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VACUUM-ASSISTED ABDOMINAL CLOSURE IN SURGICAL EMERGENCY: A SINGLE INSTITUTION EXPERIENCE TREATING A COHORT WITH A PREVALENCE OF FAECAL PERITONITIS

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Vacuum-assisted abdominal closure (VAAC) has evolved as a promising method for treatment of emergent surgical patients. The aim of the study was an assessment of the complication rate and outcomes following routine application of VAAC in a cohort of patients suffering predominantly with peritonitis of the lower gastrointestinal tract (GIT) origin. The prospectively collected data was analysed retrospectively, including demographic data, aetiological factors, comorbid conditions and severity of the disease. The indications for VAAC included complicated intra-abdominal infection, purulent peritonitis with sepsis and/or risk of increased intra-abdominal pressure. In total, 130 patients were managed with VAAC. The median age was 63.5 years, with a predominance of male patients (61.5%). Systemic inflammatory response was present in 68.5%, the median C-reactive protein (CRP) was 239.58 mg/l, Procalcitonin (PCT) level 7.02 ng/ml, and lactate 1.84 mmol/l before intervention. The median Sequential Organ Failure Assessment (SOFA) score was 4 and the Mannheim Peritonitis Index was 26. Sepsis developed in 87.0% of patients, and 43.8% had septic shock. VAAC was applied in 58.5% due to a perforation of the lower GIT, in 26.1% due to perforation of the upper GIT, and in 15.4% for other reasons. A median of two (interquartile range, IQR 1–3) VAAC system changes were performed in a period of 7 (IQR 4–11) days. In 88.6% of cases, multiple types of microorganisms were present. The application of VAAC resulted in a significant decrease of the postoperative SOFA score, and CRP, PCT and lactate levels ($p < 0.001$). The complications included a "frozen abdomen", enterocutaneous fistula, intraabdominal abscess and bleeding in 7.7%, 5.4% and 6.0% cases, respectively. Primary abdominal closure was accomplished in 76.2%, resulting in a 23.1% mortality rate. VAAC was found to be safe in the treatment of abdominal sepsis including in patients with faecal peritonitis. Complete abdominal closure can be achieved in the majority of patients resulting in a lower mortality rate.

Key words: *complicated intra-abdominal infection, sepsis, intra-abdominal hypertension.*

INTRODUCTION

The open abdomen (OA) strategy is proven as feasible and safe in the treatment of patients suffering from severe abdominal sepsis, trauma and risk of increased intra-abdominal pressure (IAP) (Morykwas *et al*., 1997; Barker *et al*., 2000; Sartelli *et al*., 2015; Bleszynski *et al*., 2016). According to the World Society of Emergency Surgery, the OA strategy is one of the greatest surgical advances in recent times and has had an enormous impact on the daily management of critically ill surgical patients (Sartelli *et al*., 2015). Vacuum-assisted abdominal closure (VAAC) has evolved as a routine procedure in the treatment of patients who are candidates for repeated exploration of the abdominal cavity

(Ribeiro Junior *et al*., 2016). However, an important limitation of the method is associated with challenging wound care. In parallel to the accepted indications for the OA strategy and the application of VAAC, the existing relative indications are influenced by the aetiology of surgical emergency and individual host response, often in a form of systemic inflammatory response (SIRS) or sepsis (Coccolini *et al*., 2017). Several factors, such as SIRS, increased vascular permeability, and aggressive crystalloid resuscitation predispose to fluid sequestration leading to peritoneal fluid formation (Coccolini *et al*., 2017). These changes may result in increased IAP when sequestration of the second- and third-space fluids and forced closure of the abdominal wall ultimately lead to intra-abdominal hypertension (IAH) or even abdominal compartment syndrome (ACS) (Sartelli *et al*., 2015; Coccolini *et al*., 2018b). The technical goal of the OA is defined as intentionally leaving the fascial edges of the abdomen unapproximated (laparostomy) and the exposed abdominal contents protected with temporary coverage (Coccolini *et al*., 2015; Sartelli *et al*., 2015). The OA technique is accepted as useful in the management of critical surgical patients with an increased risk of mortality due to comorbid or physiologically compromised conditions, frequently in cases of intra-abdominal sepsis, severe pancreatitis and septic shock. Despite potential serious complications, the OA is recommended as a life-saving intervention in catastrophically injured patients (Sartelli *et al*., 2015; Coccolini *et al*., 2018b). The need for a deferred intestinal anastomosis, or a planned second look for intestinal ischemia, persistent source of peritonitis (failure of source control), extensive visceral oedema, with a concern for development of ACS are strong indications in favour of the OA strategy (Coccolini *et al*., 2017). Starting from 2008, VAAC as an option of the OA was introduced in our hospital and routine application of the KCI Abthera systems was started in 2010 (Plaudis *et al*., 2012). Initially it was applied in a strictly selected group of patients. With increasing awareness and experience in the application of VAAC, it was implemented in the daily routine of the 24/7 surgical emergency service.

The aim of the study was an assessment of the aetiologic factors, the severity of the preoperative condition, the complication rate and outcomes following the implementation of VAAC in the surgical emergency routine.

