Who should we feed? A Western Trauma Association multi-institutional study of enteral nutrition in the open abdomen after injury

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BACKGROUND: The open abdomen is a requisite component of a damage control operation and treatment of abdominal compartment syndrome. Enteral nutrition (EN) has proven beneficial for patients with critical injury, but its application in those with an open abdomen has not been defined. The purpose of this study was to analyze the use of EN for patients with an open abdomen after trauma and the effect of EN on fascial closure rates and nosocomial infections.

METHODS: We reviewed patients with an open abdomen after injury from January 2002 to January 2009 from 11 trauma centers.

RESULTS: During the 7-year study period, 597 patients required an open abdomen after trauma. Most were men (77%) sustaining blunt trauma (72%), with a mean (SD) age of 38 (0.7) years, an Injury Severity Score of 31 (0.6), an abdominal injury score of 3.8 (0.1), and an Abdominal Trauma Index score of 26.8 (0.6). Of the patients, 548 (92%) had an open abdomen after a damage control operation, whereas the remainder experienced an abdominal compartment syndrome. Of the 597 patients, 230 (39%) received EN initiated before the closure of the abdomen at mean (SD) day 3.6 (1.2) after injury. EN was started with an open abdomen in one quarter of the 290 patients with bowel injuries. For the 307 patients without a bowel injury, logistic regression indicated that EN is associated with higher fascial closure rates (odds ratio [OR], 5.3; $p < 0.01$), decreased complication rates (OR, 0.46; $p = 0.02$), and decreased mortality (OR, 0.30; $p = 0.01$). For the 290 patients who experienced a bowel injury, regression analysis showed no significant association between EN and fascial closure rate (OR, 0.6; $p = 0.2$), complication rate (OR, 1.7; $p = 0.19$), or mortality (OR, 0.79; $p = 0.69$).

CONCLUSION: EN in the open abdomen after injury is feasible. For patients without a bowel injury, EN in the open abdomen is associated with increased fascial closure rates, decreased complication rates, and decreased mortality. EN should be initiated in these patients once resuscitation is completed. Although EN for patients with bowel injuries did not seem to affect the outcome in this study, prospective randomized controlled trials would further clarify the role of EN in this subgroup. (*J Trauma Acute Care Surg*. 2012;73: 1380–1388. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Therapeutic study, level III.

KEY WORDS: Open abdomen; damage control operation; abdominal compartment syndrome; enteral nutrition.

Enteral nutrition (EN) has been advocated in the surgical patient with critical illness.[1–11] For patients sustaining major abdominal trauma, the reduction in septic complications with the institution of early EN is particularly notable.[1–4] Despite these studies illustrating the importance of EN in the trauma population, there remains hesitancy about enteral feeding for patients with an open abdomen after injury. This may relate to issues of enteral access, concerns about bowel edema, or questions of intestinal motility and enterocyte functionality. The three studies specifically addressing EN in the open abdomen patient have conflicting findings.[12–14] One study reports increased fascial closure rates with the initiation of EN before day 4 after injury,[14] whereas the others show no impact of EN on abdominal closure rates.[12,13] In addition, one study[12] suggests a reduced incidence of ventilator-associated pneumonia with early EN, whereas the others[13,14] show similar rates of infectious complications. Despite these promising early reports, the role of EN for patients with an open abdomen has not been defined. The purpose of this study was to analyze the use of EN for patients with an open abdomen after trauma and the impact on closure rates and nosocomial infections.

PATIENTS AND METHODS

We reviewed patients requiring an open abdomen after trauma from January 1, 2002, to December 31, 2009, from 11 trauma centers from the Western Trauma Association. Patient variables including indications for the open abdomen, presence of bowel injury, type of enteral access, route of EN, timing to abdominal closure, abdominal and infectious complications, and mortality were analyzed. "Trophic feeds" or EN at a "trophic level" was defined as a tube feed rate less than 20 mL/h. Bowel injuries were defined as those full-thickness injuries involving the small bowel or the colon. Additional complications recorded included bacteremia, pneumonia, acute kidney injury, adult respiratory distress syndrome, and multiple-organ failure; complications were analyzed by the individual institutions and were self-reported. Abdominal complications included intra-abdominal abscess, anastomotic leaks, enterocutaneous fistula, and fascial dehiscence. If patients had an intra-abdominal abscess and anastomotic leak, the abscess was considered to be caused by the leak, and the patient was counted only in the leak category. For patients definitively closed with split-thickness skin grafts, "closure day" was defined as the final coverage of

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TABLE 1. EN Versus NPO Patient Populations

