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ORIGINAL SCIENTIFIC REPORT

Open Abdomen in Obese Patients: Pay Attention! New Evidences from IROA, the International Register of Open Abdomen

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Abstract

Background Open abdomen is the cornerstone of damage control strategies in acute care and trauma surgery. The role of BMI has not been well investigated. The aim of the study was to assess the role of BMI in determining outcomes after open abdomen.

Methods This is an analysis of patients recorded into the International Register of Open Abdomen; patients were classified in two groups according to BMI using a cutoff of 30 kg/m^2. The primary outcome was in-hospital mortality; secondary outcomes were primary fascia closure rate, length of treatment, complication rate, entero-atmospheric fistula rate and length of ICU stay.

Results A total of 591 patients were enrolled from 57 centers, and obese patients were 127 (21.5%). There was no difference in mortality between the two groups; complications developed during the open treatment were higher in obese patients (63.8% vs. 53.4%, $p = 0.038$) while post-closure complications rate was similar. Obese patients had a significantly longer duration of the open treatment (9.1 ± 11.5 days vs. 6.3 ± 7.5 days; $p = 0,002$) and lower primary fascia closure rate (75.5% vs. 89.5%; $p < 0,001$). No differences in fistula rate were found. There was a linear correlation between the duration of open abdomen and the BMI (Pearson's linear correlation coefficient = 0,201; $p < 0,001$).

Conclusions Open abdomen in obese patients seems to be safe as in non-obese patients with similar mortality; however, in obese patients the length of open abdomen is significantly higher with higher complication rate, longer ICU length of stay and lower primary fascia closure rate.

Trial registration number ClinicalTrials.gov, Identifier: NCT02382770.

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Introduction

The open abdomen is one of the cornerstones of the damage control strategy in acute care and trauma surgery. Leaving an abdomen "open" after surgery is at the same time a solution and a problem for the acute care surgeon. From the end of the twentieth century, open abdomen becomes to be a diffused surgical technique adopted in the management of severe intra-abdominal infections, trauma, pancreatitis, vascular emergencies and prevention or treatment of abdominal compartment syndrome (ACS) [1]; several temporary abdominal closure techniques have also been developed [2–4]. However, the debate about the correct indication, the better technique to adopt and the management is very intense. To leave the abdomen open after surgery has many advantages; on the other, hand open abdomen has many possible and fearsome complications such as the development of entero-atmospheric fistula (EAF), fascial retraction and the difficult management of the abdominal wall [4–6].

Several risk factors have been identified for the development of complications: One of the most important is the duration of the open abdomen. Miller and colleagues in 2005 observed that patients with an open abdomen duration of 9 days or more had higher complications rate than others [7]; similarly, Burlew et al. [8] found that enteric leak increased significantly with the duration of the open abdomen; similar findings were recently confirmed by a large case series [9]. General consensus and guidelines recommend to close the abdomen as soon as possible in order to prevent or reduce complications [2–5]. Other known risk factors for complications and mortality are age, APACHE II score, cancer, large bowel resection, large volume resuscitation, increased number of re-explorations, total duration of open treatment, bowel perforation, anastomotic leakage, abdominal compartmental syndrome, malnutrition and delay in nutrition [10–13].

Obesity (considered as a body mass index, BMI > 30 kg/m^2) has been identified as risk factor for intra-abdominal hypertension (IAH) and ACS: A direct correlation between obesity and increased intra-abdominal pressure (IAP) has been demonstrated with higher baseline values compared to not-obese patients [14–18]. Obesity is also associated with worse outcomes as higher mortality, longer stay in intensive care unit (ICU) and hospital and higher complication rate among injured and critically ill patients [19, 20]. The role of obesity in open abdomen is still unclear with few data in the literature. Moreover, the existing evidences are based on small case series. From the 2015, the World Society of Emergency Surgery (WSES) has launched the International Register of Open Abdomen (IROA), with the aim to better understand the open abdomen in the largest existing register of open abdomen patients [21].

The aim of this paper was to investigate the role and the impact of obesity on the outcomes after open abdomen in critically ill patients in a large cohort of patients collected in IROA.

Methods

IROA is a prospective observational cohort study including patients who underwent an open abdomen treatment for any reason. Data were recorded on a Web platform (Clinical Registers®) reachable at a dedicated Web site (www.clinicalregisters.org). The study protocol has been approved by the ethical committee, and it has been registered with the National Institutes of Health (ClinicalTrials.gov, Identifier: NCT02382770).