METHODS

The prospectively collected data from medical charts was analysed retrospectively and stored anonymously. Patients' characteristics included their demographic data, aetiologic factors, comorbid conditions and severity of the disease. A complicated intra-abdominal infection (CIAI) with purulent peritonitis and development of severe sepsis were indications for application of negative pressure therapy. The decision to apply VAAC in cases of advanced peritonitis was based on the evidence that complete source control would require a repeated laparotomy. The consent for VAAC application was provided by a certified on-duty surgeon familiar with the application of VAAC and the performing anaesthesiologist based on the preoperative assessment of the patient's condition, severity of sepsis or risk of development of ACS, and the physiologic response to the disease. IAH was defined by a sustained or repeated pathological elevation in IAP ≥ 12 mmHg. ACS was diagnosed when a sustained increase of IAP 20 mmHg and one new organ dysfunction were detected (Malbrain *et al*., 2006). The indication for decompressive laparotomy was a sustained increase of IAP > 25 mmHg for more than 24 hours despite an aggressive complex conservative therapy including continuous veno-venous hemofiltration and percutaneous drainage of the intra-abdominal fluid collections if indicated (Pupelis *et al*., 2007). The patient's physical status was assessed using the American Society of Anaesthesiology physical status (ASA) score. The severity of sepsis was assessed by calculation of the Acute Physiology and Chronic Health Evaluation II (APACHE II) score on admission, the assessment of organ dysfunction according to the Sequential Organ Failure Assessment (SOFA) score (Vincent *et al*., 1998) and inflammatory markers of sepsis on admission, before operation and during the postoperative course by a daily assessment of the SOFA score. IAP was measured with the patient in supine position, an instillation of 20 ml of sterile saline solution, with the *linea axillaris media* and *crista iliaca* cross point as the zero point. IAP was measured twice daily during the patient's ICU stay. After the operation, the Mannheim Peritonitis Index (MPI) and the amended classification of the open abdomen according to Björck (Björck *et al*., 2016) was calculated to predict the individual risk of death due to peritonitis. Sepsis was defined according to the latest Sepsis-3 definition criteria (presence of SIRS, signs of peritonitis and signs of organ dysfunction) (Singer *et al*., 2016). During the application of VAAC, all patients were treated in the ICU under the supervision of ICU specialists and surgeons. The decision to discontinue negative pressure therapy and to perform permanent closure of the abdominal cavity was based on preoperative evidence of a stable regression of the inflammatory response, regression of organ dysfunction and sepsis. Intraoperative evidence of a "visually clean abdomen" (absence of abscesses or purulent exudate, disappearance of fibrin) and well-perfused bowels with recovered transit determined the decision to close the abdomen (Plaudis *et al*., 2012). Bacteriological samples from the abdominal cavity were taken during all operations; however, we did not wait until all intraoperative cultures would become negative (Plaudis *et al*., 2012). Blood cultures from the abdominal effluent were collected until a regression of sepsis and a stable decrease of the C-reactive protein (CRP) and procalcitonin (PCT) in the blood were achieved. A positive blood culture was defined as septicaemia. The duration and incidence of VAAC system changes, complication rate, length of ICU and total hospital stay, and mortality rate were analysed. The application of VAAC was approved by the institutional ethics committee. Informed consent was obtained according to the institutional practice.

Statistical data analysis was done using the IBM Corporation Statistical Package for the Social Sciences (SPSS) Statistics 23". Statistical analysis included the analysis of normality with the Kolmogorov–Smirnov test and the Shapiro–Wilk test. Categorical data was analysed according to the conditions with Pearson's $\chi 2$ test or Fisher's Exact test, with p values and odds ratio (OR) and 95% confidence interval (95% CI), where applicable. Quantitative data was reported with a median and interquartile range (IQR). Quantitative independent data between two groups was analysed with the Mann–Whitney U test; multiple paired samples were analysed with the Friedman Two-Way ANOVA test, including post-hoc analysis with the Wilcoxon test, adjusted by Bonferroni correction to decrease the chance of type I error; $p < 0.05$ was considered significant.

The application of VAAC and conduction of study was approved by the institutional ethics committee.

RESULTS

Patient characteristics. In total, 130 patients from 2011 to 2018 were managed according to the OA strategy with the application of ABThera™ (KCI® Riga, Latvia) VAAC systems. The median age of patients in the cohort was more than 60 years, and the median APACHE II on admission was 14 (IQR 11–19). SIRS developed in the majority of patients. VAAC was more frequently used in males. The majority of patients had an increased ASA physical status score. The median MPI score was 26 (IQR 21–31) points. Signs of SIRS were present in 68.5% of patients and absent in 31.5% (Table 1). The median SOFA score before surgical intervention was 4 (IQR 2–6); the median CRP level was 239.58 mg/l (IQR 113.92–324.01) and median PCT level was 7.02 ng/ml (IQR 1.74–32.32). The blood lactate median level on admission was 1.84 mmol/l (1.20–2.61) (Table 1). Of all patients, 17.7% complied with the criteria for sepsis, 25.4% for severe sepsis and 43.8% for signs of septic shock. Vasopressor support was necessary in 44.6% of patients (Table 1).

Table 1. Preoperative and intraoperative patients' characteristics

Parameter	Value	
Total number of patients	130	
Median age, years (IQR)	63.5 (52–76)	
Gender		
Male	61.5%	$p = 0.009$
Female	38.5%	
APACHE II at admission (IQR)	14 (11–19)	
ASA physical status score (IQR)	3 (3–4)	
SIRS present	68.5%	
MPI index (IQR)	26 (21–31)	
CRP, mg/l (IQR)	239.58 (113.92–324.01)	
PCT, ng/ml (IQR)	7.02 (1.74–32.32)	
Lactate, mmol/l (IQR)	1.84 (1.20–2.61)	
Sepsis	17.7%	
Severe sepsis with organ dysfunction	25.4%	
Septic shock	43.8%	
Vasopressor support	44.6%	
Surgical treatment within 48 h from onset	46.1%	
Emergent complication of malignant process	25.4%	
Development of peritonitis from all	84.6%	
VAAC changes, count (IQR)	2 (1–3)	
VAAC use, days (IQR)	7 (4–11)	
Wound VAC for abdominal closure	11.5%	

IQR, interquartile range; VAAC, vacuum-assisted abdominal closure; APACHE II, Acute Physiology and Chronic Health Evaluation II; ASA, American Society of Anaesthesiology physical status score; SIRS, systemic inflammatory response syndrome; MPI, Mannheim peritonitis index; CRP, C-reactive protein; PCT, procalcitonin; VAC, vacuum assisted closure

