Intestinal absorption rate in children after small intestinal transplantation

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ABSTRACT

Background: Small bowel transplantation has now become a recognized treatment of irreversible, permanent, and subtotal intestinal failure.

Objective: The aim of this study was to assess intestinal absorption at the time of weaning from parenteral nutrition in a series of children after intestinal transplantation.

Design: Twenty-four children (age range: 14–115 mo) received intestinal transplantation, together with the liver in 6 children and the colon in 16 children. Parenteral nutrition was slowly tapered while increasing enteral tube feeding. The absorption rate was measured from a 3-d stool balance analysis performed a few days after the child had weaned from parenteral nutrition to exclusive enteral tube feeding. Results were analyzed according to the resting energy expenditure (REE; Schofield formula).

Results: All children were weaned from parenteral nutrition between 31 and 85 d posttransplantation. Median intakes were as follows: energy, 107 kcal·kg⁻¹·d⁻¹ (range: 79–168 kcal·kg⁻¹·d⁻¹); lipids, 39 kcal·kg⁻¹·d⁻¹ (range: 20–70 kcal·kg⁻¹·d⁻¹); and nitrogen, 17 kcal·kg⁻¹·d⁻¹ (range: 11–27 kcal·kg⁻¹·d⁻¹). Median daily stool output was 998 mL/d (range: 220–2025 mL/d). Median absorption rates were 88% (range: 75–96%) for energy, 82% (range: 55–98%) for lipids, and 77% (range: 61–88%) for nitrogen. The ratios for ingested energy to REE and absorbed energy to REE (range: 55–98%) for lipids, and 77% (range: 61–88%) for nitrogen. The ratios for ingested energy to REE and absorbed energy to REE were 2.2 (range: 1.6–3.6) and 1.8 (range: 1.3–3.3), respectively.

Conclusion: These data indicate a suboptimal intestinal graft absorption capacity with fat malabsorption, which necessitates energy intakes of at least twice the REE. Am J Clin Nutr 2013;97:743–9.

INTRODUCTION

Intestinal failure (IF) can be defined as the inability of the intestine to provide adequate nutrients and fluids for health maintenance in adults and for growth in children (1). Parenteral nutrition (PN) is necessary for as long as IF persists. In patients with short bowel syndrome (SBS), it has been shown that IF correlates better with fecal energy losses than with the length of the small bowel (1, 2). The severity of IF is usually evaluated by the amount of PN required for growth in children. PN, especially home-PN, remains the mainstay of therapy, regardless of the cause or degree of the intestinal deficit. Long-term results of home-PN in experienced centers have been reported and are excellent (3–5). However, irreversible IF together with complications of long-term PN, can result in the need for intestinal transplantation (ITx) (1, 6–9).

ITx has become a recognized treatment of irreversible, permanent, and subtotal IF (7, 8, 10, 11). Short-term results have improved due to better control of acute rejection and infections and due to careful patient selection (8, 9, 12). The 1-y patient and graft survival rates, as reported in the International Registry and from the largest centers for isolated small bowel transplantation (SBTx) and combined liver and SBTx, are >80% (7–13). The goal of ITx is to restore enough intestinal function to allow weaning from PN. We previously reported on the long-term intestinal autonomy of up to 18 y after ITx (13). We have reported that, in our patients, hyperphagia often compensated for suboptimal energy absorption and steatorrhoea, thus resulting in normal growth (13). Few studies have described the capacity of absorption of the allograft (14–18). Our aim here was to analyze more precisely the net intestinal absorption rates in children early after ITx at the time of PN weaning.

SUBJECTS AND METHODS

Patients

Fifty-three ITxs were performed in 51 children aged 12 mo to 13 y at the Necker Enfant Malades Hospital from 1 January 2002 to 31 December 2010, with the same immunosuppressive in-

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3 Abbreviations used: ETF, enteral tube feeding; IF, intestinal failure; ITx, intestinal transplantation; OF, oral feeding; PN, parenteral nutrition; REE, resting energy expenditure; SBS, short bowel syndrome; SBTx, small bowel transplantation.

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duction regimen. The surgical technique and the immunosuppressive regimens used have been reported previously (19). All patients received tacrolimus, steroids, and IL-2 blockers for induction; and all had a terminal ileostomy after the transplant. The patients who received a colon graft also had a terminal ileostomy. A nonnutritive colon infusion was performed.