	EN (n = 230)	NPO (n =367)	*p*
Demographics			
Age, mean (SEM), y	38.2 (1.1)	31.1 (0.9)	0.94
Male, n (%)	174 (76)	284 (77)	0.63
Penetrating mechanism, n (%)	**51 (22)**	**119 (32)**	**0.007**
ISS, mean (SEM)	**33.8 (0.94)**	**29.6 (0.74)**	**0.005**
AIS, mean (SEM)	3.9 (0.01)	3.8 (0.01)	0.30
ATI score, mean (SEM)	26.3 (0.9)	27.2 (0.8)	0.48
ACS, n (%)	23 (10)	26 (7)	0.21
Bowel injury, n (%)	**74 (32)**	**216 (59)**	**<0.001**
Adjunctive TPN, n (%)	48 (21)	84 (23)	0.56
Resuscitation, mean (SEM)			
24-h crystalloid	13,726 (717)	14,955 (524)	0.16
24-h red blood cells	15 (1.1)	13 (0.6)	0.11
24-h total volume	18,951 (945)	20,636 (728)	0.16
Abdominal operations			
No. laparotomies, mean (SEM)	**4.2 (0.2)**	**3.1 (0.1)**	**<0.0001**
Ultimate fascial closure, n (%)	**171 (75)**	**244 (67)**	**0.03**
Day of final closure, mean (SEM)	**9 (0.9)**	**5 (0.3)**	**<0.0001**
Complications			
Total number, n (%)	**172 (75)**	**235 (64)**	**0.006**
Pneumonia, n (%)	**98 (43)**	**120 (33)**	**0.01**
Abdominal abscess, n (%)	47 (20)	83 (23)	0.53
Anastomotic leak, n (%)	33 (14)	53 (14)	0.97
Enterocutaneous fistula, n (%)	6 (3)	13 (4)	0.80
Abdominal dehiscence, n (%)	7 (3)	11 (3)	0.58
Outcomes			
Percentage of ventilator-free days, mean (SEM)	44 (2.2)	46 (1.1)	0.26
Percentage of ICU-free days, mean (SEM)	32 (2.0)	34 (2.8)	0.26
Hospital days for survivors, mean (SEM)	**36.0 (1.7)**	**27.7 (1.1)**	**<0.0001**
Mortality, n (%)	**21 (9)**	**63 (17)**	**0.006**

Boldface indicates statistical significance.

the bowel by grafts. Patients excluded from the analysis included deaths within 24 hours, identification of injury more than 24 hours, and those transferred from an outside hospital more than 72 hours after initial injury.

Statistical analyses were performed using SAS version 9.2 (SAS Inc., Carey, NC). The alpha error level was set at 0.05, with $p < 0.05$ being considered statistically significant. Continuous data are expressed as mean (SEM), and categorical data are expressed as number (percentage). Differences in the means of continuous variables were compared using the Student's *t* test. Differences in the proportions of categorical variables were compared using the χ^2 test, and unless expected, cell counts were less than 10, in which case Fisher's exact test was used. Multivariable logistic regression analysis was used to assess for the independent contribution of EN to variability in the outcomes of interest. Covariates associated with EN at the $p < 0.20$ level by univariate analysis were added to the model using a forward selection method. To assess and quantify variability in the likelihood of EN among study centers, the mean number of patients who received EN at each site was calculated. When multiple markers of injury severity were associated with EN (e.g., both Injury Severity Score [ISS] and abdominal trauma index [ATI]), only one of the two was added to the regression model to prevent colinearity. The overall contribution of the fitted model to predicting variability in the outcome of interest was assessed using the likelihood ratio χ^2 test. The independent contribution of individual variables was assessed using the Wald χ^2 test. Individual variables are reported as odds ratio (OR) (95% confidence interval). This study was approved by each participating center's institutional review board.

RESULTS

Patient Demographics

During the study period, 597 patients required an open abdomen after trauma. The majority were men (77%) sustaining blunt trauma (72%), with a mean (SD) age of 38 (0.7) years, an ISS of 31 (0.6), and an abdominal injury score [AIS] of 3.8 (0.1). Of the patients, 548 (92%) had an open abdomen after a damage control operation (DCO), whereas the remainder experienced abdominal compartment syndrome (ACS). The mean (SD) ATI score for those patients undergoing DCO was 26.8 (0.6). Of those patients undergoing DCO, 290 patients (49%) had identified bowel injuries: 95 patients had small bowel injuries, 74 patients had colon injuries, and 121 patients had combined small bowel and colon injuries. All patients with a bowel injury had a repair or anastomosis performed, except for nine patients with isolated colonic injuries managed with colostomy.

Infused in the total study population during the first 24 hours were mean (SD) volumes of 14,477 (425) mL of crystalloid and 14 (0.6) U of packed red blood cells. The mean (SD) total number of abdominal operations for the 597 patients was 3.5 (0.1), with closure on day 6.6 (0.4). Of the 597 patients, 245 (43%) attained abdominal closure at the second operation on day 2.96. Reported complications included 130 patients (22%) with intra-abdominal abscess and 218 patients (37%) with pneumonia. Eighty-four patients died, for an overall mortality rate of 14%. The causes were as follows: multiple-organ failure, 23 patients; traumatic brain injury/stroke, 17 patients; sepsis, 16 patients; withdrawal of support, 11 patients; hemorrhage, 6 patients; cardiopulmonary arrest, 5 patients; adult respiratory distress syndrome, 3 patients; pulmonary embolus, 1 patient; and not documented, 2 patients.

