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Enteral versus Parenteral Nutritional Support following Laparotomy for Trauma: A Randomized Prospective Trial

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Although enteral nutrition is considered more 'physiologic' than parenteral nutrition, there is greater published experience with parenteral nutrition in trauma patients. To compare the efficacy of these two techniques, we prospectively randomized multiple trauma patients during their admission laparotomy to receive either central venous parenteral nutritional (TPN: *n* = 23) or enteral nutrition by jejunostomy (Jej: *n* = 23). Nutritional support began on the first postoperative day; the study period continued a maximum of 14 days.

There were no significant differences between the two groups in age, sex, injury severity, estimated caloric needs (3,322 TPN; 3,114 Jej), hours to achieve full prescription (77 PTN; 79 Jej), or the number of days on nutritional support (22 TPN; 25 Jej). Average daily caloric intakes, nitrogen balance results, and complication rates were also comparable.

These results suggest that early postoperative jejunostomy feeding is a safe and efficacious choice for multiple trauma patients undergoing laparotomy.

Although the need for maintaining nutritional integrity in severely traumatized patients is widely accepted, debate persists over the appropriate route for nutritional support. Proponents of enteral feeding say it is more 'physiologic' (28), preserves gut function (13, 16, 23, 24, 27) and costs less than parenteral nutrition (10, 19, 42). Those who advocate parenteral nutrition counter that patients rarely tolerate the high volumes of tube feeding required in the early catabolic phase of stress (8, 18, 34, 38).

In recent years, a number of reports have demonstrated that function in normal small bowel returns within a few hours postoperatively. In contrast, stomach and colon functions return at 1–2 days and 3–5 days postoperatively, respectively (39). Several investigators (14, 15, 20, 22, 32, 33, 36, 40) have applied this principle to successfully deliver enteral feeding via the small bowel in the immediate postoperative period. However, few investigators have included traumatized patients in their studies (11, 12).

The majority of early postoperative enteral nutrition studies have used elemental formulas. These formulas contain no residue and do not require hydrolysis for digestion, thus theoretically facilitating small bowel absorption (26). A few investigators (14, 15, 20, 22) have demonstrated that early postoperative enteral feeding via the small bowel is also successful using polymeric formulas and have suggestd that elemental diets are not necessary. The polymeric feedings offer several advantages over the elemental, the primary one being cost (25). In addition, a wider selection of polymeric formulas is available to meet the specific nutritional needs of patients with different diseases. Polymeric formulas are generally lower in osmolality, permitting more rapid advancement of the feeding. They are, however, more viscous than the elemental diets and require larger feeding tubes than the needle-catheter jejunostomy and/or close attention to prevent plugging of the catheter (20).

A small number of studies have prospectively compared enteral and parenteral nutrition in hospitalized patients (4, 22, 29, 34, 38). Although several reports have included surgical patients (4, 22, 29, 34), few have focused on trauma patients (38). The majority of these investigations have used elemental formulas as the enteral feeding. These studies cite an inability to advance the feeding due to gastrointestinal distress as the most frequent complaint against the use of enteral support.

The purpose of this study was to compare prospectively

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the efficacy of parenteral and enteral nutrition in trauma patients who were physically able to receive either method of support. We randomized newly admitted patients during their initial surgical procedure to receive either central venous parenteral nutrition or enteral nutrition by jejunostomy using a polymeric formula.

MATERIALS AND METHODS

Trauma patients undergoing an emergent laparotomy at admission to Harborview Medical Center, Seattle, from January 1982 to June 1984 were considered for enrollment in the study. Consenting patients who were 18–60 years of age, 80–130% of desirable weight (41), without a history of hepatic or renal failure, and who had significant injuries to two or more body systems documented in the operating room were eligible for entry. The surgical team randomized patients in the operating room to receive either total parenteral nutrition via a subclavian line (TPN) or enteral nutrition via an 8 French Witzel jejunostomy tube (Jej). Both types of feeding lines were placed during the initial surgical procedure. The protocol was approved by the University of Washington Human Subjects Review Committee.

Basal energy needs were estimated from the Harris-Benedict equation (BEE) (17) using the patient's recorded height and usual body weight. During the first 12 months of the study (Phase I), the BEE was multiplied by a stress factor of 1.68 to derive the nutritional prescription for each group (30). An interim data analysis indicated patients in both treatment groups (eight TPN, 12 Jej) consistently failed to achieve positive nitrogen balance on this prescription. The analysis also revealed the Jej patients' nutrient intakes were consistently less than the TPN patients', apparently due to more frequent interruptions in Jej feedings for medical procedures. Consequently, during the final 18 months of the study (Phase II), energy prescriptions were increased to BEE × 2.0 and an additional 20% was added to the Jej prescriptions.

Nutritional support in both groups was initiated on the first postoperative day following confirmation of proper line placement. The study period continued for 14 days or until one of the following occurred: 1) the patient consumed 70% of his estimated caloric needs orally; or 2) the attending physician felt the patient's recovery would be impaired if the study continued. TPN patients received a solution of equal parts 25% dextrose and 4.25% crystalline amino acids (Travasol; total calorie/nitrogen = 150/1). This dextrose and amino acid solution was prescribed to meet the TPN patients' estimated caloric needs. Additional caloric prescriptions of 500 ml of 10% lipid, twice weekly, were optional. All Jej patients received a polymeric enteral formula. The first five patients received Isocal HCN (total calorie/nitrogen = 170/1), the remaining 18 Jej patients received Traumacal (total calorie/nitrogen = 116/1).*

In both groups, formulas were prescribed at 50 ml per hour for the first 24 hours. On the second day, the TPN solution was advanced as tolerated, according to each physician's discretion, to achieve the estimated energy prescription. The Jej feedings were initiated at 1/2 strength. The rate of Jej feedings was advanced, beginning on the second day, by 25 ml per hour every 8 hours as tolerated, until the desired rate was achieved. After the desired rate was achieved, the tube feeding continued at 1/2 strength for an additional 8 hours and was then advanced to full strength, if tolerated.