For each patient, the following data were recorded: demographical and basic anthropometric data, comorbidities, indication to open abdomen procedure, temporary abdominal closure technique (TACT) adopted, duration of the open treatment, complications during and after treatment, development of entero-atmospheric fistulae, definitive closure of the abdomen, primary fascia closure rate (i.e., the closure of the fascia without any prosthesis), eventually need to perform intestinal anastomosis or stomas, use of prosthetic mesh to close the abdominal wall and mortality, according to the study protocol. All patients under 14 were excluded from the analysis. Indication to open abdomen and temporary abdominal closure technique were annotated for each patient: In those cases where different techniques have been used during the same open treatment, it has been summarized to the first one or the longer applied one. Patients were classified according to their BMI with a cutoff of 30 kg/m^2 that divided the cohort of patients between obese and not-obese groups. The primary outcome of the study was the overall mortality; secondary outcomes were complications (both during and after the closure of the abdomen), the development of entero-atmospheric fistulae, length of treatment, fascia closure rate, need for a prosthesis and ICU length of stay.

Statistical analysis

Continuous variables were expressed as mean and standard deviation, and they were compared with the ANOVA test and the independent Student's t test. Categorical data were expressed as percentages and were compared with the Chi-square test. Linear associations were graphically investigated with scatter-dot graph and then tested with the Pearson's linear correlation model.

Table 1 Characteristics of included and excluded patients (*BMI* body mass index, *ASA Class* American Society of Anesthesiologists Classification, *IAH* intra-abdominal hypertension, *TACT* temporary abdominal closure technique)

		Included in the analysis		Excluded from the analysis		*p*
	Cohort of patients	591 (100.0%)		164 (100.0%)		
	Age [years]	59.6 (± 18.1)		62.3 (± 16.0)		0.07
Gender	Male	343 (58.0%)		92 (54.4%)		0.404
	Female	248 (42.0%)		77 (45.6%)		
ASA Class	ASA I	39 (6.6%)		12 (7.1%)		0.12
	ASA II	92 (15.6%)		28 (17%)		
	ASA III	183 (31.0%)		50 (29.6%)		
	ASA IV	228 (38.6%)		59 (30.8%)		
	ASA V	49 (8.3%)		20 (11.8%)		
IAH grade	No IAH	413 (69.9%)		95 (76.0%)		0.436
	Grade I	72 (12.2%)		5 (4.0%)		
	Grade II	47 (8.0%)		12 (9.6%)		
	Grade III	45 (7.6%)		9 (7.2%)		
	Grade IV	14 (2.4%)		4 (3.2%)		
Main comorbidities	Cancer	158 (26.7%)		55 (32.5%)		0.347
	Cardiopathy	199 (33.7%)		70 (41.4%)		
	Diabetes	91 (15.4%)		21 (12.4%)		
	Pneumopathy	81 (13.7%)		15 (8.9%)		
	Nephropathy	64 (10.8%)		17 (10.1%)		
Indication	Peritonitis	304	51.4%	83	49.1%	0.263
	Trauma	80	13.5%	36	21.3%	
	Pancreatitis	36	6.1%	8	4.7%	
	Ischemia	35	5.9%	24	14.2%	
	Vascular emerg. or hemorrhage	87	14.7%	9	5.3%	
	ACS	27	4.6%	0	0.00%	
	Others	22	3.7%	9	5.3%	
TACT	Commercial NPWT	294	49.7%	114	67.5%	0.043
	Wittmann Patch	49	8.3%	1	0.6%	
	Skin closure	49	8.3%	23	13.6%	
	Bogota bag	121	20.5%	22	13.0%	
	Barker Vacuum Pack	78	13.2%	9	5.3%	
Overall mortality		196	33.2%	46	27.2%	0.214
Duration of open treatment (days)		6.9 (± 8.6)		5.6 (± 5.4)		0.12

All the statistical comparisons were based on two-sided tests with a 0.05 significance level, according to the study protocol.

All the statistical analyses were performed with IBM SPSS 20 (IBM Corp. Released 2011. IBM SPSS Statistics for Mac, version 20.0. Armonk, NY: IBM Corp.).

Results

From May 2015 to September 2018, a total of 760 adult patients from 57 centers were prospectively registered in IROA. Of whom, 591 with completed data about demographical and anthropometric data were included for the analysis. Characteristics of excluded patients did not differ significantly from included patients (Table 1).

The mean age was 59.6 ± 18.1 years and 58% were male; mean BMI was 27.0 ± 5.7 kg/m^2 and obese patients were 127 (21.5%). Table 2 shows in detail patients characteristics: The two patients groups (obese and not obese) significantly differ in terms of sex distribution and comorbidities (cardiopathy and diabetes rates significantly higher in obese patients).

Overall mortality rate was 33.2%, cumulative complication rate during treatment was 55.7%, and after definitive closure of the abdomen, it was 54.5%.