EN Versus Nil Per Os

Of the 597 patients, 230 (39%) received EN initiated before the closure of the abdomen, which was started on mean (SD) day 3.6 (1.2) after injury. Of the 230 patients receiving EN, 62% were maintained at trophic level, whereas 38% were advanced to full goal tube feeds before abdominal fascial closure. EN was delivered to the stomach in 139 patients (60%), duodenum in 37 patients (16%), jejunum in 49 patients (21%), and unknown in 5 patients (3%). Of the 597 patients, 42 (7%) had gastrostomy tubes placed operatively and 24 (4%) had operatively placed jejunostomy tubes.

TABLE 2. Categorization of Patients by Presence of Enteric Injuries Stratified by EN Status

	Enteric Injury (n = 290)			No Enteric Injury (n =307)		
	EN (n = 74)	NPO (n = 216)	*p*	EN (n = 156)	NPO (n = 151)	*p*
Demographics						
Age, mean (SD), y	34 (1.1)	38 (1.6)	0.09	40.1 (1.4)	38.5 (1.4)	0.42
Male, n (%)	53 (72)	174 (81)	0.11	121 (78)	110 (73)	0.34
Penetrating mechanism, n (%)	**36 (49)**	**72 (33)**	**0.02**	**15 (10)**	**47 (31)**	**<0.0001**
ISS, mean (SEM)	32.0 (1.7)	29.9 (1.0)	0.29	**34.7 (1.1)**	**29.2 (1.1)**	**0.0007**
ATI score, mean (SEM)	30.9 (1.9)	32.4 (1.0)	0.50	**23.8 (0.9)**	**18.3 (0.9)**	**<0.0001**
Adjunctive TPN, n (%)	**33 (45)**	**59 (27)**	**0.006**	15 (10)	25 (17)	0.07
Resuscitation						
24-h crystalloid, mean (SEM)	15,576 (1,260)	15,446 (606)	0.92	12,896 (866)	14,274 (926)	0.28
24-h red blood cells, mean (SEM)	**19 (2.3)**	**14 (0.9)**	**0.02**	13 (1.2)	12 (0.9)	0.40
24-h total volume, mean (SEM)	22,462 (1,707)	20,870 (864)	0.37	17,265 (1,113)	20,302 (1,269)	0.07
Abdominal operations						
No. laparotomies, mean (SEM)	**5.7 (0.4)**	**3.2 (0.1)**	**<0.0001**	**3.4 (0.1)**	**2.7 (0.1)**	**0.0001**
Ultimate fascial closure, n (%)	**41 (55)**	**169 (78)**	**0.0001**	**130 (84)**	**75 (50)**	**<0.0001**
Day of final closure, mean (SEM)	**13.0 (1.6)**	**4.8 (0.3)**	**<0.0001**	**6.6 (0.4)**	**3.6 (0.3)**	**<0.0001**
Complications						
Total number, n (%)	**59 (80)**	**126 (58)**	**0.0009**	113 (72)	109 (72)	0.96
Pneumonia, n (%)	26 (35)	63 (29)	0.33	72 (46)	57 (38)	0.14
Abdominal complications, n (%)	**33 (45)**	**65 (30)**	**0.02**	14 (9)	18 (12)	0.40
Outcomes						
Percentage of ventilator-free days	51	47	0.3	40	45	0.12
Percentage of ICU-free days	39	34	0.19	28	33	0.05
Hospital days for survivors, mean (SEM)	**46.8 (4.0)**	**29.9 (1.5)**	**<0.0001**	**30.6 (1.3)**	**24.1 (1.4)**	**0.001**
Mortality, n (%)	5 (7)	29 (13)	0.12	**16 (10)**	**34 (23)**	**0.004**

In comparing those patients with an open abdomen who received EN versus those who did not and remained nil per os (NPO), several statistically significant findings were found (Table 1). There was no difference between the two groups in age, gender, AIS, or ATI score. The enterally fed group had a significantly lower percentage of penetrating trauma patients (22% vs. 32%) and a significantly higher ISS (33.8 vs. 29.6). There were a similar number of ACS patients in each group (10% vs. 7%). Crystalloid resuscitation and red blood cell transfusions in the first 24 hours were similar between the EN and the NPO groups (crystalloid, 13,726 vs. 14,955 mL; red blood cells, 15 vs. 13 U). Significantly fewer patients with bowel injuries were started on EN (32% vs. 59%). The rates of adjunctive total parenteral nutrition (TPN) were similar between the two groups (21% vs. 23%). Overall, definitive fascial closure rate was significantly higher in those patients receiving EN (75% vs. 67%), but the time to final closure was significantly longer in the EN group compared with the NPO group (9 vs. 5 days). The total number of abdominal operations was significantly higher in the EN group (4.2 vs. 3.1). Of the total study population, 245 patients (43%) were closed at the second laparotomy at a mean of 2.96 days. Of those receiving EN, 26% were closed at the second exploration versus 54% of those not fed enterally; the initiation of EN in those closed at the second laparotomy was started approximately 12 hours before closure (mean, day 2.3).