Nutritional prescriptions were adjusted according to biweekly nitrogen balance studies, calculated with the following formula: grams of protein intake/6.25 −(24 hour total urine nitrogen + 2.0 grams estimated exogenous nitrogen losses) (43). If patients were in negative nitrogen balance following a 3-day steady state calorie and nitrogen intake, prescriptions were increased by 10–20% according to formula tolerance and the nitrogen balance results. Physicians were permitted to treat metabolic or gastrointestinal intolerances with their medication of choice and to reduce the rate and/or strength of feedings if they considered the symptoms to be severe. When necessary for fluid-restricted patients, physicians could reduce the rate of either method. If the need for fluid restriction persisted beyond 3 days, an attempt was made to concentrate the nutrient density of the TPN study solutions. When the treating physician wanted to reduce the total carbohydrate load for respirator-dependent TPN patients, the percentage of lipid calories was increased in the TPN prescriptions.

Oral feedings were initiated and advanced as tolerated according to each physician's judgment. The research dietitian monitored and documented patients' oral intakes during the study period. Oral calorie and protein intakes were based on percentages of foods consumed from standard portions. Physicians were encouraged to continue full TPN and Jej prescriptions until the patient consumed 70% of his estimated caloric needs orally.

Baseline measurements included: serum albumin, prealbumin, transferrin, SGOT, LDH, alkaline phosphatase and total bilirubin; complete blood count with differential, delayed hypersensitivity skin testing (mumps, tricophyton, Candida, PPD), triceps skinfold thickness, and mid-upper arm circumference. These measurements were repeated weekly during the study. The patient's presenting Injury Severity Score (3) and Prognostic Nutritional Index (5, 35) were also tabulated at baseline. Daily monitoring and measurements during the study included: calorie and nitrogen intake, body weight, stool output (mild diarrhea = 3–6 loose or liquid stools per day; severe ≥6 loose or liquid stools per day), gastrointestinal distress as assessed by the patient and/or medical staff, serum glucose, peak urinary glucose fractionals, total urine nitrogen excretion, peak temperature, medication prescriptions and usage, use of respirator, changes in medical status, number and type of operations, mechanical problems with feeding lines, number of line changes, and the frequency of, and rationale for, any changes or interruptions in feeding. At the time of discharge from the hospital, patients were evaluated for: length of hospital stay, intensive care unit stay, length of time on the surgical service, number of days on the respirator, number and type of operations, total number of days receiving tube feeding or TPN, first day of oral intake (either full liquid or general diet), weight at the time nutritional support was discontinued and at discharge, medical complications, mortality, and costs of nutritional support.

RESULTS

Forty-six patients were randomized, 23 to each group. There were no significant differences (NSD) between groups in age (29 ± 10 years, TPN; 30 ± 9 years, Jej), sex (M/F: 16/7, TPN; 15/8, Jej), Injury Severity Scores (3) (36 ± 12, TPN; 39 ± 12, Jej), Prognostic Nutritional Index (5, 35) (57 ± 18, TPN; 63 ± 15, Jej), total urine nitrogen excretion during the initial 24 hours (15 ± 8, TPN; 13 ± 5, Jej), and average daily total urine nitrogen excretion during the period of nutritional support (17 ± 5 gm TPN; 20 ± 8 gm Jej). Table I records the mechanism

* Mead Johnson Nutritional Division, Evansville, Indiana. Isocal HCN: 2.0 calories/ml; 690 m Osm/KgH_2O; 15% protein calories; 45% carbohydrate calories; 40% lipid calories. Traumacal: 1.5 calories/ml; 550 mOsm/KgH_2O; 22% protein calories; 40% carbohydrate calories; 38% lipid calories.

TABLE I

	TPN (n = 23)	Jej (n = 23)
Mechanism of Injury		
Motor vehicle accident	9	14
Motorcycle accident	3	3
Fall	1	3
Gunshot wound	9	2
Stab wound	1	1
Injury		
Head injury	5	9
Spine fracture	0	2
Severe facial fractures	3	2
Severe thoracic injury	4	12
Major intra-abdominal injury	22	18
Pelvic fracture	3	9
Long bone fractures	9	12
Other major soft-tissue injury	1	6
Initial Operative Procedure		
Simple exploratory laparotomy	1	5
Laparotomy with necessary procedure	22	18
Orthopedic fixation procedure (internal or external)	7	9
Craniotomy	3	2
Thoracotomy	0	3
Oral surgery/ENT procedure	1	2

TABLE II

	TPN (n = 23)	Jej (n = 23)
Estimated caloric needs	3,322 ± 610	3,114 ± 590
Number of hours to full prescription post start	58 ± 30*	49 ± 30†
Number of hours to full Rx postop	77 ± 31*	79 ± 33†
Number of days received nutritional support	22 ± 24	25 ± 40
Number of patients requiring nutritional support >2 weeks	11	9

* n = 21; data missing on 1 patient; 1 patient did not achieve full prescription.
† n = 21; 2 patients did not achieve full prescription.

of injury, types of injury sustained, and initial operative procedures performed in both groups of patients. There were no significant differences between the groups in any of these factors. The two study groups were also similar in time spent in the ICU (17 TPN patients for 10 ± 10 days, 19 Jej patients for 13 ± 11 days), on a ventilator (13 TPN patients for 10 ± 10 days, 17 Jej patients for 12 ± 11 days), and in the hospital (31 ± 29 days TPN, 30 ± 21 days Jej). Three TPN patients and one Jej patient died from 1 to 4 months postinjury of causes unrelated to nutrition support technique.

