombin time, spontaneous bleeding, GI disturbances, and/or tachypnea and tachycardia. This syndrome has been described in children receiving cottonseed oil emulsion (Lipomul, Upjohn) and patients receiving soybean oil emulsion (Intralipid).

ACKNOWLEDGMENT: We thank Ms. Mary Ellen Anderson and Ms. Cathy Dent for help in finding, classifying, and double-checking so many references.

REFERENCES


227 Allardice DB, Groves AC. A comparison of nutritional gains resulting from intravenous and enteral feedings. Surg Gynecol Obstet 1974; 139:180-84


245 Aronchik J, Elwyn DH, Silverberg PA, Epstein DM, Geter WB, Miller WT. Pneumothorax as a complication of placement of a nasoenteric tube. AMA 1984; 259:3287-88


260 Brinson RR, Kolts BE. Hypoalbuminemia as an indicator of...
264 Bauer LA. Interference of oral phenytoin absorption by continuous nasogastric feedings. Neurology 1982; 32:570-72
265 Howard PA, Hannaman KN. Warfarin resistance linked to enteral nutrition products. J Am Diet Assoc 1985; 85:713-15
271 Mitchell SE, Clark RA. Complications of central venous catheterization. AJR 1979; 133:467-76
274 Nehme AE. Nutritional support of the hospitalized patient: the team concept. JAMA 1980; 243:1906-08
289 Giaffreda DJ, Bryan-Brown CW, Lumb PD, Kwan KB, Rhoades HM. Central vs peripheral venous catheters in critically ill patients. Chest 1986; 90:805-09
302 Wretlind A. Current status of Intralipid and other fat emulsions. In: Meng HC, Wilmore DW, eds. Fat emulsions in parenteral...


334 Klock JC, Williams HE, Mestzer WC. Hemolytic anemia and somatic cell dysfunction in severe hypophosphatemia. Arch Intern Med 1974; 134:360-64

335 Juan D. The causes and consequences of hypophosphatemia. Surg Gynecol Obstet 1982; 155:589-97


343 McNeill BL. Clinical use of 10% soybean oil emulsion. Am J Hosp Pharm 1977; 34:1080-86


345 Bellin RP, Bivins BA, Jonas JZ, Young VL. Fat overload with a 10% soybean oil emulsion. Arch Surg 1976; 111:1391-93