Routine monitoring after ITx included both viral testing (blood and biopsy polymerase chain reaction) and intestinal graft biopsy. Criteria for starting enteral tube feeding (ETF) after ITx were as follows: 1) the absence of graft rejection, ie, normal villous height and low apoptosis rate, and 2) ongoing intestinal graft infectious injury. The postoperative course was based on the slow transition from total PN to total ETF. Patients were maintained on tube feeding until PN weaning. According to the protocol supported by our university hospital, the 3-d stool balance analysis was performed during the first week after withdrawal of PN as part of our routine practice during the early follow-up after intestinal transplantation. The intestinal mucosa was checked again after the 3-d stool balance period.

Only children who underwent complete 3-d stool balance analysis during the first week after withdrawal of PN were included in this study and subsequently analyzed. Patients who started oral feeding (OF) before collecting the stool samples, those who underwent anastomosis before PN weaning, those who were maintained on partial PN, and those who had a fatal outcome before PN weaning were excluded from the study. Those patients who had incomplete stool collection or discontinuation of feeding were also excluded from final analysis. A total of 24 children (9 girls, 15 boys) were included in this study (Figure 1). The median age was 59 mo (14–115 mo) at the time of ITx. The indications for transplantation included congenital enteropathies [microvillous atrophy (n = 6), epithelial dysplasia or “tufting enteropathy” (n = 4)], SBS (n = 9), and motility disorders [total aganglionosis (n = 4) or chronic intestinal pseudo-obstruction syndrome (n = 1)]. Five children received an isolated SBTx. Thirteen also received a right colon transplant; 3 received a small bowel, colon, and liver transplant; 1 received a small bowel and liver transplant; and 2 received a SBTx as part of a multiorgan transplantation. The height and weight of the children at the time of transplant were 15.8 kg (7.8–27.0 kg) and 101.5 cm (71.0–127.5 cm), respectively, corresponding to −2.1 to +1.3 SD and −1.8 to +1.5 SD, respectively (Table 1).

**Methods**

According to our protocol, continuous ETF was started between the fifth and seventh postoperative day, after the first routine control biopsies were obtained to determine the readiness for enteral feedings. Continuous ETF was performed either with a nasogastric tube (n = 10) or through a gastrostomy (n = 14). The formula used was a lactose-free protein hydrolysate (whey protein) formula, with 50% energy from fat with 50% medium-chain triglycerides (Peptijunior; Nutricia). The absorption efficiency and intestinal tolerance were routinely monitored by following the stoma output, the water-electrolytes balance, the concentration of proteins in the output, and body weight. PN was slowly tapered according to these variables, and the patient was weaned to exclusive ETF. Criteria for PN weaning were a stable stool output, a normal water-electrolytes balance, stool protein <2 g/L, and a stable or moderately increasing body weight. OF, whenever possible, was started after the stools required for the analysis of the intestinal absorption were collected.

A nutritional balance study was performed within 1 wk after completing PN weaning. The total amount of the enteral feeding (energy, fat, protein, and carbohydrates) was recorded for 3 d. The stools were collected daily and stored at +4°C. The 3-d stool samples were pooled, and analyses were performed on homogenized samples. Fat, nitrogen, and total energy content were determined by the method of Van De Kamer (20), nitrogen elemental analysis (21) (N Analyzer Flash EA 1112; Thermo Scientific), and bomb calorimetry (22) (PARR 1351 Bomb Calorimeter; Parr Instrument Company), respectively. Carbohydrate-derived energy was calculated by subtracting the energy associated with the nitrogen and fat components from the total.

**FIGURE 1.** Flow diagram of patients throughout the study. PN, parenteral nutrition.
energy in the sample (23). The energy conversion factors used were 23.6, 17.6, and 39 kJ/g for protein, carbohydrate, and fat, respectively (24). The conventional conversion factor of 6.25 was used to express elemental nitrogen content as protein content. The enteral metabolizable energy was calculated by subtracting the amount of energy excreted in stool output from that actually ingested. The coefficient of net intestinal absorption expressed as a percentage of total energy ingested for the 3 main energy sources (nitrogen, carbohydrate, and fat) and total energy represented the proportion of ingested energy not recovered in stool output.

