Hernia (2014) 18:647–652
DOI 10.1007/s10029-014-1280-2

ORIGINAL ARTICLE

Effect of botulinum toxin type A in lateral abdominal wall muscles thickness and length of patients with midline incisional hernia secondary to open abdomen management

T. R. Ibarra-Hurtado · C. M. Nuño-Guzmán · A. G. Miranda-Díaz · R. Troyo-Sanromán · R. Navarro-Ibarra · L. Bravo-Cuéllar

Received: 16 July 2013 / Accepted: 27 June 2014 / Published online: 18 July 2014

Abstract
Purpose Abdominal wall hernia secondary to open abdomen management represents a surgical challenge. The hernia worsens due to lateral muscle retraction. Our objective was to evaluate if Botulinum Toxin Type A (BTA) application in lateral abdominal wall muscles modifies its thickness and length.
Methods A clinical trial of male trauma patients with hernia secondary to open abdomen management was performed from January 2009 to July 2011. Thickness and length of lateral abdominal muscles were measured by a basal Computed Tomography and 1 month after BTA application. A dosage of 250 units of BTA was applied at five points at each side between the external and internal oblique muscles under ultrasonographic guidance. Statistical analysis for differences between basal and after BTA application measures was performed by a paired Student's t test (significance: $p < 0.05$).
Results Seventeen male patients with a mean age of 35 years were included. There were muscle measure modifications in all the patients. Left muscle thickness: mean reduction of 1 ± 0.55 cm ($p < 0.001$). Right muscle thickness: mean reduction of 1.00 ± 0.49 cm ($p < 0.001$). Left muscle length: mean increase of 2.44 ± 1.22 cm ($p < 0.001$). Right muscle length: mean increase of 2.59 ± 1.38 cm ($p < 0.001$). No complications secondary to BTA or recurrences at mean follow-up of 49 months were observed.
Conclusions BTA application in lateral abdominal muscles decreases its thickness and increases its length in abdominal wall hernia patients secondary to open abdomen management.

Keywords Incisional hernia · Open abdomen management · Botulinum toxin type A · Abdominal wall

T. R. Ibarra-Hurtado (✉) · L. Bravo-Cuéllar
Department of Trauma Surgery, Antiguo Hospital Civil de Guadalajara "Fray Antonio Alcalde", Calle Hospital 278, Col. El Retiro, 44280 Guadalajara, Jalisco, Mexico
e-mail: tomasibarra2005@yahoo.com.mx

T. R. Ibarra-Hurtado
Pólvora 495, Interior 41. Col. Lagos del Country, 45177 Zapopan, Jalisco, Mexico

C. M. Nuño-Guzmán
Department of General Surgery, Antiguo Hospital Civil de Guadalajara "Fray Antonio Alcalde", Calle Hospital 278, Col. El Retiro, 44280 Guadalajara, Jalisco, Mexico

A. G. Miranda-Díaz · R. Troyo-Sanromán
Department of Physiology, Centro Universitario de Ciencias de la Salud, Universidad de Guadalajara, Sierra Mojada 950, Col. Independencia, 44330 Guadalajara, Jalisco, Mexico

R. Navarro-Ibarra
Department of Anesthesiology, Antiguo Hospital Civil de Guadalajara "Fray Antonio Alcalde", Calle Hospital 278, Col. El Retiro, 44280 Guadalajara, Jalisco, Mexico

Introduction

Ventral hernias occur in up to 28 % of patients undergoing abdominal surgery. Recurrence rates from 24 to 43 % have been reported, even with mesh application [1].