The EN group had a higher overall complication rate (75% vs. 64%) and a higher pneumonia rate (43% vs. 33%) compared with the NPO group but similar abdominal complication rates (abscess, anastomotic leak, enterocutaneous fistula, and dehiscence). Ventilator-free days and intensive care unit (ICU)–free days were similar between the two groups, whereas hospital days for survivors were significantly higher in the EN group (36 vs. 28 days). Mortality was significantly lower in the EN group compared with the NPO group (9% vs. 17%).

After a univariate analysis, a logistic regression was performed with variables associated with EN at the $p < 0.20$ level entered into the model. There was a significant variability between study sites in the likelihood of EN (range, 10–100%), fascial closure (range, 27–92%), and mortality (range, 0–24%). As such, the study site could be a significant confounder. Logistic regression was performed for all 597 patients comparing the EN and the NPO groups controlling for site, ISS, mechanism of injury, closure at the second laparotomy, total 24-hour infused volume, and presence of bowel injury. There was an independent association between EN and ultimate fascial closure (OR, 2.1; $p < 0.01$). By logistic regression, there was no association between EN and complication rate (OR, 0.9; $p = 0.68$), but there was an association between EN and decreased mortality (OR, 0.4; $p = 0.01$).

Patients With Enteric Injury

Of the 597 patients, 290 (49%) sustained a bowel injury (Table 2). In patients with an enteric injury, 74 (26%) had an EN started with their abdomen open. In comparing patients with an enteric injury who had EN versus those kept NPO, no

TABLE 3. Analysis of Patients With Open Abdomen After Excluding Those Closed at the Second Laparotomy

	Enteric Injury (n = 169)			No Enteric Injury (n = 151)		
	EN (n = 64)	**No EN (n = 105)**	***p***	**EN (n = 93)**	**No EN (n = 58)**	***p***
Demographics						
Age, mean (SEM), y	**33.8 (1.6)**	**39.6 (1.9)**	**0.02**	39.9 (1.7)	39.2 (2.2)	0.78
Male, n (%)	47 (73)	83 (79)	0.40	71 (76)	38 (66)	0.15
Penetrating mechanism, n (%)	31 (38)	36 (34)	0.07	11 (12)	12 (21)	0.14
ISS, mean (SEM)	32.1 (1.8)	29.7 (1.4)	0.29	36.0 (1.5)	31.2 (1.8)	0.05
ATI score, mean (SEM)	31.7 (2.1)	32.5 (1.4)	0.74	22.8 (1.2)	19.7 (1.3)	0.08
Adjunctive TPN, n (%)	30 (47)	44 (42)	0.53	**11 (12)**	**19 (33)**	**0.002**
Resuscitation						
24-h crystalloid, mean (SEM)	16,920 (1,390)	15,822 (866)	0.49	14,455 (1,341)	15,039 (1,978)	0.80
24-h red blood cells, mean (SEM)	**21 (2.6)**	**15 (1.4)**	**0.04**	15 (1.9)	12 (1.3)	0.12
24-h total volume, mean (SEM)	24,283 (1,869)	22,459 (1,382)	0.42	19,824 (1,690)	21,613 (2,524)	0.54
Abdominal operations						
No. laparotomies, mean (SEM)	**6.5 (0.5)**	**4.7 (0.2)**	**0.0001**	4.1 (0.2)	3.6 (0.2)	0.08
Ultimate fascial closure, n (%)	**35 (55)**	**75 (71)**	**0.03**	**73 (79)**	**26 (45)**	**<0.001**
Day of final closure, mean (SEM)	**14.1 (1.8)**	**7.2 (0.5)**	**<0.0001**	**7.8 (0.5)**	**5.6 (0.5)**	**0.02**
Complications						
Total number, n (%)	53 (83)	79 (75)	0.25	72 (77)	45 (78)	0.98
Pneumonia, n (%)	24 (38)	34 (32)	0.50	48 (52)	26 (45)	0.42
Abdominal complications, n (%)	30 (47)	49 (47)	0.98	12 (13)	9 (16)	0.65
Outcomes						
Percentage of ventilator-free days, mean (SEM)	45 (3.2)	51 (2.7)	0.16	39 (2.1)	37 (4.0)	0.73
Percentage of ICU-free days, mean (SEM)	39 (3.0)	33 (2.4)	0.10	28 (2.0)	26 (3.2)	0.56
Hospital days for survivors, mean (SEM)	**50.6 (4.5)**	**37.7 (2.5)**	**0.01**	34.3 (1.9)	29.5 (2.1)	0.12
Mortality, n (%)	5 (8)	15 (14)	0.20	10 (11)	12 (21)	0.09

