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Immediate Postoperative Enteral Feeding Results in Impaired Respiratory Mechanics and Decreased Mobility

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Objective

The authors set out to determine whether immediate enteral feeding minimizes early postoperative decreases in handgrip and respiratory muscle strength.

Summary Background Data

Muscle strength decreases considerably after major surgical procedures. Enteral feeding has been shown to restore strength rapidly in other clinical settings.

Methods

A randomized, controlled, nonblinded clinical trial was conducted in patients undergoing esophagectomy or pancreatoduodenectomy who received immediate postoperative enteral feeding via jejunostomy (fed, $n = 13$), or no enteral feeding during the first 6 postoperative days (unfed, $n = 15$). Handgrip strength, vital capacity, forced expiratory volume in one second (FEV_1), and maximal inspiratory pressure (MIP) were measured before surgery and on postoperative days 2, 4, and 6. Fatigue and vigor were evaluated before surgery and on postoperative day 6. Mobility was assessed daily after surgery using a standardized descriptive scale. Postoperative urine biochemistry was evaluated in daily 24-hour collections.

Results

Postoperative vital capacity ($p < 0.05$) and FEV_1 ($p = 0.07$) were consistently lower (18%–29%) in the fed group than in the unfed group, whereas grip strength and maximal inspiratory pressure were not significantly different. Postoperative mobility also was lower in the fed patients ($p < 0.05$) and tended to recover less rapidly ($p = 0.07$). Fatigue increased and vigor decreased after surgery (both $p \le 0.001$), but changes were similar in the fed and unfed groups. Intensive care unit and postoperative hospital stay did not differ between groups.

Conclusions

Immediate postoperative jejunal feeding was associated with impaired respiratory mechanics and postoperative mobility and did not influence the loss of muscle strength or the increase in fatigue, which occurred after major surgery. Immediate postoperative enteral feeding should not be routine in well-nourished patients at low risk of nutrition-related complications.

Respiratory muscle and handgrip strength decrease substantially after major elective surgery, and it seems likely that the consequences of diminished strength and mobility are important causes of postoperative morbidity and mortality, particularly among older patients.[1,2] In fasted individuals and malnourished patients with inflammatory bowel disease, the provision of appropriate nutrients rapidly improves muscle function and increases handgrip and respiratory muscle strength.[3,4] Strength has not been consistently influenced by enteral feeding in surgical patients, but improved nitrogen balance, a lower incidence of septic complications, and improved wound healing responses have been described in various reports.[5-9] Enteral feeding also may minimize the catabolic responses to surgical stress.[10,11]

Placement of a feeding jejunostomy at the time of esophagectomy or procedures of similar magnitude is routine in our institution in anticipation of the possible need for nutritional support in the event of complications. We hypothesized that postoperative weakness would be minimized and the recovery of strength accelerated in such patients if they received early enteral feeding. The principal aim of this study was to compare changes in handgrip and respiratory muscle strength in patients undergoing major elective surgery between those who received immediate postoperative enteral feeding and those who did not.

METHODS

Patients for whom major elective abdominal or thoracic surgery was planned during which a jejunostomy catheter routinely is placed were considered for study. Patients must have been previously independent, community-dwelling individuals, and capable of cooperating with the protocol. Metastases identified before surgery or at the time of surgery, diabetes mellitus, and corticosteroid use were exclusions. Nutritional status (Subjective Global Assessment), smoking history, weight loss, and habitual level of physical activity were documented before surgery.[12,13]

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Immediately after surgery, patients were assigned to immediate postoperative enteral feeding or to receive no feeding during the first 6 postoperative days, using consecutive sealed envelopes. Randomization in a blocked design was determined using standard software (DESIGN 3.0, Systat Inc, Evanston, IL). Patients assigned to the immediate feeding (fed) group received a conventional enteral nutrient solution (Jevity; Ross Laboratories, Montreal, PQ) via jejunostomy tube. Full-strength feeding was begun within 6 hours after surgery at a rate of 20 mL/hour until the first postoperative morning, increased to half the target rate at that time, and increased as tolerated to the target rate on the second postoperative morning. The maximum rate of feeding was the lesser of 125% of preoperative (measured or estimated) caloric expenditure, or 2500 mL per day. Energy expenditure was measured early on the morning of surgery in seven patients in the fed group and six patients in the unfed group by respiratory gas exchange using a metabolic cart and canopy system (Horizon System, SensorMedics, Anaheim, CA). The enteral preparation provided 4.4 g protein and 445 kJ/100 mL (calorie: nitrogen ratio 150:1). Actual volumes administered were recorded daily. Intolerance of feeding (usually abdominal distension) was managed by decreasing or discontinuing feeding for 12 to 24 hours or until clinical resolution. Patients randomized to the unfed group received enteral nutrition at the discretion of the attending service no sooner than the sixth postoperative day, as has been standard clinical practice in our institution.