Incisional hernia occurs most frequently after midline laparotomy. When the linea alba is incised, the lateral abdominal wall fascia and muscle insertion at the midline is disrupted [2]. Excessive tension and subsequent ischemia at the linea alba line of suture predispose to hernia formation. This midline disruption allows for continued lateral abdominal wall muscles' contraction and retraction,

increasing the risk of midline hernia formation or further widening any midline abdominal wall defect [3]. Once the hernia has occurred, it is necessary to minimize the tension caused and maintained by the muscular contraction and retraction process. In patients managed with open abdomen whose abdominal wall closure is not performed early, a sustained lateral muscular retraction will ensue until reconstruction several months after the initial surgical event. Consequently, the lateral muscular wall thickness will increase and its length will decrease with the resultant muscular tension. During the surgical procedure, different techniques can be used to minimize the muscle tension, which include fascial release, myofascial component separation, and liberation of the scarred and restricted abdominal wall [4]. Ideally, this muscle tension should be minimized before the surgical event. There are only few alternatives for this purpose: progressive preoperative pneumoperitoneum (PPP) and placement of tissue expanders between lateral abdominal wall muscles [5, 6]. Recently, the application of Botulinum Toxin Type A (BTA) in the lateral abdominal wall muscles before hernia surgery was reported, with a significant reduction in the transverse hernia defect diameter [7]. Botulinum toxin type A is a neurotoxin that is isolated and purified from Clostridium botulinum type A bacteria which blocks the acetylcholine receptor at the neuromuscular junction, originating a 4- to 6-month reversible flaccid paralysis. Among other indications, BTA is indicated in patients with retracted and spastic muscle diseases [8].

The objective of the present work was to evaluate if the BTA application in lateral abdominal wall muscles of patients with incisional hernia secondary to open abdomen management modifies its thickness and length.

Materials and methods

A clinical trial was conducted at our department from January 2009 to July 2011. The research protocol was approved by the Research and Bioethics Committee in our Hospital. Male trauma patients with midline abdominal wall hernia secondary to open abdomen management with no previous abdominal wall closure and 12 months after their last laparotomy were included. An informed consent was signed by each patient for inclusion in the protocol. A CT scan was performed for lateral abdominal wall muscles' thickness and length measurement, in cm. These muscular measurements were performed at the umbilicus CT level between iliac crest and costal margin on both sides. A dilution of 500 units of BTA (Dysport®, Ipsen, Boulogne-Billancourt, France) in 5 ml of 0.9 % saline solution was prepared (100 units/1 ml). An injection of 0.5 ml was performed at 5 sites (50 units/0.5 ml per injection site) between the external and internal oblique muscles at one side of the abdomen, through a 25Fr subdural blockage needle and under ultrasonographic

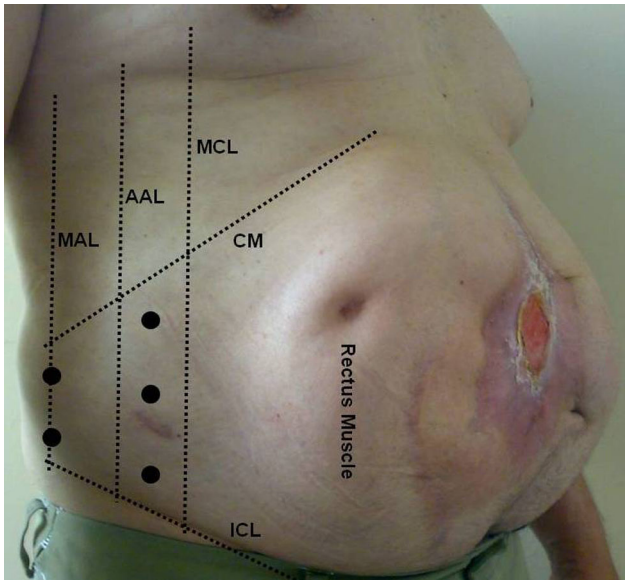

Fig. 1 BTA injection sites on the right flank abdominal wall muscles. *MAL* middle axillary line, *AAL* anterior axillary line, *MCL* middle clavicular line, *CM* costal margin, *ICL* iliac crest level