significant difference in age, gender, ISS, or ATI score was found. In the EN group, significantly more patients sustained penetrating trauma compared with the NPO group (49% vs. 33%) and more EN patients received supplemental TPN (45% vs. 27%). Although the amount of crystalloid infused in the first 24 hours was similar between the two groups, the EN group received significantly more red blood cell transfusions (19 vs. 14 U). The patients with bowel injuries given EN had significantly more operations (5.7 vs. 3.2), a lower incidence of fascial closure (55% vs. 78%), and a longer duration of the open abdomen (13 vs. 5 days). This group also had a higher overall complication rate (80% vs. 58%) and a higher abdominal complication rate (45% vs. 30%) compared with the NPO group but similar pneumonia rate. Ventilator-free days and ICU-free days were similar between the two groups, whereas hospital stay for survivors was significantly longer in the group receiving EN (47 vs. 30 days). Mortality was not significantly different between the EN and the NPO groups for patients sustaining bowel injuries.

Logistic regression was performed for the 290 patients who had a bowel injury; the EN and the NPO groups were compared while controlling for site, age, gender, ISS, mechanism of injury, closure at the second laparotomy, and total 24-hour infused volume. There was no significant association between fascial closure and EN (OR, 0.6; $p = 0.2$). There was also no association between EN and complication rate (OR, 1.7; $p = 0.19$) or mortality (OR, 0.79; $p = 0.69$).

Patients Without Bowel Injuries

Of the 597 patients with open abdomen after injury, 307 (51%) did not have a bowel injury (Table 2). In these patients, 156 (51%) had EN initiated while their abdomen was open. Comparing patients who had EN versus those kept NPO, there was no significant difference in age, gender, or administration of adjunctive TPN. The patients started on EN had a significantly lower incidence of penetrating trauma (10% vs. 31%), a higher ISS (34.7 vs. 29.2), and a higher ATI score (23.8 vs. 18.3) compared with those kept NPO. The amount of crystalloid and red blood cells infused in the first 24 hours was similar between the two groups. Patients given EN had significantly more operations (3.4 vs. 2.7) and a longer duration of the open abdomen (7 vs. 4 days) but a higher incidence of fascial closure (84% vs. 50%) compared with the NPO group. For patients without bowel injuries, the overall incidence of complications, the rate of pneumonia, and the number of abdominal complications were similar between the EN and the NPO groups. Ventilator-free days and ICU-free days were similar between the two groups, whereas hospital stay for survivors was significantly longer in the group receiving EN (31 vs. 24 days). Mortality, however, was lower in the EN group compared with the NPO group (10% vs. 23%).

Logistic regression was performed for the 307 patients without a bowel injury; the EN and the NPO groups were compared while controlling for site, ISS, mechanism of injury, closure at the second laparotomy, and total 24-hour infused volume.

TABLE 4. Subgroup Analysis by Mechanism of Injury

	Blunt Trauma (n = 427)			Penetrating Trauma (n = 170)		
	EN (n = 179)	**No EN (n = 248)**	***p***	**EN (n = 51)**	**No EN (n = 119)**	***p***
Demographics						
Age, mean (SEM), y	39.9 (1.3)	41.4 (1.1)	0.39	32.1 (1.9)	31.2 (1.4)	0.68
Male, n (%)	131 (73)	177 (71)	0.68	43 (84)	107 (89)	0.30
ISS, mean (SEM)	35.3 (1.0)	33.1 (0.9)	0.11	**28.5 (2.0)**	**22.3 (1.0)**	**0.008**
ATI score, mean (SEM)	24.3 (0.9)	26.9 (1.0)	0.06	33.0 (2.3)	27.8 (1.4)	0.05
Adjunctive TPN, n (%)	**23 (13)**	**67 (27)**	**0.004**	**25 (49)**	**17 (14)**	**<0.0001**
Resuscitation						
24-h crystalloid, mean (SEM)	**12,318 (618)**	**14,355 (544)**	**0.01**	19,006 (2,345)	16,292 (1,174)	0.30
24-h red blood cells, mean (SEM)	13 (1.1)	12 (0.7)	0.83	**23 (3.1)**	**14 (1.4)**	**0.01**
24-h total volume, mean (SEM)	16,870 (899)	19,065 (670)	0.05	26,426 (2,663)	24,040 (1,757)	0.46
Abdominal operations						
Bowel injury, n (%)	**38 (21)**	**144 (58)**	**<0.0001**	36 (71)	72 (61)	0.22
No. laparotomies, mean (SEM)	**3.7 (0.2)**	**3.1 (0.1)**	**0.002**	**6.1 (0.5)**	**3.1 (0.2)**	**<0.0001**
Closed at the second laparotomy, n (%)	**50 (30)**	**121 (51)**	**<0.0001**	**6 (13)**	**68 (59)**	**<0.0001**
Ultimate fascial closure, n (%)	**140 (79)**	**162 (65)**	**0.003**	31 (61)	82 (69)	0.31
Day of final closure, mean (SEM)	**7.3 (0.5)**	**4.7 (0.3)**	**<0.0001**	**12.1 (1.5)**	**3.6 (0.5)**	**<0.0001**
Complications						
Total number, n (%)	130 (73)	172 (70)	0.46	**42 (82)**	**63 (53)**	**0.0003**
Pneumonia, n (%)	78 (44)	100 (40)	0.50	**20 (39)**	**20 (17)**	**0.002**
Abdominal complications, n (%)	**25 (14)**	**57 (23)**	**0.02**	**22 (43)**	**26 (22)**	**0.005**
Outcomes						
Percentage of ventilator-free days, mean (SEM)	42.3	40.0	0.38	**48.3**	**58.9**	**0.01**
Percentage of ICU-free days, mean (SEM)	30.5	27.9	0.26	**36.2**	**46.7**	**0.009**
Hospital days for survivors, mean (SEM)	34.3	30.4	0.10	**41.7**	**22.7**	**<0.0001**
Mortality, n (%)	**17 (10)**	**53 (21)**	**0.001**	4 (8)	10 (8)	0.90