Handgrip strength was measured early on the morning of operation (day 0) and again on the mornings of postoperative days 2, 4, and 6 using a handgrip dynamometer (Jamar Model 1 Dynamometer, J A Preston, Toronto, ON). Handgrip strength was taken as the highest of three brief, maximal voluntary contractions in each hand, obtained 30 to 60 seconds apart, with the arm in a position of maximum comfort and the patient seated.[14] Maximal inspiratory pressure (MIP) after tidal expiration was measured using a pressure manometer (A F Hall, Burlington, ON) and forced vital capacity and forced expiratory volume in one second (FEV_1) were measured using a portable spirometer (Vitalograph Compact, Roxon medi-tech, Montreal, PQ), seated and at the same times as the handgrip measurements.[15] Body weight was measured on the morning of operation and postoperative day 6. All grip strength, respiratory, and body weight determinations were made by one individual (SMK).

Consecutive 24-hour urine collections were obtained

Table 1. PATIENT DEMOGRAPHICS: MEAN ± STANDARD DEVIATION

	Fed	Unfed
Number	13	15
Age (yr)	64 ± 11	61 ± 12
Sex (male:female)	11:2	11:4
Weight (kg)	72.2 ± 13.5	69.8 ± 13.6
Body mass index (m^2)	25.1 ± 3.1	24.3 ± 3.5
Preoperative weight loss reported (n)	3	11*
Preoperative weight loss (kg)	7.4 ± 2.8 (n = 3)	10.7 ± 4.7 (n = 11)
Subjective Global Assessment (A:B:C)	12:1:0	10:4:1
Epidural anesthesia (Y:N)	9:4	7:8

* $p < 0.05$ by Fisher exact test.

beginning at 7 AM on the morning of operation and continuing to 7 AM on the morning of the sixth postoperative day. Total nitrogen was determined by pyrochemiluminescence (Antek Chemiluminescent Nitrogen System AK-703C; Antek Instruments Inc, Houston, TX) and urea nitrogen and creatinine by standard methods. Glucose, insulin, C-peptide, glucagon, phosphate, calcium, magnesium, albumin, and total protein were measured in serum obtained before surgery and on the sixth postoperative day using standard methods.

A Profile of Mood States questionnaire (POMS; Educational and Industrial Testing Service, San Diego, California) was completed by patients before surgery and on postoperative day 6 to assess vigor and fatigue. Fatigue also was assessed using a visual analog scale.[16] The maximum level of physical activity achieved each day was documented using a descriptive scale (0, bedrest; 1, up on side of bed; 2, up to bathroom only; 3, up and about in room; 4, walking on ward; and 5, walking off ward). Visual analog pain scale scores were obtained in relation to performance of the strength measures on each occasion.[17] Narcotic administration was assessed daily from the day of surgery to the sixth postoperative day in terms of morphine equivalents.[18]

Data are expressed as mean ± standard deviation. Unpaired t-tests and Fisher's exact test were used for comparison of preoperative variables between groups; repeated measures analysis of variance was used for comparisons between fed and unfed groups over time. Sample size estimate was based on handgrip data from a previous study[1] and suggested that the inclusion of 20 patients in each group would allow detection of a difference of clinical interest with alpha < 0.05 and power $>80\%$. The protocol was reviewed and approved by the Research Ethics Committee of the Ottawa Civic Hospital, and written consent was obtained from each patient. Enrollment in the study was discontinued when unanticipated adverse effects of immediate enteral feeding were identified.