Table 2 General descriptive data about the study population (* only for 304 peritonitis patients; ° only for 80 trauma patients; *BMI* body mass index, *MPI* Mannheim Peritonitis Index, *ISS* Injury Severity Score, *ASA Class* American Society of Anesthesiologists Classification, *IAH* intra-abdominal hypertension)

		Not-obese (BMI < 30)	Obese (BMI > 30)	Total	*p* value
	Cohort of patients	464 (78.5%)	127 (21.5%)	591 (100.0%)	
	Age [years]	59.6 (± 18.8)	59.8 (± 14.9)	59.6 (± 18.1)	0.91
	BMI [kg/m^2]	24.7 (± 3.1)	35.4 (± 5.3)	27.0 (± 5.7)	< 0.001
	MPI*	23.2 (± 8.0)	23.3 (± 8.3)	23.2 (± 8.1)	0.93
	ISS°	31.4 (± 18.3)	29.6 (± 18.5)	31.1 (± 18.2)	0.77
Gender	Male	284 (61.2%)	59 (46.5%)	343 (58.0%)	0.003
	Female	180 (38.8%)	68 (53.5%)	248 (42.0%)	
ASA class	ASA I	34 (7.3%)	5 (3.9%)	39 (6.6%)	0.219
	ASA II	73 (15.7%)	19 (15.0%)	92 (15.6%)	
	ASA III	135 (29.1%)	48 (37.8%)	183 (31.0%)	
	ASA IV	180 (38.8%)	48 (37.8%)	228 (38.6%)	
	ASA V	42 (9.1%)	7 (5.5%)	49 (8.3%)	
IAH grade	No IAH	335 (72.2%)	78 (61.3%)	413 (69.9%)	0.176
	Grade I	52 (11.2%)	20 (56.7%)	72 (12.2%)	
	Grade II	36 (7.8%)	11 (8.7%)	47 (8.0%)	
	Grade III	31 (6.7%)	14 (11.0%)	45 (7.6%)	
	Grade IV	10 (2.2%)	4 (3.1%)	14 (2.4%)	
Main comorbidities	Cancer	129 (27.8%)	29 (22.8%)	158 (26.7%)	0.262
	Cardiopathy	146 (31.5%)	53 (41.7%)	199 (33.7%)	0.030
	Diabetes	52 (11.2%)	39 (30.7%)	91 (15.4%)	< 0.001
	Pneumopathy	59 (12.7%)	22 (17.3%)	81 (13.7%)	0.181
	Nephropathy	50 (10.8%)	14 (11.0%)	64 (10.8%)	0.937

Mortality was not different among the two study groups; cumulative complications developed during the open treatment were higher in obese patients (63.8% vs. 53.4%, $p = 0.038$) while post-closure complications rate was similar. The entero-atmospheric fistulae rate was similar between the two groups. Tables 3 and 4 show in detail all outcomes and complications.

Obese patients had a significantly longer duration of the open treatment (9.1 ± 11.5 days vs. 6.3 ± 7.5 days; $p = 0{,}002$) and longer ICU stays (14.2 ± 15.6 vs. 21.2 ± 35.2 days, $p = 0.003$) (Figs. 1, 2), lower primary fascia and skin closure rate (75.5% vs. 89.5%; $p < 0.001$ and 79.6% vs. 89.5%; $p = 0.009$, respectively). Prosthesis positioning was needed in 10.3% of patients with a significant difference between obese and not-obese patients (21.4% vs. 7.3%; $p < 0{,}001$); biological prosthesis was adopted in 54% of cases, non-adsorbable in 23% and adsorbable in 23% of patients. Outcomes were analyzed also in subgroup of patients with peritonitis and trauma with similar findings (Table 5).

There was a linear correlation between the duration of open abdomen and the BMI (Pearson's linear correlation coefficient = 0.201; $p < 0.001$) (Fig. 3).

Discussion

The analysis of data from the International Register of Open Abdomen shows that mortality did not differ significantly between obese and not-obese patients. Nevertheless, obesity seems to play a crucial role in determining secondary outcomes: Data demonstrated a linear correlation between BMI and the days of open abdomen, resulting in higher complication rate and worse secondary outcomes as a lower primary fascia closure rate and skin closure rate.

The present results reinforce the well-established correlation between days of open abdomen and complications [7, 9]; moreover, they highlight the role of patients characteristics and BMI in determining outcomes after a tragic situation such as the open abdomen.

Damage control strategies in acute care and trauma surgery are gaining more and more support. Nowadays, however, the open abdomen has still no clear indications: The only strong and recognized indication is to treat a rare condition called abdominal compartment syndrome [1, 22, 23]. For all the other indications, open abdomen is considered a valid treatment option in selected cases and, above all, in selected centers with indispensable skills and

Table 3 Different indications, TACTs and intra-operative data among the BMI classes (*calculated for patients who reached definitive closure; *ACS* abdominal compartment syndrome, *TACT* temporary abdominal closure technique, *NPWT* negative pressure wound therapy)