Estimated caloric needs, the time required to achieve desired prescriptions, and the overall requirements for nutritional support were also comparable between groups (Table II). The average maximum tube feeding rate among the Jej patients was 90 ± 24 ml/hour (range, 50–140 ml/hour). The first day of oral intake for 20 TPN patients was 10 ± 6 and for 20 Jej patients 11 ± 9. Nine patients in each group who began oral intake during the first 2 weeks were able to ingest ≥70% of their estimated caloric needs on average 11 ± 3 days after injury. Three patients in each group failed to resume any oral intake within the first month following injury. Bowel tones were reported on the 4th ± 2 days in TPN patients and the 2nd ± 1 day in Jej patients.

An important feature of any nutritional support technique is the ability to maintain intakes close to the desired prescription. We found feeding interruptions of more than 8 hours were far more common in the Jej patients (12 patients, 16 episodes) than in TPN patients (two patients, two episodes; $p < 0.001$). Nearly half the patients required at least one additional operation during the study period (seven TPN and nine Jej). Although the number of patients undergoing surgical procedures was similar in each group, the impact of the procedures on nutritional support was not. It was common to continue TPN throughout the perioperative period; Jej feedings were often held several hours before and after surgery. Thus, when we prescribed isocaloric feedings (Phase I), the frequent interruptions in Jej feedings resulted in much lower nutrient intakes for Jej patients than for the TPN group. Increasing Jej caloric prescriptions 20% above the actual desired prescription in Phase II achieved comparable intakes between the two groups (Table III). Figure 1 compares the average daily caloric intakes for

TABLE III

	Phase I		Phase II	
	TPN (n = 8)	Jej (n = 12)	TPN (n = 15)	Jej (n = 11)
Estimated caloric need	2,890	2,860	3,550	3,390
Calories ordered	2,890	2,860	3,550	4,070
Calories received	2,572	2,088	2,876	2,678
Per cent of estimated caloric needs received during study period	89%	73%	81%	79%

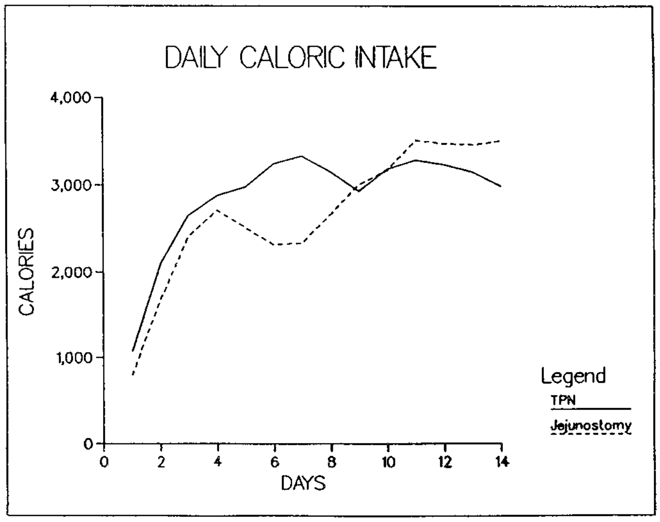

FIG. 1. Average daily caloric intake of TPN and jejunostomy patients during the 2-week study period.

all patients in each group during both phases of the study.

Promoting positive nitrogen balance is generally regarded as the goal of nutritional support in severely injured patients. We observed a significant degree of average daily negative nitrogen balance in Phase I (1.68 BEE). Increasing caloric prescriptions in Phase II (2.0 BEE) resulted in overall improvement of average nitrogen balance. Results for both Phase I and II are displayed in Table IV. Average daily nitrogen balances for patients in each group during both phases of the study are shown in Figure 2.

Nutritional assessment parameters were comparable between TPN and Jej patients. Patients in both groups maintained weight. The TPN patients had a usual body weight of 78 ± 19 kg on admission and a body weight following nutritional support of 80 ± 18 kg measured on the 17th day following injury. The Jej patients had a usual body weight of 74 ± 15 kg on admission and a body weight following nutritional support of 74 ± 13 kg measured on the 21st day. Skin tests applied within 3 days postoperatively revealed that eighteen TPN patients and 20 Jej patients were anergic. All but four of the patients in both groups remained anergic when tested one week later. Serial results for albumin, prealbumin, and transferrin are displayed in Figures 3–5. There were no significant changes in measured triceps skin fold thickness or mid-upper arm circumference from study entry to 2 weeks later in either group.

Laboratory values and medical complications were similar in each group. Average baseline creatinine and amylase values for both groups were within normal range and remained stable during the 2 weeks of study. Serum bilirubin levels were elevated during the first week (2.6 ± 2.5, TPN; 1.8 ± 2.3, Jej) and remained elevated through the second week in both groups. Complications common to severely traumatized patients, which are not directly related to nutritional support technique, occurred with almost equal frequency in both groups (Table V).

Complications related to nutritional support were similar in frequency but differed in type between the two groups. During the first 8 post-injury days, TPN patients' blood glucose levels were significantly higher than those of the Jej group. TPN patients experienced 49 of 220 patient days (22%) with blood glucose levels ≥200 mg% compared with 24 of 242 patient days (10%) for Jej patients ($p < 0.001$). This difference in blood glucose levels persisted despite higher insulin use among the TPN patients (19 TPN versus eight Jej patients; $p < 0.001$). TPN patients received 316 ± 235 units regular insulin over 9 ± 3 study days versus 37 ± 71 units over 2 ± 2 days for the Jej patients.