There was a strong independent association between EN and successful fascial closure (OR, 5.3; $p < 0.01$). There was a significant association between EN and a decreased complication (OR, 0.46; $p = 0.02$) and decreased mortality (OR, 0.30; $p = 0.01$).

Closure at the Second Laparotomy

Statistical analysis was repeated after excluding the 245 patients closed at the second abdominal exploration (Table 3). Of the 320 patients whose abdomen remained open after the second laparotomy, 169 (53%) sustained a bowel injury. In patients with an enteric injury, 64 (38%) had EN started with their abdomen open. In comparing patients with an enteric injury who had EN versus those kept NPO, no significant difference in gender, mechanism of injury, ISS, ATI score, or adjunctive TPN was found. In the EN group, patients were significantly younger compared with those of the NPO group (34 vs. 40 years). The patients with bowel injuries given EN had significantly more operations (6.5 vs. 4.7), a lower incidence of fascial closure (55% vs. 71%), and a longer duration of the open abdomen (14 vs. 7 days). The incidence of complications as well as ventilator-free days and ICU-free days was similar between the two groups. Hospital stay for survivors was significantly longer in the group receiving EN (51 vs. 38 days). Mortality was not significantly different between the EN and the NPO groups for patients sustaining bowel injuries.

Of the 320 patients whose abdomen remained open after the second laparotomy, 151 (47%) did not have a bowel injury (Table 3). In these patients, 93 (62%) had EN initiated while their abdomen was open. In comparing patients who had EN versus those kept NPO, no significant difference in age, gender, mechanism of injury, ISS, or ATI score was found. Patients kept NPO had a higher incidence of adjunctive TPN (33% vs. 12%). There was no difference in the number of abdominal operations, but patients given EN had significantly longer duration of the open abdomen (8 vs. 6 days) and a higher incidence of fascial closure (79% vs. 45%) compared with those of the NPO group. For patients without bowel injuries, the overall incidence of complications, the rate of pneumonia, and the number of abdominal complications were similar between the EN and the NPO groups. Ventilator-free days, ICU-free days, hospital length of stay for survivors, and mortality rates were similar between the two groups.

Patients With Penetrating Versus Blunt Trauma

A univariate analysis was also performed after classifying patients by mechanism of injury (Table 4). Similar findings to previous analyses were identified. Patients in the blunt trauma mechanism group who received EN had higher fascial closure rates but with significantly more laparotomies and a delay in closure compared with those of the NPO group. Although fascial closure rates in the penetrating trauma group were similar between the EN and the NPO groups, the number of laparotomies and the duration of the open abdomen were both higher in the EN group. In the blunt trauma group, the EN and the NPO groups had similar overall complication rates (73% vs. 70%) and pneumonia rates (44% vs. 40%) but lower abdominal complication rates (14% vs. 23%). In the penetrating trauma group, patients receiving EN had a significantly higher overall complication rate (82% vs. 53%), pneumonia rate (39% vs. 17%), and abdominal complication rate (43% vs. 22%). Mortality for those receiving EN was significantly lower in the blunt trauma group compared with the NPO group (10% vs. 21%) but identical in the penetrating trauma group (8% for both EN and NPO).