		Not-obese (BMI < 30)		Obese (BMI > 30)		Total		p value
		N	%	N	%	N	%	
Indication	Peritonitis	231	49.8	73	57.5	304	51.4	0.037
	Trauma	69	14.9	11	8.7	80	13.5	
	Pancreatitis	24	5.2	12	9.4	36	6.1	
	Ischemia	30	6.5	5	3.9	35	5.9	
	Vascular emerg. or hemorrhage	75	16.2	12	9.4	87	14.7	
	ACS	18	3.9	9	7.1	27	4.6	
	Others	17	3.7	5	3.9	22	3.7	
TACT	Commercial NPWT	230	49.6	64	50.4	294	49.7	0.999
	Wittmann Patch	39	8.4	10	7.9	49	8.3	
	Skin closure	39	8.4	10	7.9	49	8.3	
	Bogota bag	95	20.5	26	20.5	121	20.5	
	Barker vacuum pack	61	13.1	17	13.4	78	13.2	
Intra-op. procedures	Fluid instillation	83	17.9	24	18.9	107	18.1	0.793
	Blood transfusion*	119	32.2	24	24.5	143	30.6	0.143
	Intestinal anastomosis*	121	32.7	29	29.6	150	32.1	0.557
	Stoma*	118	31.9	34	34.7	152	32.5	0.598

Table 4 Main outcomes of the OA treatment in the whole cohort of patients (*calculated for patients who reached definitive closure; *EAF* entero-atmospheric fistula)

	Not-obese (BMI < 30)		Obese (BMI > 30)		Total		p value
EAF	39	8.4%	11	8.7%	50	8.5%	0.927
Death while open	94	20.3%	29	22.8%	123	20.8%	0.526
Death after closure*	59	15.9%	14	14.3%	73	15.6%	0.687
Overall mortality	153	33.0%	43	33.9%	196	33.2%	0.318
Primary fascial closure rate*	331	89.5%	74	75.5%	405	86.5%	< 0.001
Skin closure rate*	331	89.5%	78	79.6%	409	87.4%	0.009
Prosthesis positioning*	27	7.3%	21	21.4%	48	10.3%	< 0.001
Duration of open treatment (days)	6.3 (± 7.5)		9.1 (± 11.5)		6.9 (± 8.6)		0.002
ICU stay (days)	14.2 (± 15.6)		21.2 (± 35.2)		15.6 (± 21.3)		0.003
Cumulative complication rate while open	248	53.4%	81	63.8%	329	55.7%	0.038
Cardiovascular complications	50	10.8%	20	15.7%	70	11.8%	0.124
Ongoing sepsis	127	27.4%	52	40.9%	179	30.3%	0.030
Bleeding/transfusion	78	16.8%	23	18.1%	101	17.1%	0.730
Neurological complications	22	4.7%	5	3.9%	27	4.6%	0.700
Pulmonary infections	43	9.3%	16	12.6%	59	10.0%	0.267
Other complications	66	14.2%	23	18.1%	89	15.1%	0.278
Cumulative complication rate after closure*	204	55.1%	51	52.0%	255	54.5%	0.584
Cardiovascular complications*	32	8.6%	7	7.1%	39	8.3%	0.632
Intra-abdominal infections*	28	7.6%	8	8.2%	36	7.7%	0.844
Bleeding/transfusion*	30	8.1%	5	5.1%	35	7.5%	0.314
Sepsis (excluding abdominal and pulmonary infections)*	71	19.2%	24	24.5%	95	20.3%	0.246
Neurological complications*	20	5.4%	3	3.1%	23	4.9%	0.340
Pulmonary infections*	51	13.8%	13	13.3%	64	13.7%	0.894
Other complications*	119	32.2%	34	34.7%	153	32.7%	0.635