Indications and types of surgical interventions. In 46.1% of patients surgical intervention was performed within 48 hours from the onset of a CIAI, and 25.4% of all patients had emergent surgical complication of a malignant process in the abdominal cavity. The indications for the application of VAAC was peritonitis due to perforation of the upper part of the gastrointestinal tract (GIT) in 26.1% of cases, and due to perforation of the lower GIT in 58.5%. Defect of the gastrointestinal barrier was the reason for the development of CIAI in 84.6% of patients. However, in 15.4% cases, GIT was not the reason for a complicated intra-abdominal pathology. The damage control principle was employed in 13 laparotomies (10.0%) including ten cases of intestinal resection without anastomosis or stoma; in two cases an omental patch was used for the localisation of anastomotic leakage, and in one case the defect was extraperitonised, forming a temporary stoma (Table 2). In 60.8% of cases, VAAC was applied as the initial strategy after emergent operation, and in 39.2% cases VAAC was applied after primary abdominal closure during re-laparotomy. A median of 2 (IQR 1–3) VAAC system changes was performed in a median period of 7 (IQR 4–11) days**.** In 15 cases, wound vacuum assisted closure (VAC) was sequentially used for complete abdominal closure. The degree of contamination of the abdominal cavity according to the Bjork classification is displayed in Table 3. During the application of VAAC, Bacteroides sp. were cultured in 40.0% followed by Streptococcus sp. in 32.3%, Enterococcus sp. in 31.5%, *Escherichia coli* in 28.5% and Candida sp. in 11.5% of all samples. The majority of samples (88.6%) had more than one type of microorganism, with a median of 4 (IQR 3–5) per sample. Antibacterial resistance was found in 8 (6.2%) cultures, five cases (0.8%) of vancomycin resistant *Enterococcus faecium*, one case (0.8%) of multiresistant *Acinetobacter baumanii*, one case (0.8%) of extended-spectrum beta-lactamase (ESBL) producing *Klebsiella oxytoca* and one case (0.8%) of ESBL producing *Klebsiella pneumoniae*. The antibacterial treatment included Metronidazole (72.3%), Piperacillin/tazobactam (60.8%), Ceftriaxone (33.8%), Ciprofloxacin (20.8%) and Imipenem/cilastatin (17.7%) (Table 4).

Dynamics of inflammation after VAAC therapy. The application of VAAC resulted in a significant decrease of the postoperative SOFA score, a median of 4 (IQR 2–6) points

Table 2. Main indications for VAAC application

Indications for application of VAAC	n	%
Anastomotic insufficiency (Lower GIT)	18	13.8
Diverticulitis with perforation	18	13.8
Appendicitis	15	11.5
Tumour perforation of the large intestine	8	6.2
Decompensated bowel obstruction	7	5.4
Unspecified perforation of the large intestine	7	5.4
Ischaemic necrosis of the large intestine	7	5.4
Necrosis and perforation of the small intestine due to strangulating hernia	7	5.4
Perforation of duodenal ulcer	6	4.6
Perforation of gastric ulcer	5	3.8
Unspecified perforation of the small intestine	5	3.8
Anastomotic insufficiency (Upper GIT)	4	3.1
Primary abdominal closure impossible	4	3.1
Infected ascites	3	2.3
Ischaemic necrosis of the small intestine	3	2.3
Wound dehiscence	2	1.5
Perforation of small intestine due to metastatic tumor	2	1.5
Chron's disease with multiple fistulae	2	1.5
Traumatic intestinal injury	2	1.5
Acute pancreatitis	1	0.8
Perforation of large intestine due to metastatic tumor	1	0.8
Cholangitis	1	0.8
Infected hematoma with perforation to abdominal cavity	1	0.8
Pelvic abscess	1	0.8
In total		100%

Gastrointestinal involvement	
Perforation of upper GIT	26.1%
Perforation of lower GIT	58.5%
No involvement of GIT	15.4%
Total	100%
VAAC as initial strategy	60.8%
VAAC during relaparotomy	39.2%
Total	100%
For damage control laparotomy from all*	10%*

VAAC, vacuum-assisted abdominal closure; GIT, gastrointestinal tract

Table 3. Abdominal contamination according to Björck before application of VAAC and after removal of VAAC

Amended classification system	Before application		After application	
	count, n	per cent, %	count, n	per cent, %
1A Clean, no fixation	4	3.1	75	64.1
1B Contaminated, no fixation	68	52.3	2	1.7
1C Enteric leak, no fixation	30	23.1	1	0.9
2A Clean, developing fixation	3	2.3	27	23.0
2B Contaminated, developing fixation	14	10.8	1	0.9
2C Enteric leak, developing fixation	9	6.8	0	0
3A Clean, frozen abdomen	0	0	9	7.7
3B Contaminated, frozen abdomen	1	0.8	0	0
4 Established EA fistula, frozen abdomen	1	0.8	2	1.7
Total	130	100.0	117	100.0

VAAC, vacuum-assisted abdominal closure

Table 4. Pathogens cultured from the abdominal cavity and antibacterial treatment

More than one type of microorganism	88.6%
Microorganism count (IQR)	4 (3–5)
Antimicrobial resistance	6.2%

Microorganism profile during primary VAAC application		
n of positive abdominal cultures	n, count	%, from all cases
Bacteroides sp.	52	40.0
Streptococcus sp.	42	32.3
Enterococcus sp.	41	31.5
Escherichia coli	37	28.5
Candida sp.	15	11.5
Klebsiella pneumoniae	11	8.5
Staphylococcus	11	8.5
Pseudomonas aeruginosa	9	6.9
Prevotella	8	6,2
Clostridium perfringens	7	5.4
Clostridium sp. (except perfringens)	6	4.6
Klebsiella oxytoca	6	4.6
Peptostreptococcus sp.	6	4.6
Citrobacter sp.	5	3.8
Enterobacter cloacae	4	3.1
Proteus sp.	4	3.1
Actinomyces odontolyticus	3	2.3
Anaerobic gram-positive cocci	3	2.3
Corynebacterium sp.	3	2.3
Parvimonas micra	3	2.3
Peptoniphilus asaccharolyticus	3	2.3
Acinetobacter baumanii	2	1.5
Bacillus sp.	2	1.5
Morganella sp.	2	1.5
Aerococcus	1	0.8
Aeromonas	1	0.8
Anaerobic gram-negative rods	1	0.8
Anaerococcus prevoti	1	0.8
Bifidobacterium sp.	1	0.8
Fusobacterium necrophorum	1	0.8
Gemella sp.	1	0.8
Hafnia alvei	1	0.8
Lactobacillus salivarius	1	0.8
Propionibacterium acnes	1	0.8
Providencia rettgeri	1	0.8
Serratia fonticola	1	0.8
Veillonella parvula	1	0.8
Antibacterial regimen	n, count	%, from all cases
Metronidazole	94	72.3
Piperacillin/tazobactam	79	60.8
Ceftriaxone	44	33.8
Ciprofloxacin	27	20.8
Imipenem/cilastatin	23	17.7
Fluconazole	16	12.3
Vancomycin	12	9.2
Linezolid	5	3.8
Colistin	4	3.1
Meropenem	3	2.3
Amikacin	2	1.5