RESULTS

Forty-seven patients gave preoperative consent to participate in the study and 12 declined. Of the forty-seven patients, 16 were not randomized after surgery because of unresectability, gross metastatic disease identified at surgery, or a complicated intraoperative course. Thirty-one patients were assigned at random to immediate (n = 15) or delayed (n = 16) enteral feeding. One patient in the unfed group elected to withdraw on the fifth postoper-

Table 2. HANDGRIP STRENGTH AND SPIROMETRY: MEAN ± STANDARD DEVIATION

	Fed or Unfed	Preoperative	Postoperative Day 2	Postoperative Day 4	Postoperative Day 6
Handgrip (R) (kg)	Fed	40 ± 12	33 ± 13	33 ± 13	35 ± 12
	Unfed	40 ± 12	29 ± 11	31 ± 11	33 ± 12
Handgrip (L) (kg)	Fed	38 ± 11	31 ± 12	32 ± 11	33 ± 11
	Unfed	39 ± 12	27 ± 9	31 ± 11	32 ± 11
Forced expiratory	Fed	2.9 ± 1.0	0.9 ± 0.3	1.1 ± 0.7	1.4 ± 0.8
volume (1 sec) (L)*	Unfed	3.0 ± 0.7	1.1 ± 0.4	1.5 ± 0.4	1.7 ± 0.5
Vital capacity (L)†	Fed	3.9 ± 1.1	1.2 ± 0.4	1.5 ± 0.8	1.8 ± 1.0
	Unfed	4.1 ± 0.8	1.6 ± 0.6	2.1 ± 0.5	2.4 ± 0.6
Maximal inspiratory	Fed	−59 ± 11	−31 ± 7	−31 ± 7	−41 ± 7
pressure (cm H_2O)	Unfed	−57 ± 12	−26 ± 8	−34 ± 8	−40 ± 5

* $p = 0.07$, fed *vs.* unfed.
† $p < 0.05$, fed *vs.* unfed.

Table 3. FATIGUE AND VIGOR: MEAN ± STANDARD DEVIATION

	Fed or Unfed	Preoperative	Day 6
Vigor*	Unfed	62 ± 8	53 ± 10
	Fed	59 ± 11	50 ± 11
Fatigue*	Unfed	45 ± 7	50 ± 11
	Fed	44 ± 8	55 ± 7
Fatigue (mm)†	Unfed	33 ± 12	79 ± 19
	Fed	32 ± 20	82 ± 19

* Profile of mood states.
† Visual analog scale.

ative day. Postoperative measurements could not be made in two patients in the fed group, one of whom multiple organ failure developed. In the second patient, the jejunum became detached from the abdominal wall and feeding catheter, necessitating laparotomy. Data from 13 patients randomized to the fed group and 15 to the unfed group were analyzed.

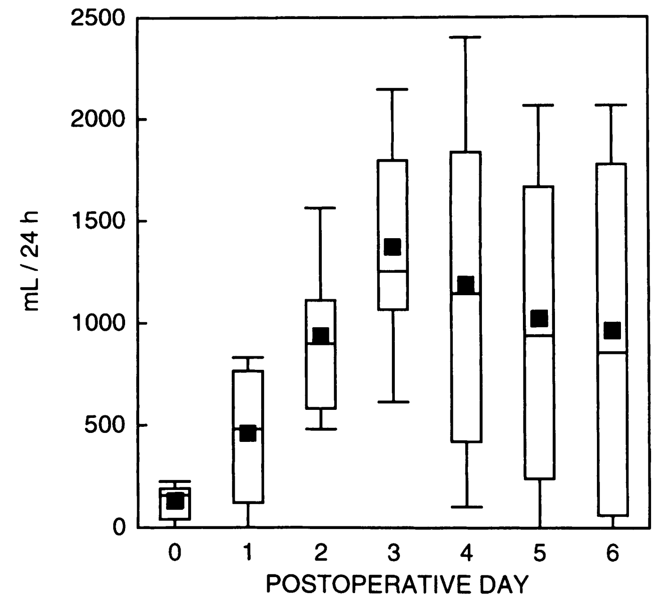

Figure 1. Box plots of daily volumes of enteral feeding. Means are shown as closed squares. Top, middle, and bottom bars represent 75th, 50th (median), and 25th percentiles, respectively. The whiskers on the bottom and top extend from the 10th to the 90th percentiles.