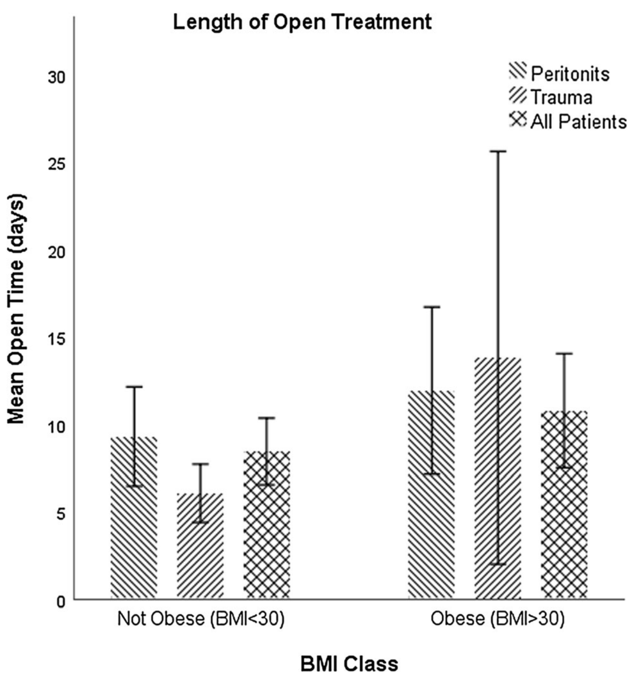


Fig. 1 Duration of open treatment for overall, peritonitis and trauma patients

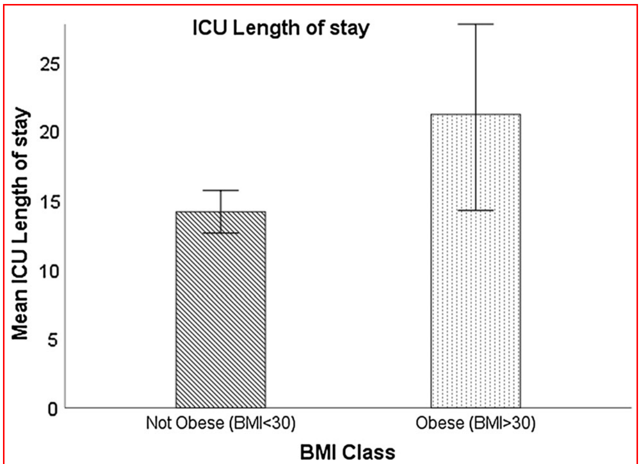


Fig. 2 Mean ICU length of stay

expertise. The open abdomen in fact is characterized by high mortality (due mostly to the critical conditions of patients) and high morbidity rates, with challenging situation such as the development of entero-atmospheric fistulae.

Several efforts have been made in order to identify risk factors for complications and mortality: The most important is the duration of the treatment [7, 9]; other factors identified were the patients clinical conditions, according to the APACHE II score, the presence of abdominal contamination and the need for anastomosis [10–13].

The role of obesity and BMI of the patients has been analyzed and investigated in few studies. Haricharan et al. [24] in 2009 analyzed retrospectively 148 patients who underwent open abdomen after an abbreviated laparotomy for trauma: They found similar mortality rate between normal weight and obese patients but a significant increase in time of open abdomen and complications in obese patients. Similarly, Duchesne et al. [25] in a retrospective cohort of trauma patients observed a higher prevalence ratio for failure of primary abdominal fascia closure in obese trauma patients, with a higher infectious complication rate. The need for a longer stay in ICU, with longer ventilation time, was also noticed by Johnston et al. [26] in 2015 in morbidly obese patients with an open abdomen for trauma.

Available data in the literature were focused on trauma patients and showed in different ways that the higher the BMI, the longer the duration of open treatment: the lengthening of days of open abdomen it translates in augmented complications.

The present study investigated the role of BMI in determining outcomes of open abdomen patients. Obese patients differed from non-obese patients in terms of comorbidities (higher prevalence of diabetes and cardiovascular diseases) and indication to open abdomen, with a higher proportion of patients treated for intra-abdominal infections in obese patients and a lower proportion of patients treated for trauma. The results, however, did not differ in the subgroup analysis of patients treated for trauma and for intra-abdominal infections, showing that outcome was not related to the indication.

Obese patients had a longer treatment with open abdomen (Fig. 2). As already demonstrated, a longer treatment conditioned an higher complication rate [7]. It is very interesting to notice that the complication rate after the closure of the abdominal wall did not differ significantly between the two groups highlighting the dramatic role of the abdomen left open in developing complications.

The longer duration of the open treatment in obese patients has no clear motivations: Several possible interpretations of these data could be supposed.

First of all, there is a mechanical factor due to the abdominal structure of obese patients: The abundant visceral and parietal fat, with great representation of subcutaneous tissue, could facilitate the fascia retraction with subsequent difficulties in re-approximating fascial edges. Our data demonstrate that in obese patients the primary fascia closure rate was lower and there was a higher proportion of prosthesis positioning in order to close the abdominal wall.

Obesity is related to worse clinical condition and higher comorbidity rates, as suggested by the baseline conditions of included patients with an higher prevalence of diabetes

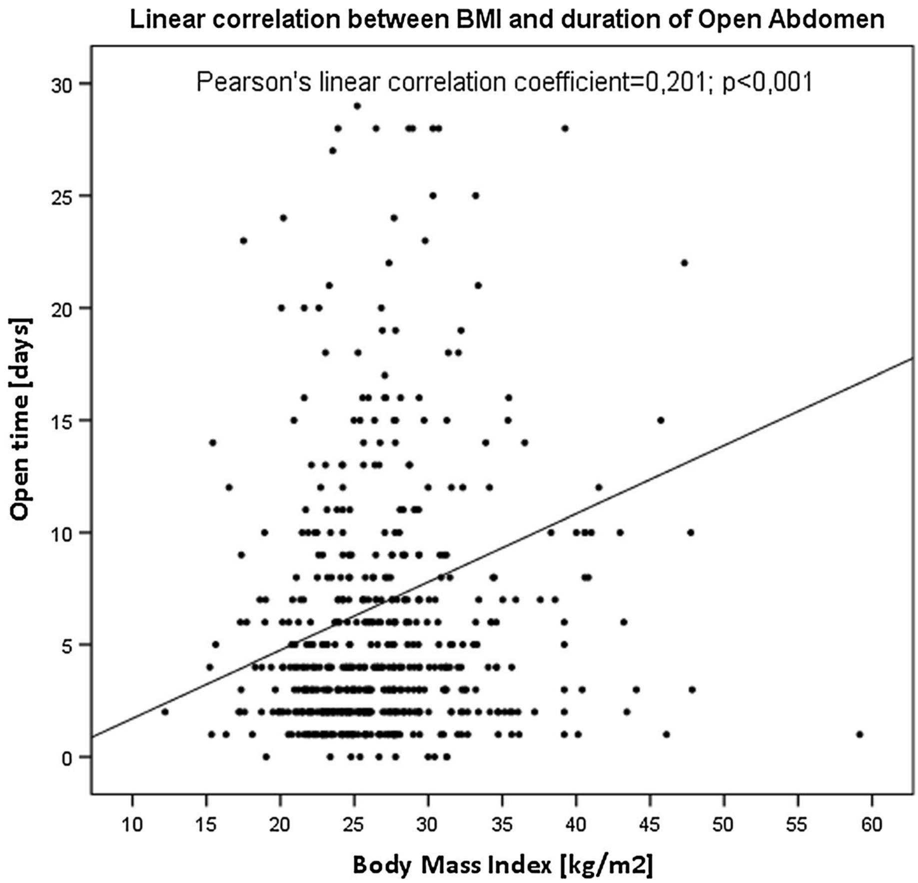
Table 5 Main outcomes of the OA treatment in the two main indications subgroups (*calculated for patients who reached definitive closure; EAF: entero-atmospheric fistula)