IQR, interquartile range; VAAC, vacuum-assisted abdominal closure

Table 5. Dynamics of inflammatory markers and SOFA score

Variable	Median (IQR) Preoperative	1st POD	3rd POD	7th POD	p value, pairwise comparisons
SOFA, points	4(2–6)	3(0–6)	1(0–3)	0(0–3)	$p < 0.001$*
CRP, mg/l	239.6(113.9–324.0)	233.7(160.2–322.1)	106.2(74.4–161.3)	57.3(32.8–106.8)	$p < 0.001$**
PCT, ng/ml	7.02(1.74–32.32)	7.20(1.73–36.24)	3.27(0.96–12.20)	0.73(0.26–2.99)	$p < 0.001$***
Lactate, mmol/l	1.8(1.2–2.6)	2.2(1.6–3.1)	1.4(1.2–2.0)	1.5(1.2–2.1)	$p = 0.001$****

Friedman's Two-Way ANOVA, post-hoc analysis with Wilcoxon's test, adjusted. Postoperative day (POD). *SOFA score: 7 vs. 3, $p = 0.037$, 7 vs. 1, $p < 0.001$, 7 vs. PRE, $p < 0.001$, 3 vs. 1, $p = 0.007$, 3 vs. PRE, $p < 0.001$, 1 vs. PRE, $p = 0.111$; ** CRP: 7 vs. 3, $p < 0.001$, 7 vs. 1, $p < 0.001$, 7 vs. PRE, $p < 0.001$, 3 vs. 1, $p < 0.001$, 3 vs. PRE, $p < 0.001$, 1 vs. PRE, $p = 1.0$; ***PCT: 7 vs. 3, $p < 0.001$, 7 vs. 1, $p < 0.001$, 7 vs. PRE, $p < 0.001$, 3 vs. 1, $p < 0.001$, 3 vs. PRE, $p = 0.001$, 1 vs. PRE $p = 1.0$; ****Lactate: 7 vs. 3, $p = 1.0$, 7 vs. 1, $p = 0.005$, 7th – PRE, $p = 0.02$, 3 vs. 1, $p = 0.03$, 3 vs. PRE, $p = 0.1$, 1 vs. PRE, $p = 1.0$.

SOFA, Sequential [Sepsis-related] Organ Failure Assessment; IQR, interquartile range; CRP, C-reactive protein; PCT, procalcitonin

before VAAC application vs. a median of 0 (IQR 0–3) points on day 7 after VAAC placement, $p < 0.001$ (Table 5). CRP decreased gradually, from a median of 239.6 mg/l (IQR 113.9–324.0) before VAAC placement, followed by a median of 33.7 mg/l (IQR 160.2–322.1), 106.2 (IQR 74.4–161.3) and mg/l 57.3 (32.8–106.8) during the 1st, 3rd and 7th day after VAAC placement, respectively ($p < 0.001$). PCT values showed a small, non-significant increase the day following the first operation with the median value rising from 7.02 ng/ml (IQR 1.74–32.32) to 7.20 ng/ml (IQR 1.73–36.24), $p = 1.0$, and then, decreasing to 0.73 ng/ml on the 7th day after VAAC application, $p < 0.001$. The same pattern as for PCT values was observed for lactate, increasing from 1.8 mmol/l (IQR1.2–2.6) to 2.2 mmol/l (IQR1.6–3.1) during the first 24 hours after VAAC placement, $p = 1.0$, and then decreasing to 0.73 mmol/l (0.26–2.99) on the 7th postoperative day, $p < 0.001$ (Figs. 1, 2, 3, 4). Complications occurred in 16.9% of cases. The so called "frozen abdomen" with secondary closure was observed in ten cases (7.7%). Enterocutaneous fistula complicated the clinical course in seven cases (5.4%), intra-abdominal abscess and bleeding from the wound in two cases each (3.0%), while wound infection was observed in one case (0.8%).

Success of abdominal closure. Full thickness abdominal closure was accomplished in 92 cases (76.2%). The remaining survived patients experienced skin and subcutaneous closure without fascial closure in ten cases. Wound VAC was used in 13 cases, while closure with mesh in one and component separation in one more patient was performed (Table 6).

Main outcomes. The overall ICU stay was a median of 13 days (IQR 8–19) and hospital stay a median of 22 days (IQR 16–31). Consequently, the ICU stay was 12 days for patients admitted with anamnesis less than 48 hours, and 14 days for patients admitted after 48 hours from the onset of the disease ($p = 0.6$) leading to a 22-day and 23.5-day not significantly different median hospital stay ($p = 0.87$). The applied OA strategy resulted in a 23.1% mortality rate. The mortality was higher in cases where the upper GIT was involved, reaching 37.1%, $p = 0.08$ (Table 6).