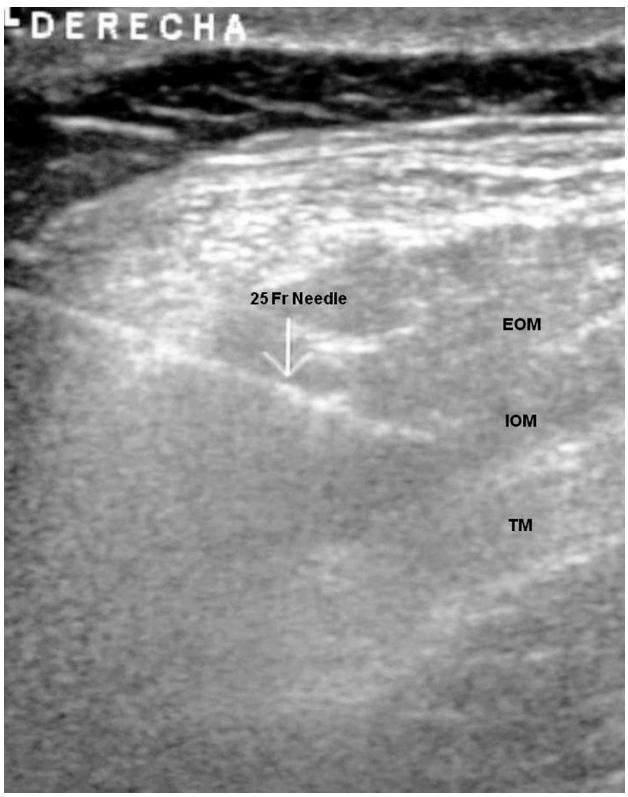

Fig. 2 US-guided injection of BTA in the lateral abdominal wall muscles. *EOM* external oblique muscle, *IOM* internal oblique muscle, *TM* transverse muscle

guidance. The same BTA dosage was injected at the opposite side of the abdomen, for a total of 500 units of BTA. The application sites were previously described by our group: two sites at the middle axillary line between costal margin and iliac crest level, and three sites between anterior axillary line and middle clavicular line between costal margin and iliac crest level, with similar sites on the opposite side [7] (Figs. 1, 2). Four weeks after BTA application, a new CT scan was performed and the thickness and length of the lateral abdominal wall muscles were compared with the previous measures. The abdominal wall reconstruction surgery was scheduled afterwards. Descriptive statistics, including means and standard deviations, were used to describe the continuous variables. Statistical analysis for differences between the basal and after BTA application CT abdominal wall muscle thickness and length measurements was performed using a paired Student's t test, with a significance level of $p < 0.05$. Statistical analysis was performed using the SPSS for Windows, version 12.0 (SPSS Inc, Chicago, IL).

Results

A total of 17 male patients with a mean age of 34.88 ± 12.34 years were included. All the patients had the background of abdominal trauma and open abdomen management of at least 12 months before. The hernia defect affected the totality of the previous laparotomy and open abdomen management site. There were no

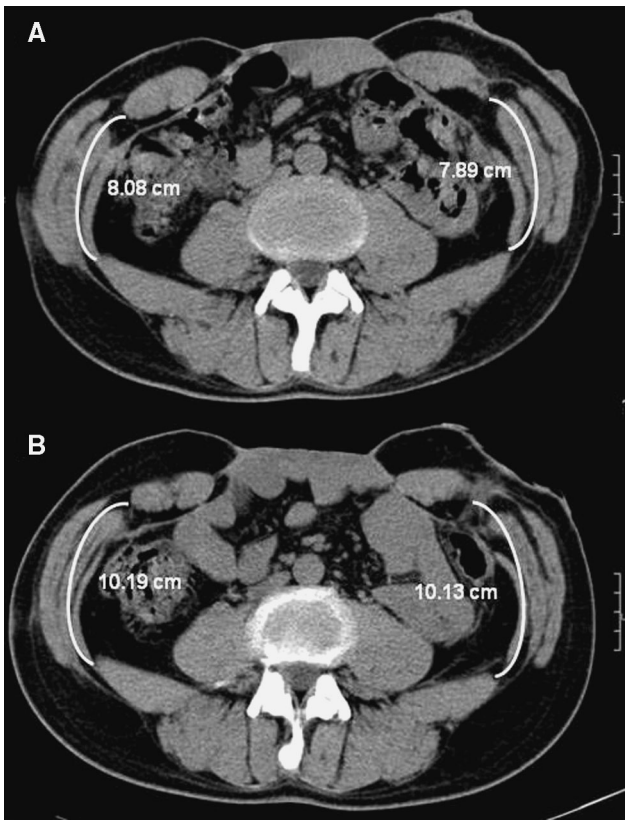

Fig. 3 **a** An illustrative CT scan of one of the patients, previous to BTA application showing an 8.08 and 7.89 cm length of the *right* and *left* lateral abdominal wall muscles, respectively, and the midline hernia defect (*arrows*). **b** CT 4 weeks after BTA application, where a 10.19 and 10.13 cm length of the *right* and *left* lateral abdominal wall muscles, respectively, can be seen (*arrows*)