		Not-obese (BMI < 30)		Obese (BMI > 30)		Total		*p* value
Peritonitis	EAF	25	10.8%	9	12.3%	34	11.2%	0.722
	Death while open	43	18.6%	12	16.4%	55	18.1%	0.674
	Death after closure*	33	17.6%	7	11.5%	40	16.1%	0.261
	Overall mortality	93	40.3%	28	38.4%	121	39.8%	0.772
	Primary fascial closure rate*	168	89.4%	45	73.8%	213	85.5%	0.003
	Skin closure rate*	166	88.3%	46	75.4%	212	85.1%	0.014
	Prosthesis positioning*	15	8.0%	16	26.2%	31	12.4%	< 0.001
	Duration of open treatment (days)	6.5 (± 7.3)		6.5 (± 7.3)		7.3 (± 8.5)		0.003
	ICU stay (days)	13.69 (± 15.60)		18.52 (± 23.65)		14.75 (± 17.75)		0.08
	Cumulative complication rate while open	123	53.2%	45	61.6%	168	55.3%	0.208
	Cumulative complication rate after closure*	107	56.9%	33	54.1%	140	56.2%	0.700
Trauma	EAF	4	5.8%	1	9.1%	5	6.3%	0.675
	Death while open	9	13.0%	3	27.3%	12	15.0%	0.220
	Death after closure*	4	6.7%	0	0.0%	4	5.9%	0.452
	Overall mortality	15	21.7%	4	36.4%	19	23.8%	0.290
	Primary fascial closure rate*	55	91.7%	8	100.0%	63	92.6%	0.396
	Skin closure rate*	52	86.7%	7	87.5%	59	86.8%	0.948
	Prosthesis positioning*	1	1.7%	0	0.0%	1	1.5%	0.713
	Duration of open treatment (days)	6.1 (± 6.9)		13.8 (± 17.6)		7.2 (± 9.3)		0.010
	ICU stay (days)	15.23(± 74.72)		48.12(± 97.99)		19.16(± 36.39)		0.015
	Cumulative complication rate while open	29	42.0%	4	36.4%	33	41.2%	0.723
	Cumulative complication rate after closure*	22	36.7%	2	25.0%	24	35.3%	0.517

and cardiovascular diseases in the obese cohort. The higher comorbidity rates, and obesity itself interpreted as a comorbidity, could justify the need for longer treatment with open abdomen due to the difficult to restore the physiological status. In obese patients, a chronic increased IAP has been described and proposed by some authors like a sort of a "chronic abdominal compartment syndrome" that may be involved in the pathogenesis of several obesity-related comorbidities affecting different systems and organs [15, 16, 27, 28]. This situation may be due to a direct mass effect of intra-abdominal adipose tissue [15, 16, 18, 27] and could facilitate the development and increase the severity of IAH with detrimental effects on the whole body by reducing physiological reserve and the abdominal wall compliance [14–18, 27, 28]; since IAH alone has been considered as an independent risk factor for worse outcomes in critically ill patients [17, 18], obese patients could be prone to develop an abdominal compartment syndrome that could justify the need for more days of open abdomen and consequently more complications [18]. Even if the prevalence of IAH and compartmental syndrome as primary indication of open abdomen was relatively low in our register, these pathological conditions could develop during the open treatment delaying the closure.