The resting energy expenditure (REE) was calculated with the Schofield formulas on the basis of sex, age, body weight, and height (25). The median REE was 847 kcal (434–1109 kcal) at the time of ITx. The following data were recorded for evaluation of nutritional efficiency: total energy intake from PN (PN energy intake), absorbed energy, as assessed by the stool balance analysis. The following ratios were calculated: PN energy intake:REE, absorbed energy:REE, and total absorbed energy:REE.

Fecal pancreatic elastase concentrations were determined by a sandwich-type ELISA (Schebo-Biotech). Results were expressed as micrograms per gram of stool.

Statistical analysis

Results are expressed as medians, means ± SDs, and percentages. Data were analyzed with nonparametric tests including Mann-Whitney, Kruskal-Wallis, and Wilcoxon’s signed-rank tests. Statistical analyses were performed with SAS, version 8.2 (SAS Institute). A P value <0.05 was considered significant.

RESULTS

Twelve of the 24 patients experienced acute intestinal graft rejection 10–28 d after transplantation. All episodes of acute rejection were controlled with high-dose methylprednisolone and subsequent adjustment of immunosuppression. Feeding was delayed for the patients treated for rejection. These patients were therefore receiving PN longer (median: 51 d) than those without a history of acute rejection (median: 38 d). Overall, the period of withdrawal of PN was between 31 and 85 d with a median of 44 d. The nutritional intakes of ETF at the time of analysis of intestinal absorption are reported in Tables 2 and 3, with an average energy intake of 110 kcal · kg⁻¹ · d⁻¹, which is higher than the average of the previously provided energy by PN (73 kcal · kg⁻¹ · d⁻¹) for achieving expected body weight.

The daily stool output was 970 ± 654 mL/d (15–123 mL · kg⁻¹ · d⁻¹) with a median of 998 mL/d (range: 220–2025 mL/d) (Table 3).

Mean (±SD) intestinal absorption average rates for energy, lipids, carbohydrates, and nitrogen were 87.3 ± 8% (median: 88%; range: 75–96%), 80.8 ± 27.5% (median: 82%; range: 55–98%), 94.6 ± 1.7% (median: 96%; range: 82–99%), and 77.4 ± 12.5% (median: 77%; range: 61–88%), respectively (Figure 2). Fecal elastase was 234 µg/g (range: 61–469 µg/g) of stools (Table 3).

The REE calculated at the time of PN weaning, with a maximal ETF intake, was 837 ± 57 kcal/d (510.0 ± 2.8 kcal · kg⁻¹ · d⁻¹). The ratios for PN energy intake to REE, absorbed energy to REE, and total intake energy to REE were 1.34 ± 0.18, 1.84 ± 0.23, and 2.15 ± 0.27, respectively (P = 0.02) (Figure 3).

The status of the patients at ages 6 mo (21 children), 1 y (19 children), 3 y (14 children), and 5 y (8 children) after SBTx are presented in Table 4.

Six months after transplantation, 5 patients were receiving exclusive OF, 3 patient lost their graft, 1 patient continued with partial PN (for water-electrolytes provision), 1 patient was receiving ETF exclusively, and the other 14 patients were orally fed but continued with enteral intake of 42.7 ± 22.1% (median: 36.0%; range: 15–81%) of their theoretical calculated needs (2.15 × REE).

One year after transplantation, 5 patients were receiving exclusive OF (patient nos. 1, 2, 3, 4, and 6), 3 patients continued to receive PN (2 receiving exclusive PN and 1 receiving PN for water-electrolytes balance (patient nos. 17, 18, and 20)), 11 patients had limited oral intakes, and 2 patients had died. Those patients who were receiving tube feedings had intakes representing 48.8 ± 24.0% of their calculated energy needs (median: 39%; range: 19–100%).

Three years after transplantation, 7 patients (patient nos. 1, 2, 3, 4, 5, 7, and 8) were exclusively receiving OFs, 4 had lost their graft, and 7 patients (patient nos. 9, 10, 11, 13, 14, 15, and 16) were receiving oral and enteral nutrition with intakes representing 51.9 ± 32.3% of their theoretical needs (median: 41%; range: 15–93%). There were no patients receiving PN at this time.