Table 1 Age and surgical techniques in 17 male trauma patients with midline abdominal wall hernia secondary to open abdomen management

Case	Age (years)	Surgical technique	Other procedures	Mesh use	Complications	Follow-up (months)
1	45	Component separation	None	No	None	43
2	44	Component separation	Colostomy closure	No	Intestinal fistula	42
3	39	Component separation	None	No	None	41
4	23	Component separation	Colostomy closure	No	Seroma	39
5	38	Component separation	Colostomy closure	No	None	37
6	17	Component separation	Colostomy closure	No	None	38
7	47	Component separation	Colostomy closure	No	Seroma	37
8	58	Rives technique	None	Yes	None	54
9	22	Component separation	Right lat. hernioplasty	No	Seroma	51
10	29	Rives technique	None	Yes	None	61
11	22	Simple Closure	None	No	None	57
12	36	Component separation	Colostomy closure	No	Skin dehiscence	58
13	31	Simple Closure	None	No	None	57
14	41	Simple Closure	Colostomy closure	No	Intestinal fistula	59
15	31	Rives technique	None	Yes	Seroma	56
16	17	Simple Closure	None	No	None	54
17	53	Rives technique	None	Yes	None	49

complications or mortality secondary to BTA application (Table 1).

There was a decrease in the lateral abdominal wall muscles' thickness on both sides after BTA application in all the patients. On the left side, there was a mean reduction of 1 cm [$p < 0.001$; 95 % confidence interval (CI), 0.7217–1.2901]. On the right side, there was a mean reduction of 1 cm ($p < 0.001$; 95 % CI, 0.7481–1.2518). There was an increase in the lateral abdominal wall muscles' length on both sides after BTA application in all patients as well. On the left side, there was a mean increase of 2.44 cm ($p < 0.001$; 95 CI, 1.8122–3.0701). On the right side, there was a mean increase of 2.59 cm ($p < 0.001$; 95 % CI, 1.8769–3.2995) (Figs. 3, 4) A decrease in the transverse hernia defect was observed as well (Table 2).

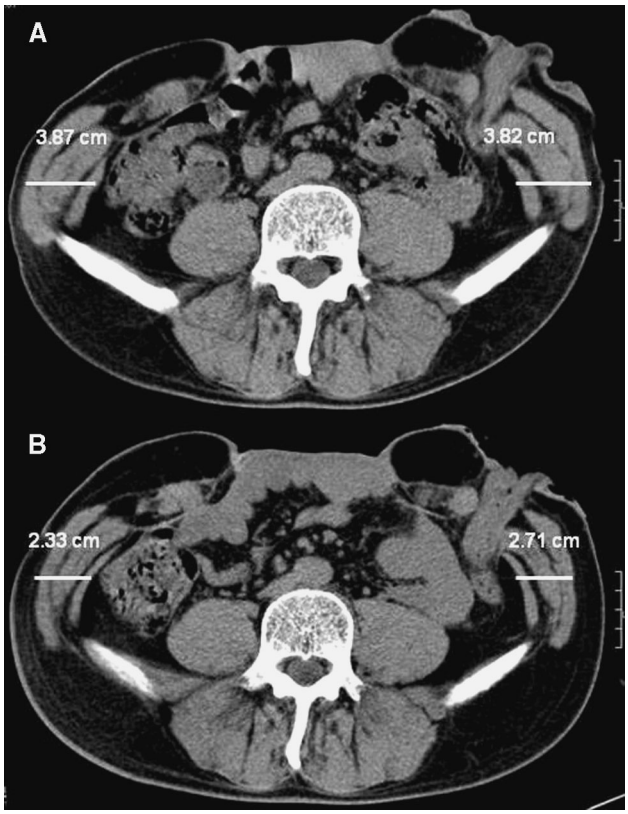

Fig. 4 **a** An illustrative CT scan of one of the patients, previous to BTA application, which shows a 3.87 and 3.82 cm thickness of the *right* and *left* lateral abdominal wall muscles, respectively (*arrows*). **b** CT 4 weeks after BTA application showing a 2.33 and 2.71 cm thickness of the *right* and *left* lateral abdominal wall muscles, respectively (*arrows*)