Table 6. Success of abdominal closure and main outcomes

Abdominal closure	Value	
Full thickness abdominal closure	76.2%	
Skin and subcutaneous closure	13%	
Additional wound VAC used	16.9%	
Closure with mesh	1 case	
Component separation	1 case	
Outcomes		
Overall hospital stay, days (IQR)	22 (16–31)	
ICU stay, days (IQR)	13 (8–19)	
Mortality rate	23.1%	
Mortality rate – upper GIT	37.1%	$p = 0.08$
Mortality rate – lower GIT	18.4%	
Mortality rate – no involvement of GIT	15.8%	

VAC, vacuum assisted closure; IQR, interquartile range; GIT, gastrointestinal tract

DISCUSSION

The OA strategy evolved from preplanned relaparotomies, the Bogota bag (Kreis, 2013), and the Wittmann patch (Tieu *et al*., 2008) to the Baker pack (Barker *et al*., 2000) and commercially available negative pressure wound therapy (NPWT) devices. It has dramatically improved the treatment outcomes of critically ill surgical patients and is regarded as one of the greatest surgical advances in recent times (Sartelli *et al*., 2015). The 2018 WSES guidelines have stressed the importance of the correction of physiologic derangements in critically ill surgical patients who are selected for NPWT. The main requirement for a successful outcome is an early definitive fascial and/or abdominal closure (Coccolini *et al*., 2018b). The consensus statements have been based on the experience gained during the recent decades (Coccolini *et al*., 2014; 2015; Sartelli *et al*., 2015; Coccolini *et al*., 2017; 2018b; 2019). Routine implementation of NPWT in our hospital started with occasional self-made Baker pack systems; however, the first cases us-

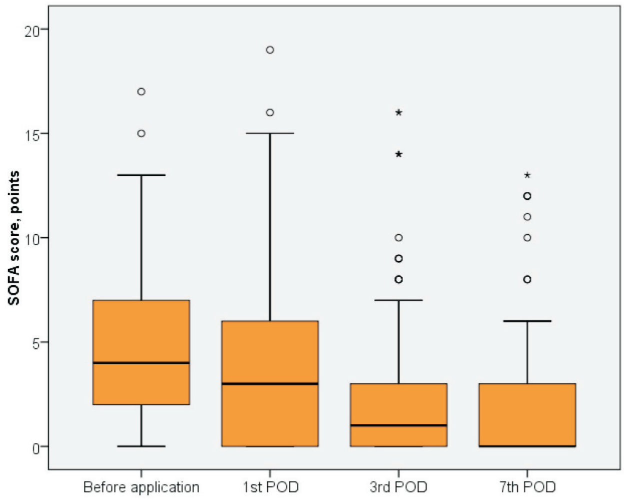

Fig. 1. Dynamics of Sequential Organ Failure Assessment (SOFA) score. POD, postoperative day.

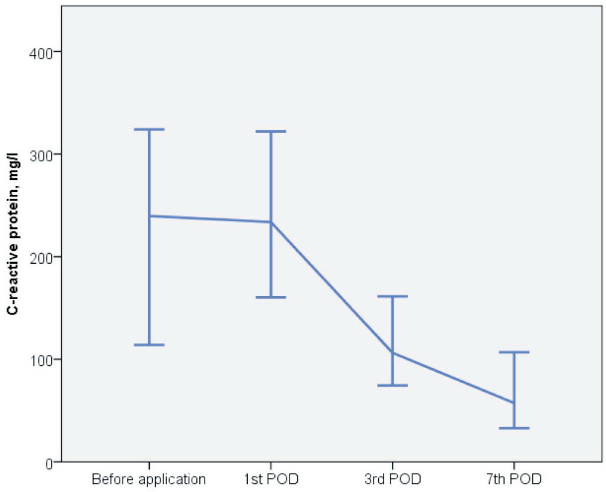

Fig. 2. Dynamics of C-reactive protein (CRP). POD, postoperative day.

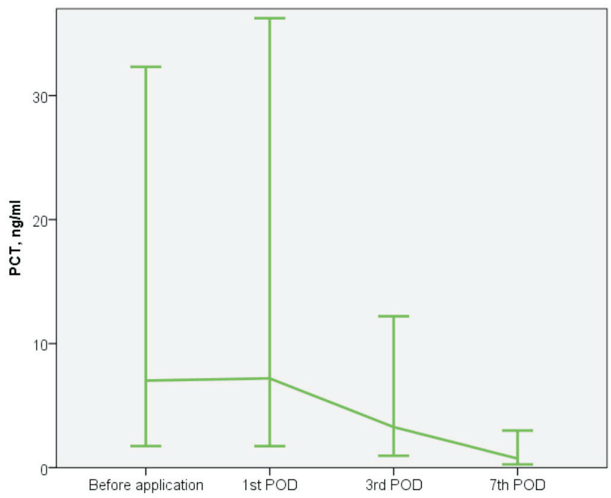

Fig. 3. Dynamics of procalcitonin (PCT). POD, postoperative day.

ing commercially available KCI ABTHERA™ systems occurred in 2010. Following that, VAAC was introduced in our emergency service on a routine basis. Several studies report similar results (Kafka-Ritsch *et al.*, 2012; Bleszynski

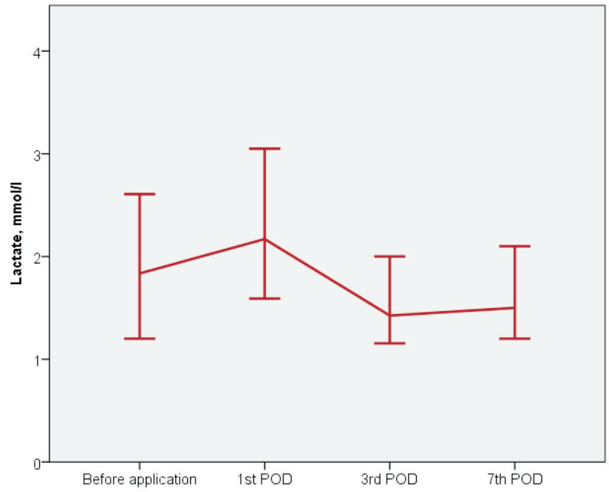

Fig. 4. Dynamics of lactate. POD, postoperative day.