It should be noticed that obese patients had a higher prevalence of intra-abdominal infection as indication to open abdomen compared to not-obese patients. Another interesting interpretation of the longer duration of open abdomen in obese patients could rise from the recent evidences about the role of adipose tissue in the modulation of the inflammatory response. Adipose tissue secretes more pro-inflammatory cytokines and induces a state of chronic inflammation [29–31]; in obese patients, the response to intra-abdominal infections seems to be less effective and also delayed as demonstrated by a late onset of septic symptoms [27]. The abundance of adipose tissue, with poorly vascularized fat cells, is characterized by a poor penetration of antibiotics and anti-inflammatory drugs and by an aberrant production of pro-inflammatory cytokines that may have a role in maintaining the inflammatory response [27]. No specific evidences about the role of adipose tissue in modulating the inflammatory response during open abdomen exist, and dedicated studies are advocated in order to understand the physiological response to abdominal sepsis when the peritoneal

Fig. 3 Linear correlation graph between BMI and OA duration



physiology is subverted. This aberrant and prolonged septic status could provide also the interpretation to the higher rate of patients with persistent septic status (indicated as ongoing sepsis) and the development of infectious complications during the treatment as shown in Table 4.

Despite all these possible interpretations, no clear answers could be provided from our data.

Open abdomen in obese patients seems to be safe as in non-obese patients with similar mortality; however, in obese patients the length of open abdomen is significantly higher with higher complication rate, longer ICU length of stay and lower primary fascia closure rate. The measure of BMI nowadays seems to be surpassed for the measurement of body composition and real metabolic condition of a patients [32]; an interesting perspective could be the study of patients with open abdomen with a particular interest in the changing of body composition and the metabolism during the open treatment, highlighting the correlation among the real role of nutrition, metabolism and body composition in determining clinical outcomes in dramatic situations as open abdomen.

The present study analyzed data from the largest register of open abdomen patients and provides data about the role of BMI: Despite the great number of included patients, the study has some limitations due to the missing data and the restricted number of variables available or analysis; moreover, it should be noticed that it is a multicenter study that collects patients from 57 different centers around the world, with great variability in indications and techniques adopted as a possible bias.

In conclusion, obese patients can be safely treated with open abdomen with similar mortality rates of non-obese patients. Despite the absence of clear indication, open abdomen remains and could be considered as a valid therapeutic option in critically ill patients with the need of damage control surgery in selected centers with necessary expertise. Obesity seems to play a detrimental role in determining longer duration of open abdomen with a direct linear correlation between BMI and length of open treatment; this augmented length of treatment, with consequent longer need for ICU, seems to be associated with worse secondary outcomes as the lower primary fascia closure rate and the higher complication rate. Dedicated studies on the role of body composition and the role of adipose tissue are needed to better understand their role in the management of these patients.

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References

1. Coccolini F, Roberts D, Ansaloni L et al (2018) The open abdomen in trauma and non-trauma patients: WSES guidelines. World J Emerg Surg 13:7. https://doi.org/10.1186/s13017-018-0167-4
2. Leppäniemi AK (2010) Laparostomy: why and when? Crit Care 14:216. https://doi.org/10.1186/cc8857
3. Sartelli M, Abu-Zidan FM, Ansaloni L et al (2015) The role of the open abdomen procedure in managing severe abdominal sepsis: WSES position paper. World J Emerg Surg 10:35. https://doi.org/10.1186/s13017-015-0032-7
4. Coccolini F, Montori G, Ceresoli M et al (2017) The role of open abdomen in non-trauma patient: WSES consensus paper. World J Emerg Surg 12:39. https://doi.org/10.1186/s13017-017-0146-1
5. Demetriades D, Salim A (2014) Management of the open abdomen. Surg Clin North Am 94:131–153. https://doi.org/10.1016/j.suc.2013.10.010
6. Tarasconi A, Chiara O, Cimbanassi S et al (2018) Open abdomen complications: prevention and management. In: Coccolini F, Ivatury R, Sugrue M, Ansaloni L (eds) Open abdomen: a comprehensive practical manual. Springer International Publishing, Cham, pp 215–228
7. Miller RS, Morris JA, Diaz JJ et al (2005) Complications after 344 damage-control open celiotomies. J Trauma 59:1365–1371. https://doi.org/10.1097/01.ta.0000196004.49422 **discussion 1371–1374**
8. Burlew CC, Moore EE, Cuschieri J et al (2011) Sew it up! A Western Trauma Association multi-institutional study of enteric injury management in the postinjury open abdomen. J Trauma 70:273–277. https://doi.org/10.1097/TA.0b013e3182050eb7
9. Coccolini F, Montori G, Ceresoli M et al (2017) IROA: international register of open abdomen, preliminary results. World J Emerg Surg 12:10. https://doi.org/10.1186/s13017-017-0123-8
10. Cristaudo AT, Jennings SB, Hitos K et al (2017) Treatments and other prognostic factors in the management of the open abdomen:

a systematic review. J Trauma Acute Care Surg 82:407–418. https://doi.org/10.1097/TA.0000000000001314
11. Bradley MJ, Dubose JJ, Scalea TM et al (2013) Independent predictors of enteric fistula and abdominal sepsis after damage control laparotomy: results from the prospective AAST Open Abdomen registry. JAMA Surg 148:947–954. https://doi.org/10.1001/jamasurg.2013.2514
12. Richter S, Dold S, Doberauer JP et al (2013) Negative pressure wound therapy for the treatment of the open abdomen and incidence of enteral fistulas: a retrospective bicentre analysis. Gastroenterol Res Pract 2013:6–11. https://doi.org/10.1155/2013/730829
13. Coccolini F, Ceresoli M, Kluger Y et al (2019) Open abdomen and entero-atmospheric fistulae: an interim analysis from the international register of open abdomen (IROA). Injury 50:160–166. https://doi.org/10.1016/j.injury.2018.09.040
14. Wilson A, Longhi J, Goldman C, McNatt S (2010) Intra-abdominal pressure and the morbidly obese patients: the effect of body mass index. J Trauma—Inj Infect Crit Care 69:78–83. https://doi.org/10.1097/TA.0b013e3181e05a79
15. Frezza EE, Shebani KO, Robertson J, Wachtel MS (2007) Morbid obesity causes chronic increase of intraabdominal pressure. Dig Dis Sci 52:1038–1041. https://doi.org/10.1007/s10620-006-9203-4
16. Sugerman H, Windsor A, Bessos M, Wolfe L (1997) Intra-abdominal pressure, sagittal abdominal diameter and obesity comorbidity. J Intern Med 241:71–79. https://doi.org/10.1046/j.1365-2796.1997.89104000.x
17. Lambert DM, Marceau S, Forse RA (2005) Intra-abdominal pressure in the morbidly obese. Obes Surg 15:1225–1232. https://doi.org/10.1381/096089205774512546
18. Malbrain MLNG, De Keulenaer BL, Oda J et al (2015) Intra-abdominal hypertension and abdominal compartment syndrome in burns, obesity, pregnancy, and general medicine. Anesthesiol Intensive Ther 47:228–240. https://doi.org/10.5603/AIT.a2015.0021
19. Brown CVR, Neville AL, Rhee P et al (2005) The impact of obesity on the outcomes of 1,153 critically injured blunt trauma patients. J Trauma—Inj Infect Crit Care 59:1048–1051. https://doi.org/10.1097/01.ta.0000189047.65630.c5
20. Liu T, Chen J, Bai X et al (2012) The effect of obesity on outcomes in trauma patients: a meta-analysis. Injury 44:1145–1152. https://doi.org/10.1016/j.injury.2012.10.038
21. Coccolini F, Catena F, Montori G et al (2015) IROA: the international register of open abdomen. An international effort to better understand the open abdomen: call for participants. World J Emerg Surg 10:37. https://doi.org/10.1186/s13017-015-0029-2
22. Cheatham ML, Malbrain MLNG, Kirkpatrick A et al (2007) Results from the international conference of experts on intra-abdominal hypertension and abdominal compartment syndrome. II. Recommendations. Intensive Care Med 33:951–962. https://doi.org/10.1007/s00134-007-0592-4
23. Kirkpatrick AW, Roberts DJ, De Waele J et al (2013) Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the world society of the abdominal compartment syndrome. Intensive Care Med 39:1190–1206. https://doi.org/10.1007/s00134-013-2906-z
24. Haricharan RN, Dooley AC, Weinberg JA et al (2009) Body Mass Index affects time to definitive closure after damage control surgery. J Trauma Inj Infect Crit Care 66:1683–1687. https://doi.org/10.1097/TA.0b013e3181a4e818
25. Duchesne JC, Schmieg RE, Simmons JD et al (2009) Impact of obesity in damage control laparotomy patients. J Trauma Inj Infect Crit Care 67:108–114. https://doi.org/10.1097/TA.0b013e3181a92ce0
26. Johnston M, Safcsak K, Cheatham ML, Smith CP (2015) Management of the open abdomen in obese trauma patients. Am Surg 81:1134–1137
27. Frezza EE (2004) New concepts of physiology in obese patients. Dig Dis Sci 49:1062–1064. https://doi.org/10.1023/B:DDAS.0000034572.76687.2d
28. Sugerman HJ (1998) Increased intra-abdominal pressure in obesity. Int J Obes 22:1138. https://doi.org/10.1038/sj.ijo.0800757
29. Kohlgruber AC, LaMarche NM, Lynch L (2016) Adipose tissue at the nexus of systemic and cellular immunometabolism. Semin Immunol 28:431–440. https://doi.org/10.1016/j.smim.2016.09.005
30. Ji Y, Cheng B, Xu Z et al (2018) Impact of sarcopenic obesity on 30-day mortality in critically ill patients with intra-abdominal sepsis. J Crit Care 46:50–54. https://doi.org/10.1016/j.jcrc.2018.03.019
31. Stenholm S, Harris TB, Rantanen T et al (2008) Sarcopenic obesity: definition, cause and consequences. Curr Opin Clin Nutr Metab Care 11:693–700. https://doi.org/10.1097/MCO.0b013e328312c37d
32. Gonzalez MC, Correia MITD, Heymsfield SB (2017) A requiem for BMI in the clinical setting. Curr Opin Clin Nutr Metab Care 20:314–321. https://doi.org/10.1097/MCO.0000000000000395

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