A surgical repair with closure at the midline was possible in all the patients. Nine cases (53 %) were managed with the "components separation" technique. Only the vertical incision of the external oblique fascia lateral to the linea semilunaris and dissection of the plane between the external oblique muscle and internal oblique muscle were needed, with no further incision being required [9, 10]. Four cases (23.5 %) were repaired using the Rives technique [11]. The remaining four cases (23.5 %) were managed under a simple closure. No recurrence has occurred in a mean follow-up of 49 months (range 37–61). Colostomy closure was performed in the same surgical event in seven patients. The complications were secondary to surgical procedure and resolved with medical management. Table 1 summarizes the demographic characteristics, surgical techniques, complications, mesh use, and follow-up.

Discussion

The open abdomen is defined as a surgical abdomen with the surgical edges purposefully left unapproximated [12]. Damage control laparotomy and open abdomen are critical techniques in the treatment of severely injured patients [12–14]. Severe abdominal infection, acute mesenteric ischemia, necrotizing infection of the abdominal wall and intraabdominal hypertension are also indications for leaving the abdomen open at the end of a laparotomy [15].

Many of the trauma patients managed by open abdomen were traditionally managed by prosthesis placement at the

Table 2 Differences in lateral abdominal wall and transverse hernia defect measures (cm) before and after 4 weeks of BTA application in patients with hernia after open abdomen management ($n = 17$)

	Basal	After BTA	Mean difference ± SD	*p* Value	95 % CI
Left muscular thickness	2.94 ± 0.76	1.93 ± 0.48	1.0058 ± 0.5528	<0.001	0.7166–1.2901
Right muscular thickness	2.97 ± 0.64	1.97 ± 0.46	1 ± 0.4899	<0.001	0.7481–1.2519
Left muscular length	10.85 ± 2.19	13.29 ± 2.76	2.44 ± 1.2232	<0.001	3.0701–1.8122
Right muscular length	10.73 ± 2.15	13.32 ± 2.77	2.59 ± 1.3833	<0.001	3.2995–1.8769
Transverse hernia defect	14.65 ± 2.18	9.68 ± 1.63	4.79 ± 1.16	<0.001	3.627–6.313

SD standard deviation

p value derived from Student's *t* test

time of loss of abdominal wall integrity. When possible, prosthesis was removed and fascial closure was performed during the following 2–3 weeks [16]. While 20–75 % of surviving patient managed with an open abdomen will have the abdominal fascia closed prior to discharge, the remaining patients may undergo abdominal wall reconstruction afterwards [17]. These patients have been managed as a planned ventral hernia, with abdominal wall reconstruction after a delay of 6–12 months [16].

A lateral retraction of the abdominal wall will take place with a consequent and progressive enlargement of the fascial defect during the first week following the initial laparotomy, making it difficult to reapproximate the fascial edges [18, 19]. In patients managed with open abdomen whose abdominal wall closure is not performed early, a sustained lateral muscular retraction will ensue until reconstruction several months after the initial surgical event. A similar process is present in midline abdominal wall hernias, where a continued myofascial lateral contraction enhances the defect. The rectus sheaths are also translated laterally [4]. Therefore, these lateral forces will result in muscular tension in patients with midline abdominal wall hernia and open abdomen management with a planned ventral hernia. Muscular thickness increase and length decrease will ensue as part of the contraction and retraction process, with the consequent muscular tension, making difficult any surgical attempt.