### TABLE 1
Clinical characteristics of the 24 children included in the study

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>REE</th>
<th>Delay for weaning from PN</th>
</tr>
</thead>
<tbody>
<tr>
<td>mo</td>
<td>kg</td>
<td>cm</td>
<td>kcal</td>
<td>d</td>
</tr>
<tr>
<td>Median 59</td>
<td>15.8</td>
<td>101.5</td>
<td>847</td>
<td>43.5</td>
</tr>
<tr>
<td>Minimal 115</td>
<td>7.8</td>
<td>71</td>
<td>439</td>
<td>31</td>
</tr>
<tr>
<td>Maximal 14</td>
<td>27.0</td>
<td>127.5</td>
<td>1109</td>
<td>85</td>
</tr>
</tbody>
</table>

1 PN, parenteral nutrition; REE, resting energy expenditure.

### TABLE 2
Nutritional intake by tube feeding during the 3-d stool balance analysis performed in the 24 children included in the study

<table>
<thead>
<tr>
<th>Energy</th>
<th>Fat</th>
<th>Carbohydrates</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>kcal/d</td>
<td>kcal · kg⁻¹ · d⁻¹</td>
<td>kcal/d</td>
<td>kcal · kg⁻¹ · d⁻¹</td>
</tr>
<tr>
<td>Mean 1804</td>
<td>110.6</td>
<td>648</td>
<td>40.1</td>
</tr>
<tr>
<td>SD 351</td>
<td>17.5</td>
<td>124</td>
<td>6.2</td>
</tr>
<tr>
<td>Median 1702</td>
<td>106.7</td>
<td>622</td>
<td>38.6</td>
</tr>
</tbody>
</table>
Five years after transplantation, 4 children (patient nos. 1, 2, 5, and 7) were receiving exclusive OF, 1 patient lost his graft, 1 patient had undergone retransplantation and was receiving PN (patient no. 3), and 3 patients (patient nos. 9, 10, and 11) were orally fed but also received ETF, which supplied them with 45.3% of their estimated energy needs.

**DISCUSSION**

The nutrition management of ITx patients continues to be challenging during the postoperative period. This study highlights that the early intestinal graft is not as efficient as expected and that successful ITx is not only based on “graft survival” but should be based on “graft efficiency.” Indeed, a functional intestinal graft should maintain a water-electrolyte balance and sustain normal body weight gain and long-term growth in size. The absorptive capacity of the graft can be affected by immunologic and nonimmunologic factors, including enteric lymphatic disruption, preservation injury, viral enteritis, systemic infections, and rejection. Our first aim was to measure the intestinal absorption of the graft early after transplantation. Our second aim was to compare the lipid absorption rate in these children with our previously published results showing insufficient lipid absorption rates in children long after ITx (13). By using a 3-d stool balance analysis performed early after transplantation, we showed that enteral autonomy was achieved after using ETF volumes that provided more than twice the calculated REE. These high rates of ETF are presumably related to intestinal graft malabsorption occurring immediately after the transplantation.

ITx recipients require PN immediately after transplantation and sometimes later on for both nutrient supply and compensation of water-electrolytes losses. ETF should be initiated as soon as possible, generally within 5–7 d from transplantation (26). Enteral nutrition results in a trophic effect that improves and maintains the mucosal barrier, optimizing the intestinal absorption and preventing bacterial translocation (27, 28). The tolerance of ETF after ITx is often disturbed by the consequences of surgery (ischemia-reperfusion injury, extrinsic denervation, lymphatic damages) and by rejection. Even though it is recognized as being highly important, nutritional management after ITx, including timing, route, and type of feeding, is different according to different centers (7, 9, 26). Because there are no randomized studies, there are no universally accepted guidelines for the nutritional management of children after ITx. As we reported earlier, we always use a hydrolyzed protein formula to reduce the antigenic load early after grafting and also because small peptides are better absorbed than free amino acids (29). We also emphasize a diet rich in medium-chain triglycerides to enhance absorbable energy (26). Thus, in our practice, early nutritional management after ITx is based on a lactose-free protein hydrolysate (whey protein) diet with 50% of energy as fat, and with 50% of the fat in the form of medium-chain triglycerides. This diet optimizes the intestinal absorption and minimizes posttransplantation food sensitization (15, 26, 30, 31). OF is allowed later on, after good tolerance of the enteral feedings is established by stool analysis.