Table 4. SERUM BIOCHEMISTRY: MEAN ± STANDARD DEVIATION

	Fed or Unfed	Preoperative	Day 6
Glucose	Fed	6.6 ± 1.4	6.3 ± 1.5
(mmol/L)	Unfed	6.5 ± 1.5	5.7 ± 0.9
Insulin	Fed	89 ± 65	117 ± 102
(pmol/L)	Unfed	76 ± 61	54 ± 52
C-Peptide	Fed	999 ± 529	1150 ± 539
(pmol/L)	Unfed	912 ± 491	771 ± 599
Glucagon	Fed	22 ± 7	25 ± 9
(pmol/L)	Unfed	23 ± 5	24 ± 7
Albumin*	Fed	40 ± 5	31 ± 4
(g/L)	Unfed	41 ± 4	34 ± 4
Total protein*	Fed	74 ± 4	58 ± 5
(g/L)	Unfed	70 ± 6	57 ± 4
Urea nitrogen	Fed	4.9 ± 1.3	6.8 ± 3.7
(mmol/L)	Unfed	4.5 ± 1.7	4.1 ± 2.7
Creatinine*	Fed	92 ± 15	77 ± 19
(mmol/L)	Unfed	88 ± 21	78 ± 23
Potassium	Fed	4.3 ± 0.4	4.2 ± 0.3
(mmol/L)	Unfed	4.2 ± 0.3	4.3 ± 0.6
Phosphate†	Fed	0.95 ± 0.22	1.11 ± 0.33
(mmol/L)	Unfed	1.15 ± 0.20	1.18 ± 0.33
Magnesium	Fed	0.80 ± 0.15	0.85 ± 0.09
(mmol/L)	Unfed	0.86 ± 0.09	0.71 ± 0.11
Calcium*	Fed	2.26 ± 0.11	1.99 ± 0.28
(mmol/L)	Unfed	2.34 ± 0.11	2.11 ± 0.23

* $p < 0.001$, preoperative *vs.* day 6.
† $p < 0.05$, fed *vs.* unfed.

The fed and unfed groups were similar in terms of age, weight, height, body mass index, smoking status, gender distribution, preoperative nutritional status, and habitual activity level (Table 1). Most patients were well nourished by Subjective Global Assessment and only one, in the unfed group, was severely malnourished. Recent weight loss was reported more frequently ($p < 0.05$) in the unfed group than in the fed group. Two patients in the fed group had benign disease, whereas all in the unfed group had malignancy (NS). All patients underwent esophagectomy except one in the unfed group who underwent pancreaticoduodenectomy. The surgical approach included thoracotomy in all patients but two in the fed group and four in the unfed group (NS). Duration of the surgical procedure and the use of epidural anesthesia were similar in the two groups. Preoperative grip strength, respiratory variables, vigor, and fatigue were similar in the two groups (Tables 2 and 3). Age and gender were significant predictors of FEV_1, vital capacity, and MIP ($r^2 = 0.31$–0.45, all $p < 0.05$). Handgrip strength was strongly related to age, gender, and nutritional status (left, $r^2 = 0.58$, all $p < 0.05$ and right, $r^2 = 0.69$, all $p \leq 0.001$). Handgrip strength, FEV_1, and vital capacity also were related to body weight and age ($r^2 = 0.29$–0.53, all $p < 0.05$). Preoperative serum biochemistry was not different between groups with the exception of serum phosphate, which was slightly lower in the fed group ($p < 0.05$) (Table 4). Oral intake was resumed no sooner than the sixth postoperative day in any patient.

The enteral feeding rate was at least 480 mL/24 hours

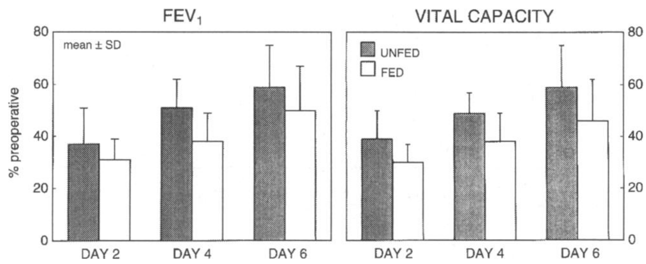

Figure 2. Vital capacity and forced expiratory volume in one second (FEV_1) on postoperative days 2, 4, and 6 expressed as a percentage of preoperative values (mean ± standard deviation); $p < 0.05$ and $p = 0.07$, fed vs. unfed, for vital capacity and FEV_1, respectively.

on the second postoperative day in all patients randomized to immediate feeding and was 960 mL or more in 10 of 13 patients on the third postoperative day (Fig. 1). Three and five patients received <480 mL on the fifth and sixth postoperative days, respectively. Temporary reductions from the target rate of administration were made in eight patients (62%), because of abdominal distension in all instances but one, for whom the reason was diarrhea.