Diarrhea occurred 18 times in 11 Jej patients (48%) for an average total duration of 3.5 days per patient, compared with ten times in six TPN patients (26%) for an average duration of 3.8 days (NSD). Over half the diarrhea episodes in both groups were classified as mild. Diarrhea in the Jej group was controlled in most patients by slowing the rate of tube feeding. In some cases, diarrhea was not treated at all. Only four Jej patients actually received antidiarrheal medications for an average of 3 days (range, 1–8); none of the TPN patients received antidiarrheal medications. Stool softeners or laxatives were administered to 14 TPN patients and 20 Jej patients during the study period. These medications and others which might affect bowel function are listed in Table VI. Other symptoms of GI distress were common in both groups and not significantly different between groups. Bloating, cramps, or nausea were reported in 16 TPN and 19 Jej patients and occurred for an average of 5 days per group.

Mechanical complications of the nutritional support technique were also common in both groups. Thirteen TPN patients required 19 line changes for suspected catheter sepsis, of which two were confirmed by culture and subsequent clinical course. TPN was later discontinued in one of those patients because of clinically documented catheter sepsis. TPN lines malfunctioned nine times in seven patients while jejunostomy tubes clogged 13 times in nine patients. All but two of the patients in each group resumed nutritional support after the tube was replaced or cleared.

Problems with enteral feeding in four Jej patients required conversion to TPN. One Jej patient had an intestinal leak at a suture fixation point for the jejunostomy. He was re-explored on the first postoperative day and the jejunostomy removed. Following surgery, he required 9 additional days of TPN. Three of the Jej patients suffered severe gastrointestinal distress or diarrhea which was unresponsive to therapy after 6, 8, and 12 days of treatment. These three Jej patients subse-

TABLE IV

	Phase I		Phase II	
	TPN (n = 8)	Jej (n = 12)	TPN (n = 15)	Jej (n = 11)
Feeding prescription	1.68 BEE	1.68 BEE	2.0 BEE	2.0 BEE + 20%
Average daily nitrogen balance	−4.1 ± 4.6	−8.7 ± 6.8	−1.0 ± 4.1	+1.9 ± 8.1
Per cent of patients with at least one positive nitrogen balance	88%	58%	93%	82%
First day of positive nitrogen balance	4.3 ± 2.7	6.0 ± 3.4	3.7 ± 2.1	3.3 ± 1.2

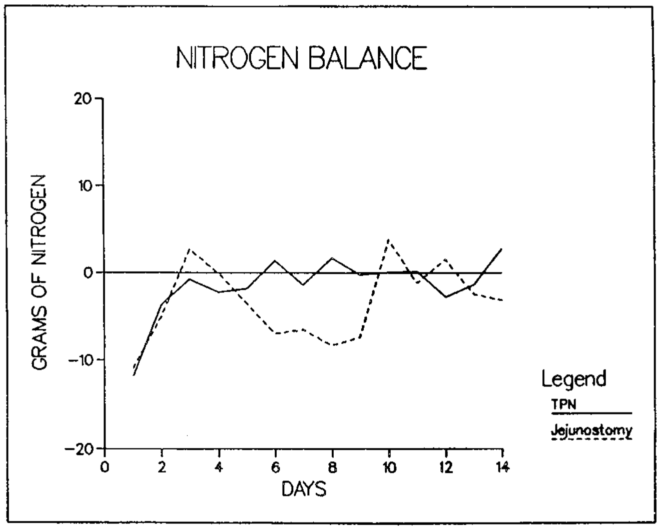

FIG. 2. Comparison of nitrogen balance determinations between the two groups in the first 14 days of post trauma.

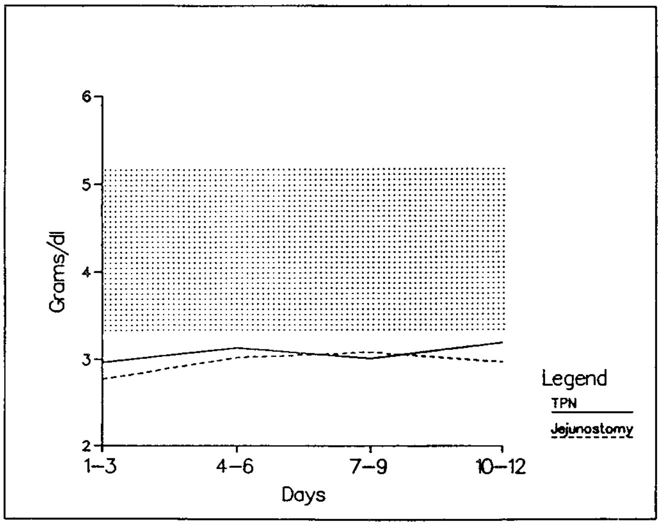

FIG. 3. Average serum albumin levels (normal range, 3.4–5.2 gram/dl).

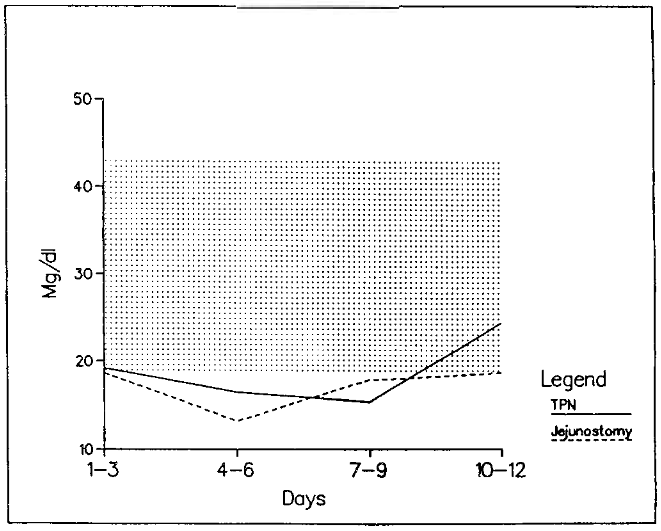

FIG. 4. Changes in serum levels of prealbumin (normal range, 19–43 mg/dl).