A logistic regression was performed for the patients with blunt trauma; the EN and the NPO groups were compared while controlling for site, ISS, mechanism of injury, closure at the second laparotomy, bowel injury, and total 24-hour infused volume. There was an independent association between EN and successful fascial closure (OR, 2.9; $p < 0.01$). There was also a significant association between EN and decreased complication rate (OR, 0.50; $p = 0.02$) and decreased mortality (OR, 0.31; $p < 0.01$).

DISCUSSION

Although the advantage of EN in the patient with severe injury is well documented,[1–7] its application in those patients with an open abdomen has yet to be defined. This study appears to be the largest reported to date in the literature, with approximately 600 patients with open abdomen after injury reviewed from 11 trauma centers. A univariate analysis of the data yielded several intriguing results. For the entire study population, fascial closure rates were higher in the EN group compared with the NPO group, but final closure occurred at a later day after injury and the number of laparotomies were higher. After dividing patients into those with and without bowel injuries, in the enteric injury group, there was a lower incidence of fascial closure if the patient received EN; conversely, in the group with no bowel injuries, there was a higher incidence of fascial closure in those started on EN. For the entire study population, the total number of complications was higher in the EN group, including a higher incidence of pneumonia, whereas abdominal complications were similar between the EN and the NPO groups. Despite more complications in the EN group, mortality was significantly lower in the EN group compared with the NPO group. When the total population is subdivided into patients with and without bowel injuries, the significantly higher total complication rate remained in the enteric injury group receiving EN, but there was a higher rate of abdominal complications rather than pneumonia. Complication rates were no longer significantly different between the EN and the NPO groups for those patients without bowel injury. Mortality rates were not significantly different in the enteric injury group, but they were significantly lower in the EN group without bowel injury compared with the NPO group.

If one were to draw conclusions based upon these analyses, without controlling for potential confounders, one would presume that EN is advantageous in those patients without bowel injury but hinders fascial closure and increases abdominal complications in those with an enteric injury. However, logistic regression analysis for those patients with a bowel injury demonstrates no significant association between EN and fascial closure, complication rate, or mortality. Hence, EN seems to be neither advantageous nor detrimental for these patients. For those patients without a bowel injury, however, logistic regression confirms that EN is associated with higher fascial closure rates, decreased complications, and decreased mortality. Although higher fascial closure rates and lower infectious complications have been previously suggested, this is the first study to identify a significant difference in mortality between patients with open abdomen after injury receiving EN compared with those remaining NPO.

Published reports to date evaluating EN for patients requiring an open abdomen have disparate results. The first dedicated evaluation of EN in the open abdomen was in 2007 by Collier et al.[14] They reviewed 78 patients requiring open abdomen management past day 4 after injury. Those with early EN, defined as initiation before day 4, had higher fascial closure rates (74% vs. 49%) and a lower fistula rate (9% vs. 26%); there was no difference in infectious complications. Although the study population was a mix of patients with blunt and penetrating trauma as well as patients with ACS and patients who underwent DCO, it is unclear whether they included patients with bowel injuries. The multicenter Glue Grant group analyzed the effect of early EN, defined as initiation within 36 hours after completed resuscitation, in 100 patients with blunt trauma.[12] Their study population did not include patients with bowel injuries. The authors demonstrated a lower rate of pneumonia (44% vs. 72%) in those patients undergoing early enteral feeding. They also reported no difference in time to closure or in fascial closure rates, but more than 90% of patients in both groups attained abdominal closure with an average of three laparotomies per patient. A final study of EN in the open abdomen included 23 patients with blunt and penetrating trauma with more than half sustaining bowel injury.[13] Fascial closure was significantly later in the EN group, on day 7, compared with the NPO group on day 3.4. Successful fascial closure was attained in 66% of the total study population, but stratification by enteral feeding was not performed. The incidence of ventilator-associated pneumonia was similar between those who received EN and those who did not.

With different inclusion and exclusion criteria in these three studies, it is difficult to compare them with the current multicenter study. Our comparison of EN versus no EN in the entire study population most closely mirrors the study of Byrnes et al.[13] Similar to their findings, our data suggest that fascial closure is delayed in those receiving EN. Although the study of Byrnes et al.[13] did not report the percentage of closure rates in the EN group versus the NPO group, our analysis indicates a higher fascial closure rate in those patients receiving EN. The study of Byrnes et al.[13] reported no significant difference in ventilator associated pneumonia rates, apparently based on univariate analysis; our logistic regression showed no association between EN and pneumonia after controlling for potential confounders. An analysis of all patients requiring an open abdomen while controlling for those closed at the second laparotomy would provide the closest comparison with the study of Collier et al.[14] Our regression analysis demonstrates increased fascial closure rates with EN, which is similar to the findings of Collier et al.[14] Our regression analysis of only patients with blunt trauma, controlling for bowel injury, would most closely mirror the Glue Grant study.[12] Although that study showed no difference in closure rates but a lower ventilator-associated pneumonia rate, our regression shows an association between EN and increased fascial closure rate, decreased overall complication rates, and decreased mortality.