Handgrip strength, FEV_1, vital capacity, and MIP each decreased after surgery, comparing postoperative day 2 with preoperative values (all $p < 0.001$). Decreases in handgrip and respiratory variables were not related to preoperative values or to age, gender, smoking history, diagnosis of cancer, or the use of thoracotomy or epidural anesthesia. Left and right handgrip strength and MIP on postoperative days 2, 4, and 6 were similar in the two groups. Vital capacity was lower (25%–29%) in the fed compared to unfed group throughout the postoperative period of study ($p < 0.05$), and the difference in FEV_1 (18%–27%) approached statistical significance ($p = 0.07$) (Fig. 2). The recovery of the handgrip and respiratory variables after surgery (i.e., group-time interaction) was similar in the fed and unfed groups. Daily postoperative maximal activity levels were higher ($p < 0.01$) and tended to recover more rapidly ($p = 0.07$) in the unfed group (Fig. 3). Among patients in the fed group, postoperative strength values and rate of recovery were not related to the tolerance of feeding. Visual analog pain scale scores and narcotic administration did not differ between fed and unfed groups (Table 5). Vigor declined after surgery ($p < 0.001$), but there was no difference between groups. Fatigue, assessed by visual analog scale and by POMS, increased markedly from preoperative values to postoperative day 6 (both $p \leq 0.001$), but did not differ between groups.

Serum albumin, total protein, creatinine, and calcium decreased after surgery (all $p < 0.001$) but were not different between groups. Serum magnesium increased from preoperative to postoperative day 6 in the fed group relative to the unfed group ($p = 0.002$). Postoperative urine volume was lower and nitrogen excretion higher (both $p < 0.05$) in the fed group; urine creatinine and cortisol were not different (Table 6). Body weight on postoperative day 6 was not different from preoperative weight in either group. Three anastomotic leaks were clinically evident in the unfed group and one was diagnosed radiologically, compared with one leak apparent only on contrast radiography in the fed group ($p = 0.23$ for clinical leaks). Length of stay in the intensive care unit (2.9 ± 1.7 and 2.3 ± 1.2 days in the fed and unfed groups, respectively) and overall postoperative length of stay (17 ± 9 and 16 ± 7 days, respectively) did not differ between groups.

DISCUSSION

The patients in the fed and unfed groups were similar in terms of most preoperative and intraoperative clinical, biochemical, and other variables likely to influence postoperative strength. Preoperative handgrip strength and spirometry were related to the expected predictors (e.g., age, gender, and body weight) and were similar in the two groups. More patients in the unfed group reported preoperative weight loss; however, such weight loss should offer no benefit and more probably disadvantaged the unfed patients in maintaining handgrip and respiratory muscle strength after surgery. The exclusion of the two patients in the fed group who sustained major postoperative complications and were unable to complete the study should have further biased the results in favor of the fed group.

The feasibility of immediate postoperative feeding via nasoenteric tube or jejunostomy has been shown in exten-

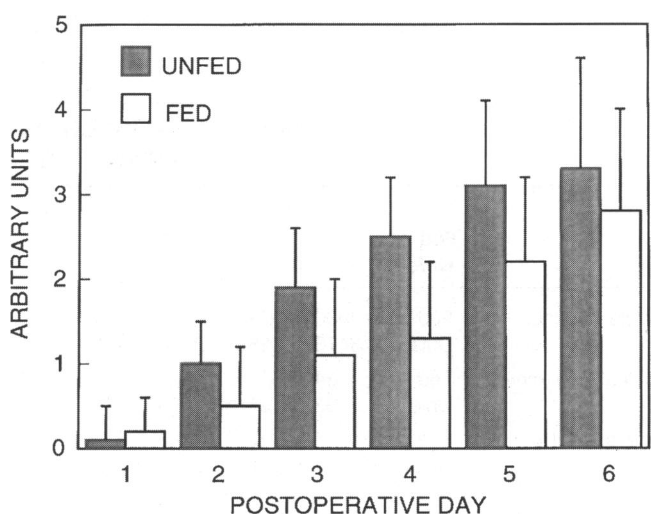

Figure 3. Daily maximal level of activity in the postoperative period according to a standardized descriptive scale (mean ± standard deviation); $p < 0.01$, fed vs. unfed.