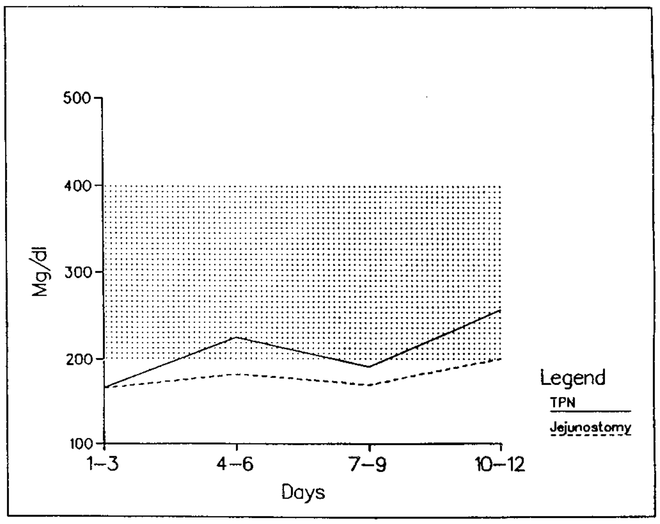

FIG. 5. Serial transferrin determinations (normal range, 200–400 mg/dl).

quently received 5, 8, and 20 days of TPN before resuming oral intake.

Two patients in the TPN group had potentially life-threatening complications. One patient's TPN line disconnected as he got out of bed, resulting in a major air embolism on the eighth postoperative day. He suffered neither hemodynamic nor neurologic compromise following aspiration of the air emboli and continued on TPN for 5 more days. The second TPN patient's line eroded into a right upper lobe bronchus on the seventh postoperative day, resulting in a small pneumothorax and significant hypoxemia. Her TPN line was not replaced and she began eating the following day. Two comatose TPN patients converted to tube feeding following 3 to 4 weeks of TPN. One of the two patients received nasoenteric feedings for 9 days before resuming oral intake. The second TPN patient returned to surgery at 6 weeks postinjury for a jejunostomy tube placement. She developed a small bowel obstruction near that jejunostomy site and returned to the operating room 10 days later for release of the obstruction and revision of the feeding jejunostomy. She subsequently received 68 days of enteral support.

TABLE V

	TPN (n = 23)	Jej (n = 23)
Wound infection	0	2
Pneumonia	8	11
Intra-abdominal infection	2	1
Persistent fever without obvious cause	5	1
Gastrointestinal bleeding	0	0
Hepatic failure	1	1
Acute renal failure	1	1
Pancreatitis	1	2

At our institution, the average charge for a TPN line insertion, including the surgeon's fee and one chest X-

TABLE VI

	TPN (n = 23)			Jej (n = 23)		
	No. of Patients	No. Days Given	No. of Patient Days	No. of Patients	No. Days Given	No. of Patient Days
Antidiarrheal	0	0	0	4	3 ± 3	5
Narcotics	22	11 ± 4	96	23	9 ± 4	82
Laxatives	6	2 ± 1	5	11	2 ± 2	9
Antacids	19	7 ± 5	53	20	6 ± 5	47
Cimetidine	12	6 ± 4	29	8	9 ± 3	29
Antibiotics	22	7 ± 5	61	22	8 ± 5	70

ray is $210.00. The cost of placing a jejunostomy tube as an adjunct procedure, as we did in this study is $495.00. This cost includes the surgeon's fee and 15 additional minutes operating room and anesthesiologist's charges. In contrast, the charge for a jejunostomy tube placement as a primary procedure is $1,785.00.

While the charge for placing a jejunostomy tube during another procedure is more than twice that for inserting a TPN line, the lower cost of enteral solutions results in a cost savings for jejunostomy feeding by the third day of nutritional support. The daily expense of delivering 2,600 calories of the study formulas (i.e., the average daily caloric intake for our 46 patients), including the necessary materials and laboratory work, was approximately $153.00 per TPN patient versus $37.00 per Jej patient. The cost of providing 23 days of nutritional support per patient (i.e., the average time on nutritional support for this group of patients) was $3,729.00 in the TPN group and $1,346.00 in the Jej group. The total cost difference between groups was $54,809.00 or $2,383.00 per patient.

DISCUSSION

The relative merits and optimal circumstances for parenteral or enteral nutritional support of severely ill or injured patients have been the subject of much discussion and some study. Most clinicians subscribe to the folk wisdom, if the gut works, use it, but it is unknown how many actually practice this philosophy. The actual data supporting the superiority of enteral to parenteral nutrition, in patients who could receive either, are scant. Muggia-Sullam et al. (34) studied 15 patients having scheduled abdominal procedures and found no significant difference, other than cost, between enteral support by needle catheter jejunostomy and parenteral support. The enteral formula used was an elemental diet which caused some gastrointestinal tolerance problems and hence was not advanced to full strength before the 5th day on average. They deliberately slowed the advancement of TPN infusions to match the enteral infusions. They concluded TPN might be preferable for patients with "great needs." Burt et al. (4) compared TPN with jejunostomy feeding using an elemental diet in preoperative patients with cancer of the esophagus. The jejunostomies were placed in the preliminary operation. They found slightly better, but not significantly different, nitrogen balance with TPN; nitrogen intake was not equal between the two groups. McArdle et al. (31) studied 24 patients with severe weight loss who required nutritional support. They administered an isocaloric, isonitrogenous solution (Aminosyn, 3.5% and dextrose or Polycose, 25%) either by central vein or nasoduodenal tube. Nitrogen balance and other nutritional parameters were equivalent but serum insulin levels were markedly lower in the enteral group. Lim et al. (29) compared parenteral feeding with gastrostomy feeding in a group of preoperative patients with esophageal cancer. They found the gastrostomy patients achieved positive nitrogen balance later in the postoperative period due to slow advancement of feeding. Nevertheless, they favored enteral feedings for safety and cost.