We acknowledge the weaknesses inherent in any nonrandomized study. This open-abdomen patient group was managed in a heterogeneous manner by a wide variety of trauma surgeons. The particulars of surgical decision making on any single patient cannot be inferred. This, we think, only reflects the current management questions in caring for these complex patients. Our logistic regression attempted to control for such factors including differing demographics, resuscitation, closure rates, and institutional variables. We did not measure the initial physiologic parameters in this patient population because the initiation of EN does not occur until resuscitation and physiologic restoration are completed. Additional variables that may have affected fascial closure rates and infectious complications, such as use of paralytics, vacuum-assisted closure devices, continuous fascial tension during abdominal closure attempts, type of enteral formula, and intensive insulin therapy, were not evaluated. With a recent study reporting similar clinical outcomes when comparing trophic versus full EN rates,[15] we did not further subdivide our analysis based upon this variable. With an overall low complication rate, further stratification of those patients based upon location of EN delivery (stomach vs. duodenum vs. jejunum) was not performed because of concerns for a type II error in the analysis.

CONCLUSION

EN in the open abdomen after injury is feasible. Therefore, once resuscitation is complete, the initiation of EN should be considered in all injured patients. For patients without a bowel injury, EN in the open abdomen is associated with a marked increase in successful fascial closure, a decrease in complication rates, and a decrease in mortality. Enteral access should be obtained and nutrition initiated after physiologic restoration. Although EN for patients with bowel injuries does not seem to alter fascial closure rates, complications, or mortality, prospective randomized controlled trials are warranted to further clarify the role of EN in this subgroup.

AUTHORSHIP

C.C.B. designed this study. All authors participated in data collection, analysis, and interpretation. C.C.B., E.E.M., and F.M.P. drafted the manuscript, which all remaining authors critically reviewed.

DISCLOSURE

The authors declare no conflicts of interest.

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EDITORIAL CRITIQUE

Over the past two decades, the general consensus of clinicians caring for critically ill patients is that GI feeding is preferable to either TPN or prolonged starvation. Most clinical trials show significant reductions in pneumonia and intra-abdominal sepsis when enteral feeding is instituted soon after injury. In this study, the authors evaluated data from 597 patients requiring an open abdomen after trauma following damage control operation or the occasional abdominal compartment syndrome. Combining the data from 11 institutions, the authors concluded that enteral feeding was associated with increased fascial closure, decreased complications, and lower mortality if no enteric injury was present. However, there was no benefit in patients with bowel injuries. When examining the data, the outcome actually appeared to be worse with enteral feeding (though this was not confirmed by logistic regression analysis). Surprisingly, pneumonia increased in enterally-fed patients and in the patients with penetrating injuries. Abdominal complications increased after enteral feeding as well.

These results would seem at odds with prior randomized trials and the question is: why? A number of potential reasons come to mind. First, the open abdomen may limit the peritoneum's ability to control contamination. Experimental studies showed that animals fed enterally generate a greater inflammatory cytokine response while slowing bacterial proliferation after intraabdominal sepsis (Ann Surg 223(1): 84–93. 1996). The open abdomen may preclude this. A second, and probably a more relevant issue, may relate to the manner in which feedings were delivered. In early nutrition studies from Denver (J Trauma 26: 874–879. 1986; J Trauma 29: 916–923. 1989) and Memphis (Ann Surg 215:503–513. 1992), patients were fed directly into the small intestine and advanced to a goal rate as tolerated. In the early Denver trials, limitations on severity of injury allowed successful advancement of tube feedings to goal rate within 72 hours. In the Memphis trial, more severely injured patients were included but jejunal feedings we advanced to goal rate (and many patient reached goal) as soon as possible. In the current study, 62% of patients only received "trophic feeding" at 20 ml an hour; only 38% had their rate advanced. At the same time, 60% received only gastric feedings while only 37% were fed into the duodenum and a few into the small bowel. In my clinical experience, the stomach in an open abdomen doesn't empty. It is unlikely that any of the gastric tube feedings generated any effect—negative or positive—on immunity and host resistance. Although Rice et al. showed no outcomes differences between trophic and full feedings in mechanically ventilated patients with acute respiratory failure, the relevance of these data obtained from a medical ICU to severely injured patients is at best a stretch (Crit Care Med. 39:967–974. 2011).The authors chose not to analyze their results based on the rate of enteral feeding because of the Rice trial but I would be particularly interested in the results after jejunal or duodenal feeding compared to intra-gastric feeding. But because of their commitment to successful enteral feeding in trauma patients, I would be especially interested in the Denver results (compared to the other sites) since they recently described a 100% success rate in closure of the open abdomen after trauma (J Trauma Acute Care Surg. 72(1):235–41. 2012)—and I suspect most patient were fed enterally.

This is an intriguing trial of interest to clinicians caring for critically ill trauma patients. Like all good research, it raises more questions than it answers.

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