Table 5. POSTOPERATIVE PAIN AND ANALGESIA: MEAN ± STANDARD DEVIATION

	Fed or Unfed	Postoperative Day 0	1	2	3	4	5	6
Narcotic administration (mg morphine equivalents)	Fed	58 ± 54	43 ± 35	33 ± 30	32 ± 27	35 ± 34	24 ± 18	11 ± 16
	Unfed	34 ± 28	42 ± 28	33 ± 16	39 ± 19	25 ± 20	24 ± 19	16 ± 18
Visual analog pain scale score (mm)	Fed	—	—	41 ± 27	—	40 ± 20	—	28 ± 27
	Unfed	—	—	50 ± 23	—	39 ± 29	—	22 ± 18

sive clinical experience over many years.[19] The nature of the enteral preparations has varied widely, and we chose a conventional preparation in common use in our institution for comparison with unfed control subjects. The rates of infusion and final target that we used are similar to those of other recent studies of elective surgical patients, although perhaps higher than were the study to be designed now.[9,20–23] Methods of reporting the tolerance of feedings also have varied considerably, but clinically significant intolerance is described in several recent series of elective surgical patients. In one recent study, feeding was considered to have been established successfully in 75% of patients.[9] Twenty-two (79%) of 28 patients in another report received >600 kcal/day from a standard enteral diet.[23] Eighteen (72%) of 25 patients achieved a feeding rate of >40 mL/hour in a third series[20]; however, gastrointestinal complications were described in 15 (83%) of 18 patients receiving a standard enteral preparation, most commonly nausea and vomiting, distension, and diarrhea. Feeding was termed successful in all 14 patients in another study, with no ''excessive'' distension, although abdominal distension and other gastrointestinal disturbances were noted in both fed and control patients.[21] Thus, the alteration of the feeding rate at some point in eight (62%) of our patients is in keeping with the experience of others.

Maximum voluntary handgrip contraction is a reproducible and responsive measure of muscle strength, which has been used extensively in studies of surgical patients and nutritional interventions.[1,24,25] Preoperative grip strength has been shown to predict postoperative complications and length of hospital stay in patients undergoing a variety of surgical procedures.[14,26–29] Delayed recovery of grip strength after major vascular surgery has been associated with increased morbidity, especially septic complications.[30] The extent of postoperative decreases in grip strength has been shown to reflect the magnitude of the procedure and, as expected, the postoperative decreases in grip strength in this study are more marked than we and others have observed after less major procedures.[1,24,25]

Nutritional support has been accompanied by rapid im-

Table 6. URINE BIOCHEMISTRY (24 HOUR COLLECTIONS): MEAN ± STANDARD DEVIATION

	Fed or Unfed	Postoperative Day 0	1	2	3	4	5	6
Volume* (mL)	Fed	2930 ± 1490	2190 ± 1140	2250 ± 1120	1910 ± 910	1320 ± 870	1420 ± 890	1550 ± 640
	Unfed	3410 ± 1280	2780 ± 1680	2170 ± 850	2010 ± 1240	1650 ± 1200	1980 ± 990	1900 ± 680
Creatinine (mmol)	Fed	94 ± 51	100 ± 60	102 ± 57	96 ± 46	100 ± 47	112 ± 50	95 ± 46
	Unfed	92 ± 49	76 ± 34	84 ± 32	95 ± 44	69 ± 41	78 ± 42	84 ± 36
Nitrogen* (g)	Fed	7.7 ± 3.5	8.5 ± 5.3	8.9 ± 6.5	9.3 ± 5.2	10.3 ± 4.2	11.7 ± 4.3	11.6 ± 6.3
	Unfed	5.4 ± 2.9	6.6 ± 3.8	7.2 ± 4.8	7.6 ± 3.5	6.2 ± 3.1	7.3 ± 3.9	6.7 ± 2.9
Cortisol (nmol)	Fed	2240 ± 510	710 ± 440	355 ± 270	380 ± 370	370 ± 320	240 ± 200	325 ± 264
	Unfed	2250 ± 890	742 ± 560	270 ± 230	370 ± 520	190 ± 210	270 ± 200	190 ± 150

* $p < 0.05$, fed *vs.* unfed.