Although time consuming, the 3-d stool balance analysis is the gold standard for the measurement of net intestinal absorption of macronutrients. This method has been used in adult patients with SBS (32, 33) as well as in pediatric SBS patients receiving recombinant growth hormone for improvement of intestinal adaptation (34). Because this method requires constant patient monitoring with special attention to a detailed and very precise stool collection for 3 d, it can be difficult to achieve, especially in children who may not cooperate with the test. For this reason, patients who did not complete the test were excluded from the final analysis. In the present study, a suboptimal energy absorption rate with a lipid absorption rate as low as 55% was observed in most patients. Previous studies reported a fat absorption rate of <90% (13, 35). In these studies, as in ours, the fat malabsorption was not due to pancreatic insufficiency, because fecal elastase was normal in most children. In our study, 8 children had stool elastase below the normal value of 200 μg/g. However elastase concentration may be lowered artificially in watery stool samples due to dilution. When measured in dried stool samples, no child had elastase <1000 μg/g dry stools, which has been proposed as a normal cutoff (36).

![FIGURE 2. Mean (±SD) intestinal absorption average rates (%) for energy, lipids, carbohydrates, and nitrogen in the 24 intestinal transplantation patients a few days after the children weaned from parenteral nutrition to exclusive enteral tube feeding. Total absorption represented the proportion of ingested energy not recovered in stool output. The absorption of proteins and lipids was calculated by subtracting the amount excreted in feces from the amount ingested. Carbohydrate absorption was calculated from the difference between total calories and fat plus protein calories.](https://academic.oup.com/ajcn/article-abstract/97/4/743/4577035)
children with the lowest fecal elastase amounts had the highest stool outputs, confirming the influence of dilution on the results. Moreover, as previously reported in our patients, treatment with pancreatic enzymes is ineffective (13). Early after transplantation, lymphatic injury and dilated lymphatic vessels in intestinal biopsies seen in some patients (data not shown) confirm the expected impairment in the intestinal lymphatic circulation. Lymphatic anastomosis is impossible during ITx surgery, and the normal circulation of chylomicrons released from the enterocytes is not restored. There is a lymphatic stasis seen in histologic analysis with the presence of lymphangiectasia. In the absence of graft rejection, the fat malabsorption is thus probably due, to some degree, to insufficient reestablishment of a functional lymphatic circulation. Posttransplantation chylous ascites may occur after ITx but was not observed in this cohort of patients. This may be due to our practice of limiting enteral long-chain triglycerides during the first 2 to 6 wk after transplantation. As suggested by our previously reported results, it is likely that fat assimilation is progressively improving over time (13). It is not clear how long-term posttransplantation lymphatic regeneration occurs. Even if the majority of ITx recipients achieve the ultimate goal of nutrition autonomy, fat malabsorption may persist. If the patients are not anorectic, the fat malabsorption may be compensated by hyperphagia, resulting in normal growth, as previously reported (13).

According to our published data, the low lipid absorption rate seems to improve over time, with the lowest point immediately after grafting. The early 3-d stool balance analysis allows identification of those children with the lowest lipid absorption rate to adapt the diet as needed and to follow both the tolerance and efficiency (body weight gain and growth) over the long term, especially when the stoma is closed.

In our group of 24 patients, energy intake was high, well above the recommendations for age in most patients. Protein intake was