et al., 2016; Tartaglia *et al.*, 2019) and some differ (Rezende-Neto *et al.*, 2016; Jensen *et al.*, 2017; Sartelli *et al.*, 2019) from the current study. The important criteria for definitive closure included visual signs of intestinal viability, provision of full source control, no need for further surgical re-exploration, and no concerns for ACS (Rezende-Neto *et al.*, 2016; Coccolini *et al.*, 2018b; Sartelli *et al.*, 2019). We have recognised some differences in the published cohorts. Our data indicate that a selective assessment of treatment results in different groups of patients who undergo NPWT is important for definitive conclusions. The majority of studies focus on the methods of complete abdominal closure and include the whole patient spectrum in different proportions. The time of complete abdominal closure differs significantly between trauma patients with damage control and patients with advanced peritonitis (Carlson *et al.*, 2013; Godat *et al.*, 2013; Atema *et al.*, 2015; Jensen *et al.*, 2017; Hu *et al.*, 2018). The OA strategy, or postponing complete abdominal closure, is recommended in patients who are at risk of postoperative IAH, if repeated abdominal exploration is necessary due to CIAI and advanced peritonitis, or in critical patients with severely deranged physiologic response according to the damage control strategy (Coccolini *et al.*, 2018b). In patients with severe abdominal sepsis, trauma, acute pancreatitis and other abdominal emergencies associated with a need for large fluid replacement, the clinical course may be complicated by sustained IAH (Morykwas *et al.*, 1997; Malbrain *et al.*, 2006; Tieu *et al.*, 2008; Beckman *et al.*, 2016; Griggs and Butler, 2016; Coccolini *et al.*, 2017; Sartell *et al.*, 2017a). High amounts of pus and contaminated fibrin in the case of CIAI and sepsis mandate staged laparotomies. A patient with critical trauma, pancreatitis or bowel ischaemia receiving massive amounts of resuscitation fluids may develop excessive gut oedema affecting gut motility, increasing volume of intraabdominal contents and affecting the compliance of the abdominal wall (Carlson *et al.*, 2013; Beckman *et al.*, 2016; Rezende-Neto *et al.*, 2016; Coccolini *et al.*, 2017; Coccolini, Roberts, *et al.*, 2018; Griggs and Butler, 2016; Hu *et al.*, 2018; Reintam Blaser *et al.*, 2019). The evaluation of a patient's haemodynamic stability and tissue perfusion before the decision towards an abbreviated "damage control" strategy is crucial (Tieu *et al*., 2008; Kreis, 2013; Atema *et al*., 2015; Griggs and Butler, 2016; Rezende-Neto *et al*., 2016; Singer *et al*., 2016; Coccolini *et al*., 2017). The consensus decision of the intensive care specialist, anaesthesiologist and surgeon about the timing, extent and duration of surgical intervention is decisive (Godat *et al*., 2013; Beckman *et al*., 2016; Rezende-Neto *et al*., 2016; Loftus *et al*., 2017; Sartelli *et al*., 2017a; Hu *et al*., 2018; Sartelli *et al*., 2019). Our data supported the advantage of a multidisciplinary approach. The improvement of the patient's vital resources maintaining a relatively low preoperative serum lactate matched the recently published recommendations (Godat *et al*., 2013; Beckman *et al*., 2016; Rezende-Neto *et al*., 2016; Sartelli *et al*., 2017a; Coccolini,*et al*., 2018b; Hu *et al*., 2018). In the current study, 84.6% of patients lost the integrity of the gastrointestinal barrier, and 68.5% developed SIRS, showing that the most frequent reason for the OA strategy was diffuse peritonitis including the cases of diverticulitis or anastomotic leakage in the lower GIT (Tieu *et al*., 2008; Kafka-Ritsch *et al*., 2012; Carlson *et al*., 2013; Atema *et al*., 2015; Griggs and Butler, 2016; Rezende-Neto *et al*., 2016; Sartelli *et al*., 2014; 2017; 2019). Preoperative comorbidity assessment revealed a high median ASA score and MPI. The maximum MPI score was 37 among the survivors, and 40 in non-survivors, mostly in those who referred later than 48 hours from the onset. A quarter of patients had an oncologic disease (Basnet, 2010; Muralidhar *et al*., 2014; Salamone, 2016; Batra *et al*., 2017; Coccolini *et al*., 2018b; Sartelli *et al*., 2019). Most patients suffered peritonitis associated with a large bowel pathology. The aging population is reflected in the median age of our cohort, which reached 63.5 years. The patient age, gender and value of MPI in our cohort was rather high, confirming the prognostic value of both criteria (Basnet, 2010; Kafka-Ritsch *et al*., 2012; Carlson *et al*., 2013; Salamone, 2016; Loftus *et al*., 2017; Reintam Blaser *et al*., 2019; Sartelli *et al*., 2019). VAAC was more frequently applied in males; similar data has been reported earlier (Tieu *et al*., 2008; Basnet, 2010; Carlson *et al*., 2013; Sartelli *et al*., 2014; Bleszynski *et al*., 2016; Loftus *et al*., 2017; Sartelli *et al*., 2019; Tartaglia *et al*., 2019). Still, damage control laparotomy was applied less frequently due to a relatively low number of trauma patients, in contrast to data from other studies (Kafka-Ritsch *et al*., 2012; Godat *et al*., 2013; Sartelli *et al*., 2014; Salamone, 2016; Reintam Blaser *et al*., 2019; Sartelli *et al*., 2019). The OA strategy has changed substantially since MJ Morykwas published his experimental study. The reported reduction of bacterial counts within 4 days of the application of negative pressure therapy, the faster rate of granulation and fourfold increase of the blood flow applying 125 mmHg negative pressure were important findings (Morykwas *et al*., 1997). Further development of the idea included different attempts to fight IAH and to treat peritonitis (Barker *et al*., 2000; Malbrain *et al*., 2006; Pupelis *et al*., 2007; Sartelli *et al*., 2015; Bleszynski *et al*., 2016; Coccolini *et al*., 2017; Coccolini *et al*., 2018b). It was found that there was a necessity to maintain a balance between an effective removal of fluid and avoiding causing potential damage to underlying organs by using lower negative pressure secondary to the physiological status of the patient (Wittmann *et al*., 1996; Barker *et al*., 2000; Wondberg *et al*., 2008; Kafka-Ritsch *et al*., 2012; Frazee *et al*., 2013; Kreis, 2013; Rasilainen *et al*., 2015; Rezende-Neto *et al*., 2016; Tartaglia*et al*., 2019). The type of the pathogen and the physiological response to the contamination of the abdominal cavity largely depend on the gastrointestinal segment involved in the pathological process and typical food characteristics for patients (Kafka-Ritsch *et al*., 2012; Carlson *et al*., 2013; Sartelli *et al*., 2014; 2017a; Tartaglia *et al*., 2019). The most frequent cultures were *Bacteroides*, *Streptococcus*, *Enterococcus*, *Escherichia coli* and *Candida*, including resistant flora in 6.2%. It was confirmed that the predominant source is from the lower GIT segments and that the microflora is associated with late colonisation, when a longer duration of the OA is needed (Rasilainen *et al*., 2015). The different bacteriologic pattern reported earlier may be explained by the large difference in patient cohorts and the