provements in muscle strength and function in malnourished patients and fasted subjects in nonsurgical settings.[3,4,31] Postoperative supplemental "sip" feeding also has been associated with improved postoperative handgrip strength in one study of elective abdominal surgical patients.[8] Thus, we postulated that immediate enteral feeding via jejunostomy would minimize the loss of strength that occurs after major surgical procedures. Recruitment to the study was terminated before the planned enrollment of 20 patients per group because of effects on respiratory mechanics. However, postoperative grip strength did not differ significantly between the fed and unfed groups ($p = 0.40$ and 0.34 for right and left handgrip, respectively). There also was no influence of feeding on postoperative fatigue or vigor. The lack of a major effect of enteral nutritional support on postoperative grip strength is consistent with the observations of Schroeder et al.,[9] who assessed both voluntary grip strength and involuntary muscle function using ulnar nerve stimulation before surgery and 2 weeks after surgery. Postoperative nutrition support has been associated with preservation of grip strength in one report, but with a rather different protocol using an oral dietary supplement.[8] Supplements were begun on the sixth postoperative day on average, and grip strength measurements made 3 days later and at discharge and compared with preoperative values. Perhaps a beneficial effect of immediate enteral feeding on grip strength would have been apparent if assessed later in the postoperative period than our measurements were made or if we had selected patients with significant preexisting malnutrition or poor recent nutritional intake.[32,33] However, postdischarge nutritional supplementation did not result in preservation of strength, functional capacity, or quality of life in a recent randomized trial.[34] Postoperative losses in lean body mass were more marked in the legs than in the arms and trunk, suggesting that decreases in strength may be more apparent in the lower extremities.[34]

The most sensitive clinical measures of respiratory muscle strength are maximal inspiratory and expiratory pressures, and we observed no difference in MIP between fed and unfed groups.[15] Vital capacity and FEV_1 also reflect the strength of the respiratory muscles in part, but are influenced by other factors as well.[35] Substantial decreases in vital capacity and FEV_1 after abdominal and thoracic operations have long been recognized, and our observations are consistent in this regard.[36–38] Such changes reflect diminished neural drive to the diaphragm and a reduction in the ratio of abdominal-to-rib-cage motion, and they predispose to increased closure of small airways, atelectasis, and ventilation-perfusion mismatch.[39–44] Vital capacity and FEV_1 were reduced markedly after surgery in all patients and, unexpectedly, were 18% to 29% lower in the patients receiving immediate jejunal feeding compared with those who were not fed. Reductions in planned rates of enteral feeding were made in approximately half of fed patients because of clinically apparent abdominal distension, and such distension may have been an important causative factor. However, even mild degrees of distension, insufficient to elicit clinical attention, may have been significant. Vital capacity and FEV_1 were lower in fed patients as early as the second postoperative morning, despite enteral feeding rates, which were relatively low (maximum 40 mL/hour) and very good tolerance of feeding from a clinical perspective. Moreover, among fed patients, postoperative vital capacity and FEV_1 did not differ between those who tolerated feeding uneventfully and those who did not. Perhaps compensatory mechanisms prevented further declines in vital capacity and FEV_1 in those who became overtly distended compared with those who were fed but did not; alternatively, there may simply be inadequate statistical power within this small fed group to show such differences. The impairment of vital capacity and FEV_1 in the enterally fed group seems most likely to be related to abdominal distension sufficient to influence diaphragm function even if not clinically recognized or of a magnitude sufficient to elicit a change in management. Diminished vital capacity and FEV_1 in the fed patients could contribute to the development of postoperative respiratory complications and to increased work of breathing.[2,45] We did not assess such complications directly, but intensive care unit and total postoperative lengths of stay did not differ between groups. The explanation for the lower level of physical mobility after surgery in the fed patients is unclear. Presumably, there are many factors that influence early postoperative mobility, including muscle strength, respiratory status, pain, the presence of intravenous catheters and other tubes and drains, sense of well-being, motivation, and protocols for clinical care.