Tension-free reapproximation of the rectus muscles and linea alba in the abdominal midline is the method of choice for midline abdominal wall repair [4]. But in many instances this is not possible, and tension limits the abdominal wall approximation at the midline. During the surgical procedure, different techniques can be used to minimize the muscle tension, which include fascial release, myofascial component separation, and liberation of the scarred and restricted abdominal wall [4, 10, 20]. Ideally, this muscle tension should be minimized before the surgical event. There are only few alternatives for this purpose: PPP, placement of tissue expanders between lateral abdominal wall muscles and BTA application in lateral abdominal wall muscles [5–7].

PPP is a method originally described to treat massive hernias and eventrations [5]. The purpose of this method is to produce elongation of the abdominal wall muscles, but it also lengthens the incisional hernia [21]. The progressive increase in abdominal capacity produces respiratory adaptation to tolerate hernia content reduction to the abdominal cavity but it could also cause respiratory restriction. A recent study reported a generally well-tolerated restrictive syndrome, which causes pulmonary adaptation, while it increases the abdominal volume and facilitates bowel reduction [22]. Potential risks also include bowel injury and cutaneous complications.

Tissue expanders placed between the external oblique and internal oblique muscles, to expand the external oblique muscle and fascia have been used for primary closure of the abdominal wall [23]. The gradual expansion provides autogenous, innervated, healthy tissue, allowing reapproximation of the natural tissue [24]. This technique requires a previous surgical procedure to place the tissue expanders.

Recently, the application of BTA in the lateral abdominal wall muscles before hernia surgery was reported, with a significant reduction in the transverse hernia defect diameter [7]. This reduction in the defect size may facilitate a repair under less tension.

More recently, Zielinski et al. reported a retrospective review of their results of 300 units of BTA injection under ultrasound guidance in the lateral abdominal wall muscles of patients managed with open abdomen after a damage control laparotomy. The authors recommend this procedure only after hemodynamic stability has been achieved, which generally takes 12–24 h. All the patients were managed with negative pressure dressings for temporary abdominal closures until primary fascial closure was performed. Almost 90 % of patients who underwent a "chemical component separation", as called by the authors, within 24 h of the initial open abdomen procedure, achieved primary fascial closure [27]. As mentioned by the authors, BTA subjective clinical effect is not noticed for 48 h. Therefore, a major aid for primary fascial closure might have been also the use of negative pressure dressings, which prevent abdominal wall lateral retraction. The BTA effect duration will reduce lateral tension on the closed abdominal wall.

In the present work, a significant decrease in thickness and increase in length of lateral abdominal wall muscles were observed after the application of BTA. These muscular changes are the result of the muscle paralysis and involution of the contraction and lateral retraction process, which can be visualized by CT scan. This allowed the reconstruction with fascial approximation in the abdominal midline in all the patients. In a previous study, no further muscular changes were observed after 4 weeks of BTA application [7]. Therefore, the patients were scheduled for surgery afterwards. The performed surgical techniques were Rives technique and "components separation" technique. Simple closure was performed as well. Colostomy closure was performed in seven patients.

The overall complication rate was similar to others previously reported [2, 9, 25, 26]. Unfortunately, we had two patients with intestinal fistulae secondary to colostomy closure which was solved with medical management only. There was no mortality.

The application of BTA in lateral abdominal wall muscles may facilitate otherwise difficult abdominal wall

hernia surgery. This BTA-induced reversible 4- to 6-month flaccid paralysis may allow a hernia repair under less tension.

Conclusions

The BTA application in lateral abdominal wall muscles decreases its thickness and increases its length in patients with abdominal wall hernia secondary to open abdomen management.

Conflict of interest There are no conflicts of interest.