traditional consumption of meat and animal fats (Carlson *et al*., 2013; Sartelli *et al*., 2014; Rasilainen *et al*., 2015; Jensen *et al*., 2017; Sartelli *et al*., 2017a). Several laboratory tests and scores are approved as effective criteria for the assessment of the clinical course of sepsis, including the biochemical markers of inflammation — CRP, PCT, the SOFA score and others (Schmit and Vincent, 2008; Cho and Choi, 2014; Sartelli *et al*., 2017b; Schmidt de Oliveira-Netto *et al*., 2019). The regression of sepsis and systemic inflammatory reaction is the mainstay of source control, reflecting the efficacy of surgical treatment in case of peritonitis. The results of our study confirm that the application of VAAC is associated with a regression of sepsis, showing a slight increase of the CRP immediately after surgical intervention with a decrease and normalisation in parallel with the normalisation of PCT. Both inflammatory markers and the SOFA score, as well as lactate, decreased most significantly on the third day after the initial operation, showing a positive therapeutic effect of the OA strategy (Morykwas *et al*., 1997; Schmit and Vincent, 2008; Cho and Choi, 2014; Sartelli *et al*., 2015; Reintam Blaser *et al*., 2019; Sartelli *et al*., 2019; Schmidt de Oliveira-Netto *et al*., 2019). In recent decades, the outcomes associated with the OA strategy have improved in the selective category of patients who need a multidisciplinary approach and preoperative assessment of physiological derangements. The development of enteroatmospheric fistula, bleeding and the so-called "frozen abdomen" are late complications (Sartelli *et al*., 2014; Coccolini *et al*., 2015; Ribeiro Junior *et al*., 2016; Tartaglia *et al*., 2019). According to literature, the fistula rate is between 5.7% and 17.2% (Carlson *et al*., 2013; Atema *et al*., 2015; Sartelli *et al*., 2017a; Reintam Blaser *et al*., 2019). The overall complication rate in the current study was 10.0%, including bleeding and the development of enteroatmospheric fistula in 5.4%. Considering the characteristics of our cohort where 87.0% of patients suffered sepsis and 43.8% of them had septic shock, the OA strategy proved to be safe and effective. Similar rates of enteroatmospheric fistula, "frozen abdomen", intraabdominal abscesses, and bleeding are comparable with reports from other authors (Carlson *et al*., 2013; Godat *et al*., 2013; Bruhin *et al*., 2014; Sartelli *et al*., 2014; Atema *et al*., 2015; Coccolini *et al*., 2015; Krebs and Jagrič, 2017; López-Cano *et al*., 2018; Tartaglia *et al*., 2019). One of the most discussed questions challenging the outcomes of the OA strategy is the timing of complete abdominal closure. Generally, all authors agree that complete abdominal closure should be attempted as soon as possible, but the red line starts on the 5th–7th postoperative day (Cothren *et al*., 2006; Bruhin *et al*., 2014; Fortelny *et al*., 2014; Huang *et al*., 2016; Acosta *et al*., 2017; Coccolini *et al*., 2017; Krebs and Jagrič, 2017; Montori *et al*., 2017; Willms *et al*., 2017; López-Cano *et al*., 2018; Salamone *et al*., 2018). If the application time is too long and the NPWT system changes are too frequent, the rate of enterocutaneous fistula formation, bowel obstruction, bleeding and other complications can increase (Basnet, 2010; Muralidhar *et al*., 2014; Beckman *et al*., 2016; Salamone, 2016; Coccolini *et al*., 2017; Hu *et al*., 2018). Different techniques have emerged to improve the results of complete abdominal closure, including component separation, split-thickness skin grafting, use of biological mesh materials, and commercially available systems (Wittmann *et al*., 1996; Pupelis *et al*., 2007; Wondberg *et al*., 2008; Kafka-Ritsch *et al*., 2012; Beckman *et al*., 2016; Sartelli, Catena, *et al*., 2017), mesh-mediated fascial traction and sequential dynamic closure technique (Bruhin *et al*., 2014; Arai *et al*., 2015; Sharrock *et al*., 2016; Tolonen *et al*., 2017; Berrevoet, 2018; López-Cano *et al*., 2018; Salamone *et al*., 2018;), component separation and mesh repair (Sharrock *et al*., 2016; Berrevoet, 2018). Sequential dynamic primary closure involves the application of small amounts of tension to the fascia at each repeat laparotomy to reach the goal of primary fascial closure. It is important that fascial closure is 'tension free' avoiding ischaemia and fascial necrosis, thus reducing the risk of ACS (Bruhin *et al*., 2014). NPWT with continuous mesh or suture mediated fascial traction or dynamic retention sutures results in a 73.1–73.6% fascial closure rate (Atema *et al*., 2015; Acosta *et al*., 2017; Willms *et al*., 2017; Berrevoet, 2018). Our experience is limited to dynamic fascial traction and wound VAAC when indicated, resulting in a 76.0% success rate of abdominal closure, achieved with a median of two system changes within one week of treatment, which is in compliance with the latest reports. The decision to perform abdominal closure largely depends on the surgeon's experience and expertise. It is based on the macroscopic evidence of resolution of peritonitis by the attending surgeon and clinical assessment. However, recommendations for the appropriate fascial closure time are still lacking, and in the late stage of the disease, surgeons are mostly fighting with complications that are associated with NPWT application (Morykwas *et al*., 1997; Atema *et al*., 2015; Bleszynski *et al*., 2016; Coccolini *et al*., 2017; Tolonen *et al*., 2017; Coccolini, Ceresoli, *et al*., 2018). Clearance of the purulent contents and fibrin deposits, signs of well-perfused functioning bowels, regression of sepsis, normalisation of CRP and visual confirmation of complete source control during the repeated laparotomy may indicate that definitive abdominal closure is possible even in cases when abdominal bacterial cultures are positive (Plaudis *et al*., 2012; Rasilainen *et al*., 2015; Jensen *et al*., 2017; Loftus *et al*., 2017; Sartelli *et al*., 2017a; Tolonen *et al*., 2017). The median ICU and hospital stay varies greatly and depends on the medical condition and reason why the OA strategy has been chosen. The median ICU stay was 13 days and hospital stay 22 days in our cohort, which was comparable with data from the treatment of a mixed patient category differing for patients with trauma and peritonitis, as it was predominantly in our study. Some authors report longer ICU and hospital stays (Rasilainen *et al*., 2015; Bleszynski *et al*., 2016; Krebs and Jagrič, 2017; Montori *et al*., 2017; Tolonen *et al*., 2017; Coccolini *et al*., 2018a; Salamone *et al*., 2018), and further treatment results would need a more selective approach for analysis. Mortality in the OA is largely influenced by the medical condition and the degree of physiological derangement, ranging from 12% to 25% in a non-septic population increasing from 22% to 40% in septic or mixed populations, which is close to our results of 23% (Carlson *et al*., 2013; Bruhin *et al*., 2014; Krebs and Jagrič, 2017; Tolonen *et al*., 2017; Coccolini *et al*., 2018a; López-Cano *et al*., 2018; Sartelli *et al*., 2019).