The benefits of enteral feeding in surgical patients are widely accepted, specifically an enhancement of immunocompetence, reduced clinical infection rates, maintenance of gut structure and function, and potentially attenuation of catabolic stress responses.[6,7,10,11,46] Enteral feeding after laparotomy for abdominal trauma has been accompanied by a reduction in septic complications in patients receiving jejunal feeding beginning 12 to 18 hours after surgery compared with control subjects given parenteral nutrition from the fifth postoperative day.[6] A reduction in septic complications in high-risk surgical patients receiving postoperative enteral feeding versus parenteral nutrition also has been identified in a meta-analysis of eight randomized, controlled trials.[7] Notably, the reduction was most significant among trauma patients, and the overall incidence of postoperative septic complications was considerably lower in nontrauma surgical patients. Incorporation of hydroxyproline into a subcutaneous Gortex tube, taken as a marker of wound healing activity, was increased in enterally fed patients compared with unfed control subjects in another report.[9] Anastomotic healing also might be influenced by the redistribution of bloodflow and oxygen delivery to the gut, which has been shown to accompany continuous duodenal feeding in a canine model of positive pressure ventilation.[47] We did observe fewer anastomotic leaks among fed than unfed patients, but this difference was not statistically significant and may be attributable to other factors such as the greater preoperative weight loss among the unfed patients. We did not observe a difference in urine cortisol between groups to suggest that enteral feeding altered the neuroendocrine responses to these surgical procedures.

In summary, we have conducted a randomized clinical trial of immediate jejunal feeding after major surgery compared with no nutritional support. Postoperative decreases in muscle strength and vigor and increases in fatigue were substantial and similar in the fed and unfed groups. Unexpectedly, postoperative decreases in vital capacity and FEV_1 were more marked in fed patients, and postoperative mobility was impaired to a greater extent. These adverse effects limit the net clinical benefit of early enteral feeding. Immediate postoperative enteral feeding should not be routine in well-nourished patients at low risk of nutrition-related complications.

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Discussion

DR. JONATHAN L. MEAKINS (Montreal, Canada): Nutritional support has enjoyed enormous popularity in surgical clinical practice and has indeed changed outcome in a number of areas. It certainly can be considered to be one of the most important advances both enterally and parenterally.

In elective surgery, there were hopes for dramatic reductions in complications with the use of either of these modalities. The Veterans Affairs study of total parenteral nutrition (TPN), which indicated only in major malnutrition were there clear benefits, and surprisingly, in the other groups that TPN was associated with a higher rate of complications rather than a lower rate.

Enteral feeding is a more physiological approach, and in trauma and other stress areas, appears to have proven its worth. Today Dr. Watters has shown that routine early postoperative enteral feeding in nourished patients having an esophagectomy not only does not improve outcome but has a cost. That cost to the patient is with respect to respiratory function, specifically reduced vital capacity, and FEV_1, as well as their activity levels, both of which intuitively, although the data do not demonstrate it in terms of complications, are associated with increased complications.

When Dr. Watters first showed me these data last summer, my response was, well, the data are the data, but I did not have any expectations that I might be expected to comment on them in a public forum and try to find a way to explain them, which unfortunately I cannot. These results fall into the category of the unexpected and unanticipated results articulated yesterday by President Barker.

The study is remarkable not only for its results, but for its design because the control group received no feeding, counterculture in the present surgical practice but design-wise quite correct as no extra feeding was the usual standard of care. When we evaluate new changes in therapy, we should use controls with no additional therapy rather than comparing two specific forms of therapy and saying that one is better than the other when we do not know whether either is better than nothing.

Dr. Watters, if the vital capacity or FEV_1 changes and the reduction in activity cannot be explained on the basis of any differences in pain control, which was one of my initial thoughts, can they be explained on the basis of distension from the feeding and accompanying fermentation and gas production with increased abdominal contents and therefore resistance to vital capacity and FEV_1? Would indeed another solution that might be metabolized differently by the gastrointestinal tract be of use?

In light of the philosophy of the use of President Barker's unanticipated results, where do you intend to take these results, which show a cost rather than a benefit in the routine use of postoperative feeding jejunostomies?

DR. JOHN L. ROMBEAU (Philadelphia, Pennsylvania): I too congratulate the authors on a very important and intriguing study. As Dr. Meakins mentioned, a very important component of this study is the inclusion of a nonfed control group. In reviewing the postoperative literature on enteral feeding and parenteral feeding, it is very difficult to find the presence of this group. In many instances, the inclusion of this group has not been permitted by many institutional review boards because of inherent biases.

Interestingly, the conclusions of this study parallel those to be presented tomorrow by Dr. Heslin and colleagues, again in a prospective controlled trial in cancer patients, including a nonfed control group.

I have several questions.

A very important determinant in outcome in feeding studies is the preoperative nutritional status of the patients. In review of the manuscript, it was noted that only 1 of 27 patients was characterized as severely malnourished. Many clinicians are now restricting postoperative feeding for the severely malnour-