Rapp et al. (38) compared early (i.e., within forty-eight hours) TPN with "standard enteral" nutrition in patients with severe head injury. Standard enteral nutrition consisted of nasogastric tube feeding begun after bowel sounds were heard and gastric residual volume was less than 100 ml/hour. The mean daily caloric intake for the enteral group was substantially less than for the TPN group (685 kcal vs. 1,758 kcal); average daily enteral intake did not approach TPN intake until the fourteenth postinjury day. The outcome measured by survival was significantly better in the TPN group (85% vs. 50%; $p = 0.02$). This study actually compares early nutritional support with the more traditional laissez-faire approach to nutrition in trauma patients, rather than parenteral vs. enteral nutrition. Hulten et al. (22) actually included a control group (i.e., fluid maintenance and diet advanced as tolerated) as a third arm in their prospective comparison of enteral and parenteral nutrition in postoperative patients. Following a 1-week study period, they concluded the TPN and tube feeding groups were comparable in terms of tolerance, caloric intake, and nitrogen balance. Caloric intakes and nitrogen balance results for both groups were greater than the control group.

Thus, when enteral and parenteral nutritional support have been prospectively compared in patients who could receive either, the differences have been small. There has been a tendency to find greater weight gain and/or positive nitrogen balance in TPN patients but these differences have not been large. Some of the differences can be ascribed to difficulty in advancing elemental enteral diets or to reluctance to advance enteral support rapidly in the early postoperative period.

Reports of postoperative enteral nutritional support often refer to problems in advancing the diet caused by diarrhea, nausea, bloating, or cramps (8, 18, 21, 34). These symptoms are common in postoperative patients regardless of nutritional support technique. In this study, gastrointestinal symptoms other than diarrhea were equally common in the TPN and Jej groups and even the difference in the frequency of diarrhea between the TPN and Jej patients was not statistically significant. Indeed, laxatives and stool softeners were given more often than antidiarrheal medications for both study groups. Unfortunately, when a patient is receiving enteral feeding, diarrhea may be falsely attributed to the feeding solution rather than to fecal impaction, medications, or other causes.

Despite a long history of tube feeding use in medical settings (10, 19, 37), it was the arrival of TPN which revolutionized clinical nutrition support. The high risks of parenteral feeding were clearly understood early in its development. Strict protocols, an abundance of published research, nutritional support teams, and extensive experience have all helped reduce TPN complication rates to acceptable levels in most institutions (9, 10). Andrassy (2) reported 60%–70% "compliance" with enteral feeding orders. There is a tendency to interrupt enteral feedings for other procedures, which is not the case with TPN. When a patient leaves the surgical ward for an X-ray or other procedures, it is routine to continue TPN. For enteral feedings, however, it is common to 'hold' feedings while the patient is off the floor. This is especially true if the patient goes to the operating room for any procedure, which occurred in nine of our Jej patients (39%) during the study. When a tube feeding patient returns from the operating room, another concern arises. What rate of tube feeding will the patient tolerate following surgery? We found the majority of the Jej patients tolerated resumption of jejunostomy feedings at the preoperative rate and strength.

Clifton et al. (7) suggest that early enteral feeding in the acute phase of injury is possible only with careful attention to detail by the medical staff and readjustment of infusion rates in the first week. This view is shared by others (6, 10). Because of the tendency among all medical personnel to be less compulsive about continuity in enteral feeding than in parenteral feeding, we changed our prescription practices during Phase II of our study. We routinely ordered 20% more tube feeding formula by rate of infusion than we actually desired for the patient. Using this technique, the percentage of the desired prescription delivered was comparable for the enteral and parenteral groups (Jej 79%; TPN 81%). It is worth noting that, even for TPN patients, compliance with orders averaged only 84% over both phases. If the full amount of any nutritional prescription is considered important, close attention to the quantities actually delivered is necessary. With either enteral or parenteral nutritional techniques, it is rare for the full order to be delivered but this tendency is more pronounced with enteral support.

We believe a striking aspect of this study was our ability to deliver high levels of calorie and nitrogen support by the enteral route to very sick trauma patients in the early postinjury period. All study patients had laparotomies with two or more intra-abdominal injuries or additional major injuries in other anatomic regions (Table I). The average Injury Severity Scores (36–39) are associated with mortality rate of 30% (3). Despite this, enteral support began with 31 hours of surgery (±8; range, 16–48) and advanced to full strength and rate by postoperative day 3.1 ± 1.4 (range, 2–8). Nineteen (83%) of 23 patients tolerated and received full nutritional support by the enteral route for an average of 26 ± 44 days (range, 5–200) until resumption of oral intake. Our success with enteral feeding was at least equivalent to that achieved by the parenteral route in all measured parameters. Although indices of severity were not significantly different between the enteral and the parenteral groups, any small bias did not favor the enteral group. Indeed, the ISS scores were higher, overall average nitrogen excretion was greater, and more patients spent longer times in the ICU and on the ventilator in the Jej group than in the TPN group.