The main strength of this study is the possibility to analyse the treatment results of a uniform cohort of patients. In the majority of cases, patients suffered a severe course of sepsis and septic shock with a breach of the gastrointestinal barrier, predominantly because of the large bowel pathology. The other important aspect is the multidisciplinary approach and support of the specialised ICU unit we had during the whole study period. The weakness of the study is a retrospective analysis of data from a single institution with possible statistical biases.

CONCLUSION

The OA strategy is feasible and safe in the treatment of patients suffering from severe abdominal sepsis, trauma, and the risk of increased IAP. Favourable outcomes could be achieved in the treatment of patients with peritonitis, especially when the lower GIT barrier is broken. The commercial ABThera™ VAAC systems are reliable in the setting of the ICU unit. Complete abdominal closure can be achieved in the majority of patients using the dynamic fascial traction and wound VAAC.

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VĒDERA DOBUMA SLĒGŠANA AR VAKUUMA PALĪDZĪBU NEATLIEKAMAJĀ ĶIRURĢIJĀ: KLĪNISKĀ CENTRA PIEREDZE, ĀRSTĒJOT KOHORTU AR PREVALĒJOŠI FEKĀLU PERITONĪTU

Vēdera dobuma slēgšana ar vakuuma palīdzību ir attīstījusies par daudzsološu neatliekamu ķirurģisku pacientu ārstēšanas metodi. Šī pētījuma uzdevums ir novērtēt komplikāciju biežumu un rezultātus pēc vēdera dobuma slēgšanas ar vakuuma palīdzību pacientiem pie prevalējoša, no apakšējā gastrointestinālā trakta patoloģijas radīta peritonīta. Prospektīvi savāktie dati analizēti retrospektīvi, iekļaujot demogrāfiskos datus, izraisošos faktorus, blakussaslimšanas un slimības smaguma pakāpi. Indikācijas vēdera dobuma slēgšanai ar vakuuma palīdzību bijušas komplicēta intra-abdomināla infekcija, strutains peritonīts ar sepsi un/vai risks pieaugt intra-abdominālajam spiedienam. Vakuuma asistēta vēdera dobuma slēgšana bijusi lietota 130 pacientiem. Mediānas vecums bija 63,5 gadi, biežāk vīriešiem (61,5%). Pirms operācijas sistēmisks iekaisuma atbildes sindroms (SIRS) bija 68.5% pacientu, mediānas C-reaktīvais olbaltums (CRO) bija 239,58 mg/l, prokalcitonīns bija 7,02 ng/ml, un laktāts 1,84 mmol/l. Mediānas secīgā orgānu bojājuma novērtējuma skala (SOFA) bija 4 punkti un Mannheimas peritonīta indekss (MPI) bija 26 punkti. Sepse attīstījās 87% pacientu, un 43,8% bija septisks šoks. Vēdera dobuma slēgšana ar vakuuma palīdzību tika veikta 58.5% gadījumu sakarā ar apakšējā gastrointestinālā trakta perforāciju, 26,1% gadījumu — ar augšējā gastrointestinālā trakta perforāciju un 15,4% gadījumu — sakarā ar citām patoloģijām. Vakuumaspirācijas sistēmas maiņas mediānas vērtība bija 2 (IQR 1–3) ar dienu perioda mediānas vērtību septiņas dienas (IQR 4–11). 88,6% gadījumu operācijas materiāla uzsējumos konstatēti vairāki mikroorganismi. Vēdera pagaidu slēgšanas rezultātā samazinājās SOFA punktu skaits, CRO, prokalcitonīna un laktāta līmeņi (p < 0,001). Komplikāciju biežums — "*frozen abdomen*" 7,7% gadījumu, enterokutāna fistula 5,4% gadījumu, intraabdomināls abscess un asiņošana 6% gadījumu katra. Vēdera dobums slēgts primāri 76,2% gadījumu. Mortalitāte bijusi 23,1%. Vēdera dobuma slēgšana ar vakuuma palīdzību ir droša pacientiem pie abdominālas sepses sakarā ar fekālu peritonītu. Pilna vēdera dobuma slēgšana ir iespējama vairumam pacientu, kā arī ir zemāka mortalitāte.