References

1. Poulose BK, Shelton J, Phillips S et al (2012) Epidemiology and cost of ventral hernia repair: making the case for hernia research. Hernia 16:179–183
2. Nguyen V, Shestak KC (2006) Separation of anatomic components method of abdominal wall reconstruction–clinical outcome analysis and an update of surgical modifications using the technique. Clin Plast Surg 33:247–257
3. Abrahamson J, Eldar S (1989) Abdominal incision. Lancet 1:847
4. Levine JP, Karp NS (2001) Restoration of abdominal wall integrity as a salvage procedure in difficult recurrent abdominal wall hernias using a method of wide myofascial release. Plast Reconstr Surg 107:707–716
5. Goni Moreno I (1951) Rational treatment of chronic massive hernias and eventrations; preparation of a patient with progressive pneumoperitoneum; original technic. Prensa Med Argent 38:10–21
6. Livingston DH, Sharma PK, Glantz AI (1992) Tissue expanders for abdominal wall reconstruction following severe trauma: technical note and case reports. J Trauma 32:82–86
7. Ibarra-Hurtado TR, Nuño-Guzmán CM, Echeagaray-Herrera JE et al (2009) Use of botulinum toxin type a before abdominal wall hernia reconstruction. World J Surg 33:2553–2556
8. Hughes AJ (1994) Botulinum toxin in clinical practice. Drugs 48:888–893
9. Girotto JA, Ko MJ, Redett R et al (1999) Closure of chronic abdominal wall defects: a long-term evaluation of the components separation method. Ann Plast Surg 42:385–394
10. Ramirez OM, Ruas E, Dellon AL (1990) "Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study. Plast Reconstr Surg 86:519–526
11. Rives J, Pire JC, Flament JB et al (1985) Treatment of large eventrations. New therapeutic indications apropos of 322 cases. Chirurgie 111:215–225
12. Regner JL, Kobayashi L, Coimbra R (2012) Surgical strategies for management of the open abdomen. World J Surg 36:497–510
13. Rotondo MF, Schwab CW, McGonigal MD et al (1993) "Damage control": an approach for improved survival in exsanguinating penetrating abdominal injury. J Trauma 35:375–382
14. Stone HH, Strom PR, Mullins RJ (1983) Management of the major coagulopathy with onset during laparotomy. Ann Surg 197:532–535
15. Schecter WP, Ivatury RR, Rotondo MF et al (2006) Open abdomen after trauma and abdominal sepsis: a strategy for management. J Am Coll Surg 203:390–396
16. Fabian TC, Croce MA, Pritchard E et al (1994) Planned ventral hernia. Staged management for acute abdominal wall defects. Ann Surg 219:643–650
17. Zarzaur BL, DiCocco JM, Shahan CP et al (2011) Quality of life after abdominal wall reconstruction following open abdomen. J Trauma 70:285–291
18. Scott BG, Feanny MA, Hirshberg A (2005) Early definitive closure of the open abdomen: a quiet revolution. Scand J Surg 94:9–14
19. Smith LA, Barker DE, Chase CW et al (1997) Vacuum pack technique of temporary abdominal closure: a 4-year experience. Ann Surg 63:1102–1107
20. Thomas WO 3rd, Parry SW, Rodning CB (1993) Ventral/incisional abdominal herniorrhaphy by fascial partition/release. Plast Reconstr Surg 91:1080–1086
21. Koontz AR, Graves JW (1954) Preoperative pneumoperitoneum as an aid in the handling of gigantic hernias. Ann Surg 140:759–762
22. Sabbagh C, Dumont F, Fuks D (2012) Progressive preoperative pneumoperitoneum preparation (the Goni Moreno protocol) prior to large incisional hernia surgery: volumetric, respiratory and clinical impacts. A prospective study. Hernia 16:33–40
23. Jacobsen WM, Petty PM, Bite U et al (1997) Massive abdominal-wall hernia reconstruction with expanded external/internal oblique and transversalis musculofascia. Plast Reconstr Surg 100:326–335
24. Van Geffen HJ, Simmermacher RK (2005) Incisional hernia repair: abdominoplasty, tissue expansion, and methods of augmentation. World J Surg 29:1080–1085
25. Lowe JB 3rd, Lowe JB, Baty JD et al (2003) Risks associated with "components separation" for closure of complex abdominal wall defects. Plast Reconstr Surg 111:1276–1283
26. de Vries Reilingh TS, van Goor H, Charbon JA et al (2007) Repair of giant midline abdominal wall hernias: "components separation technique" versus prosthetic repair: interim analysis of a randomized controlled trial. World J Surg 31:756–763
27. Zielinski MD, Goussous N, Schiller HJ et al (2013) Chemical component separation with botulinum toxin A: a novel technique to improve primary fascial closure rates of the open abdomen. Hernia 17:101–107