Even with early aggressive nutritional support, some patients in both groups did not achieve positive nitrogen balance or did so only after several days of support. Clifton et al. (7) demonstrated the ability to deliver sustained high levels of enteral calories and protein (3,500 kcal and 27–34 gm N_2/24 hr) over 2 to 3 weeks to severely head-injured patients. Despite these high calorie and nitrogen levels they did not achieve positive nitrogen balance in the majority of their patients. One may ask whether it is desirable or possible to achieve positive nitrogen balance in these patients. This question was not systematically addressed here, but the most realistic goal in severely stressed patients may be to limit net nitrogen losses as much as possible. In very severe cases of injury and hypermetabolism this clearly can be life saving.

A second question not addressed by this study, is whether these patients actually needed early, intensive postoperative nutritional support at all. Overall 20 of 46 patients (43%) required nutritional support for more than 2 weeks. An equal number of patients (20 of 46; 43%), however, were able to resume a normal diet within 7 days of injury and almost certainly would have done as well without any special attention to nutritional support. The report by Rapp (38) supports the value of early nutritional support in patients with isolated severe head injuries, but their study did not examine patients with abdominal injuries. Hulten et al. (22) found superior nitrogen balance results in both enterally and parenterally fed surgical patients when compared to an unfed group in the first postoperative week. The groups were small ($n = 5$), however, and no comparisons of medical outcome were made.

We initially included a third arm in our study proposal, consisting of similar patients who would not receive any special postoperative nutritional support unless they had gone for 10 days without adequate oral intake. Our institutional review board did not approve this control group. Few would argue against the benefits of nutritional support for patients undergoing laparotomy for major injury and who cannot eat within 10 days. This is especially true if additional procedures are performed or if conditions exist, such as head injury or nosocomial infection, which increase or prolong the catabolic state (1). It also seems likely that a person who does require nutritional support following major injury and who cannot eat for 10 or more days would benefit from support begun as promptly as possible, but this hypothesis is untested. What we lack at this time is an accurate means of determining shortly after injury who will be unable to eat and will need support. Defining criteria for who does and does not require this type of intervention is difficult but necessary.

We believe that any patient undergoing a laparotomy and who is likely to need nutritional support for more than 10 days postoperatively should be considered seriously for a feeding jejunostomy placement. Notable exceptions to this recommendation for jejunostomy placement may include patients with Crohn's disease, small bowel obstruction, or widespread peritonitis. Our study shows that traumatized patients can be supported with equal efficacy, no more complications, and far less expense with jejunostomy feedings when compared with TPN. Indeed, if we can reliably predict that a patient will require nutritional support longer than 13 days, it is cost effective to perform a laparotomy solely for placement of a feeding jejunostomy.

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DISCUSSION

DR. JAMES LONG (Spartanburg General Hospital, Spartanburg, SC 29303): Doctor Dellinger, congratulations on a well-presented paper and a well put together study. I have no major objections to the basic thrust of this paper or of the previous one, and I would agree that, yes, it is better to feed than not to feed, and, second, enteral feeding is probably as good as and perhaps in some circumstances better than parenteral feeding. However, there are a number of comments I would like to make that basically stem from the difficulties that I have had in accomplishing enteral feeding.

Many times we tend to think of enteral feeding as something that can be done simply, while parenteral feeding is complex. I would hasten to say that, in my experience, enteral feeding by jejunostomy or by nasogastric or nasoduodenal routes is certainly as complicated. As a matter of fact, in our hands, tube feedings require the commitment of approximately three times more personnel time to ensure safety than does parenteral feeding in comparable patients.

I also have a related concern along the lines of Doctor Border's earlier comments. Both of these papers used basal energy expenditure as the basis for calculation of the amount of nutrition to be given rather than using nitrogen excretion and aiming for nitrogen equilibrium with a much lower calorie-nitrogen ratio.

One question I would ask Doctor Dellinger stems from the fact that early in the study a few patients on enteral feeding received Isocal, which has a much higher calorie-nitrogen ratio than Traumacal which was used in the latter part of the study. I would like to know if he analyzed the difference between the two groups because that might suggest feeding of a lower calorie-nitrogen ratio with a total larger nitrogen intake.

I would also hasten to say that in any study in which nitrogen balance is an answer, it is very important to know nitrogen intake. For all practical purposes groups should receive isonitrogenous feedings in order to be able to draw conclusions from a nitrogen balance study.

In terms of the cost, certainly there is a difference between enteral feeding by any route and parenteral feeding, but I would hasten to recommend that we look at the total cost (not charge) of the hospitalization of these patients. For example, we have had one recent disaster from a needle-catheter jejunostomy that slipped back a bit, and several cans of enteral feeding were put into the periotoneal cavity, which the patient did not tolerate very well, resulting in a prolonged hospitalization on the ventilator in the ICU. The total hospital bill was in excess of $100,000. The point is that it takes only an occasional major disaster or a few minor disasters to offset any cost advantage of enteral feeding.

I would also add another caution before I close. We must be careful not to take information as given in these two studies about feeding through jejunostomies inserted in the operating room and assume that we are going to have the same good experience with feeding into the small bowel through the nasoduodenal or nasojejunal route. Our experience in using tubes through the nose into the stomach, duodenum or jejunum, is that they are fraught with many hazards, and that the incidence of vomiting and aspirating to some degree is probably 25%. It may be as high as 30%, which represents a frightening prevalence of difficulty with the technique. We are not talking about the same thing when we talk about jejunostomies inserted in the operating room and feeding into the small bowel via nasal tubes.