### Table 4

Nutritional follow-up of the 24 children included in the study

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Type of nutrition</th>
<th>Total energy delivered by ETF</th>
<th>Recommended daily energy intakes</th>
<th>Percentage provided by ETF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kcal/d</td>
<td>kcal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 mo 1 y 3 y 5 y 6 mo 1 y 3 y 5 y</td>
<td>6 mo 1 y 3 y 5 y 6 mo 1 y 3 y 5 y</td>
<td>6 mo 1 y 3 y 5 y 6 mo 1 y 3 y 5 y</td>
</tr>
<tr>
<td>1</td>
<td>OF</td>
<td>0</td>
<td>1976</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>OF</td>
<td>0</td>
<td>1746</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>OF</td>
<td>0</td>
<td>1214</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>OF</td>
<td>0</td>
<td>1987</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>OF + ETF</td>
<td>0</td>
<td>1785</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>OF + ETF</td>
<td>0</td>
<td>1671</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>OF + ETF</td>
<td>0</td>
<td>1903</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>OF + ETF</td>
<td>NA</td>
<td>1769</td>
<td>NA</td>
</tr>
<tr>
<td>9</td>
<td>OF + ETF</td>
<td>NA</td>
<td>1838</td>
<td>NA</td>
</tr>
<tr>
<td>10</td>
<td>OF + ETF</td>
<td>NA</td>
<td>1834</td>
<td>NA</td>
</tr>
<tr>
<td>11</td>
<td>OF + ETF</td>
<td>1560</td>
<td>1948</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>OF + ETF</td>
<td>600</td>
<td>2131</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>OF + ETF</td>
<td>500</td>
<td>1860</td>
<td>NA</td>
</tr>
<tr>
<td>14</td>
<td>OF + ETF</td>
<td>380</td>
<td>1448</td>
<td>NA</td>
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<tr>
<td>15</td>
<td>OF + ETF</td>
<td>568</td>
<td>1742</td>
<td>NA</td>
</tr>
<tr>
<td>16</td>
<td>OF + ETF</td>
<td>469</td>
<td>1625</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>OF + ETF</td>
<td>643</td>
<td>2049</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>OF + ETF</td>
<td>355</td>
<td>2391</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>OF + ETF</td>
<td>0</td>
<td>2012</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>OF + ETF + PN</td>
<td>892</td>
<td>1625</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>ETF</td>
<td>1700</td>
<td>1660</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>IGR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>IGR</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>24</td>
<td>IGR</td>
<td></td>
<td></td>
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</tbody>
</table>

*Grafts in patient nos. 22, 23, and 24 were removed within 6 mo posttransplantation. ETF, enteral tube feeding; IGR, intestinal graft removal; NA, not applicable because patient entered the study too recently; OF, oral feeding; PN, parenteral nutrition; †, death.*
also higher than recommended. According to the Schofield formulas for REE (25), the ratio of PN energy intake to REE was 1.34 ± 0.18, the ratio of absorbed energy to REE was 1.84 ± 0.23, and the ratio of the total absorbed energy to REE was 2.15 ± 0.27. The Schofield formulas have been established from indirect calorimetry measurements and are based on age, sex, body weight, and height (25). They are routinely used in our department as in many others. We prefer using this formula over indirect calorimetry measurements, which are based on short recording times and may be influenced by short-term factors. The necessary energy supply was, as expected, significantly higher with ETF than with PN. With high fat losses in stools, it was more than twice the REE. After transplantation, food intakes should thus be adjusted according to the signs of digestive tolerance such as stool losses. The use of maltodextrin may increase the energy content of the food may be limited by low intestinal disaccharidase activities, as previously reported (26–28).

Over the long term, as emphasized in our previous study, spontaneous oral or supplementary ETF, as well as fat-soluble vitamins and growth should be carefully monitored due to the observed persistent fat malabsorption in many patients (13). Even 10 y after ITx some children had a steatorrhea, with fecal stool losses of >10 g/24 h (13).

In conclusion, in the absence of graft rejection, ITx results in intestinal autonomy (PN weaning) despite suboptimal intestinal function. We report here on the function of the early intestinal graft, through a functional analysis of the stools. The absorption of energy, especially fat, is not optimal, presumably largely due to alterations of the lymphatic circulation. This fat malabsorption results in a need for a high enteral energy intake, both by feeding tube and later by oral intake. According to this reduced lipid absorption rate, an optimal feeding strategy, in terms of tolerance and efficiency, should be based on a formula rich in medium-chain triglycerides such as the commercially available protein hydrolysate formula we used for these children. The energy intakes with ETF may exceed 2 times the REE calculated to achieve appropriate weight gain.

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The authors’ responsibilities were as follows—NK and OG: concept and design of the study and statistical analysis; CC, YR, and FS: surgical procedures; FC, SG, LMT, VC-J, JS, CT, AC, and FR: clinical supervision of the procedures; ED: organization and supervision of the 3-d stool balance procedures; FC, SG, LMT, VC-J, JS, CT, AC, and FR: clinical supervision of the patients; FO, NK, and OG: drafting of the manuscript. All of the authors critically revised the manuscript for important intellectual content. None of the authors had a conflict of interest.

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