In summary, I would say that in my hands in a large community teaching hospital that enteral feeding is cheaper, if you look at it in raw terms. It may not be cheaper, if you look at the whole picture, particularly if you look at costs caused by complications and personnel costs required to do it safely.

Second, a single major disaster with any technique can destroy cost effectiveness. And finally, at least in my experience, TPN because of its reliability and my ability to control the formula in a very precise manner, is still the standard for early postinjury care despite the encouraging results of these excellent papers.

Thank you very much for the opportunity to discuss this paper.

DR. G. H. A. CLOWES (New England Deaconess Hospital, Boston, MA 02215): I have found these two papers remarkably interesting. The only trouble is that there have been no good parameters measured relative to protein synthesis and immunocompetence. Somehow or other nitrogen balance and caloric balance are not what we are really interested in. We are interested in protein synthesis for the principal purposes of maintenance of immunocompetence, for wound healing, and for the preservation of organ function. None of these things are really measured in these papers.

One wonders about the low incidence of infection. Were the patients really as seriously injured as in many other reported series?

Although I don't have any data to support either of these regimes, one favors the enteral route because that is nature's way. The other point is that made by Doctor Border which is that feeding the intestine is good for maintenance of its protein structure and its immunological function. Probably with a big enough series, there might be a lesser incidence of multisystem failure.

I am sorry about these rambling remarks, but I don't think either paper quite settles the issue.

Thank you.

DR. HARRY DELANY (North Central Bronx Hospital, Bronx, NY 10467): I very much enjoyed the paper.

There have been several reports in the literature recently that criticized needle catheter jejunostomy and jejunostomy feedings because of the high incidence of both local problems with the catheter and diarrhea.

My question, Doctor Dellinger, is how did you define diarrhea? In some of those articles they state that the incidence was as high as 30 to 40%, but again no clear definition of whether it was two bowel movements, three bowel movements, or watery discharge.

Please let me know what your definition was.

DR. BRIAN ROWLANDS (6431 Fannin, Houston, TX 77030): Despite Doctor Clowes' reservations about nitrogen balance, I would like to ask the authors about the nitrogen balance throughout the study period. I do not think it is legitimate to compare nitrogen balance throughout the 14-day study period. Some differences between the groups might be revealed if the data were analyzed either daily, or in blocks of several days, which correspond to the catabolic, anabolic, and recovery phase of the metabolic response to injury.

DR. FRANCIS C. NANCE (St. Barnabas Med. Ctr, Livingston, NJ 07039): Can I ask you from a strictly cost benefit, you are saying that the best strategy is to hyperaliment for 3 days and then given enteral feedings? Since that is the point that the two lines cross in your data. [Laughter]

DR. E. P. DELLINGER (Closing): Mathematically that is not correct. I am not sure I have time to explain that. I suspect you are pulling my leg. [Laughter]

I would like to thank Doctor Long for your very kind comments. You mentioned that there is often an assumption that enteral feedings are simple and TPN complex and that that is the reason to favor enteral.

Actually, I think our study supports exactly the opposite. We had trouble with our enteral feedings at first, and I think that is because parenteral feeding has had a lot of attention placed on it in the last decade or so as it became more widely used and we have learned to do it well, and enteral feedings have been neglected.

[Slide] I didn't have time in the 10-minute presentation to discuss this, but we did have an initial phase of this study where we started our prescriptions at 1.68 times basal energy expenditure, and we found we had a very high rate of negative nitrogen balance and of patients who never achieved nitrogen balance, and we also found that this was far worse in the enteral group than it was in the parenteral group. When we analyzed our data, we saw that what we had ordered for the patients was not being delivered. There are a variety of reasons for this, one of which is that the nurses and the house staff are much more casual about interrupting enteral feedings than parenteral feedings.

[Slide] You see here in Phase I that 88% of parenteral patients achieved positive nitrogen balance whereas 58% of our enteral patients did at first, and it took much longer for the enteral feeding patients to get to nitrogen balance.

In the second part of the study we increased the total prescription, and we put a 20% fudge factor in. We ordered more enteral feedings than we wanted in order to get what we wanted. With this prescription a much higher proportion of both patient groups achieved a positive nitrogen balance.

You mentioned that perhaps striving for nitrogen equilibrium is more important than an arbitrary basal energy expenditure. We agree. We used a factor times basal energy expenditure as something to start with.

You asked whether we compared the Isocal versus Traumacal patients. That change was made very early in the study. We don't have enough Isocal patients to really compare.

We agree that a low calorie to nitrogen ratio is preferable.

You also commented on not translating our experience with jejunostomy feedings into nasoenteral feedings. I agree wholeheartedly. That is why we stressed that if the belly is open and if the patient is nutritionally at risk, that we believe a jejunostomy should be placed at the original laparotomy.

I view the attempted placement of nasoenteral tubes in ICU patients as a way to harrass the house officers, and the ICU nurses.

Doctor Clowes, you mentioned that there really is limitation in our information regarding nitrogen balance and caloric intake and that what is more interesting and important is protein synthesis. I couldn't agree more. We weren't set up to look at that, and took the poor man's way at it.

Doctor Delany, you asked how we define diarrhea. It was three or more liquid stools a day.

[Slide] Doctor Rowlands, this shows the average nitrogen balance for each group. Unfortunately, we have lumped Phase I and Phase II here. You can see there is quite a dip in the jejunostomy group in days 4 to 8. This was the time period when patients were most likely to be going back to the OR for another procedure or down to the CT suite or something, and when the house officers and the nurses were stopping the enteral feeding, and so what we were striving for wasn't being delivered here.

I think that is something that for the most part can be corrected with more experience with the technique.

I would like to thank the Association for the privilege of presenting this paper and the audience for hanging around. [Applause]