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ORIGINAL ARTICLE

Prevention of component separation in complex abdominal wall surgery by Botox prehabilitation: a propensity-matched study

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Abstract

Aim To facilitate midline fascial closure in complex abdominal wall surgery, component separation techniques (CST) are usually required. However, CST is associated with an enlarged morbidity. Prehabilitation could increase the compliance of the abdominal wall and thereby decrease the necessity of myofascial release. This can be accomplished by administration of botulinum toxin type A (BTA) in the lateral abdominal wall musculature. The aim of this study was to determine the effect of BTA on the subsequent necessity to perform CST in patients with complex abdominal wall hernias.

Methods Patients with a complex abdominal wall hernia, planned to undergo CST between July 2020 and November 2022 were included. Outcome of procedures with 300U of BTA 4 (2–6) weeks prior to surgery, were retrospectively analyzed by comparison with propensity matched subjects of an historical group. Hernia width difference was assessed by CT and operative details were included.

Results A total of 13 patients with a median hernia width of 12 cm (IQR 9–14, range 24) were prehabilitated with BTA between July 2020 and November 2022. A CST was planned for all, however not required in 6/13 patients (46%) to accomplish midline fascial closure. A mean elongation of lateral abdominal wall musculature of 4.01 cm was seen in patients not requiring CST. Compared to the propensity score matched control group, a 27% reduction ($p = 0.08$) in the need for CST was observed.

Conclusion There is a tendency for decrease of necessity for CST by preoperatively administered BTA in patients with complex abdominal wall defects. Although small, as this study used propensity matched comparison, further exploration of BTA should be encouraged.

Keywords Complex abdominal wall surgery · Prehabilitation · Botulinum toxin A · Hernia · Postoperative outcomes · Myofascial release

Introduction

One of the main difficulties in reconstructing complex abdominal wall hernias is obtaining midline fascial closure. Chronic muscle retraction enlarges the defect size, precluding reduction of hernia sac contents and fascial closure during abdominal wall reconstruction [1]. Fascial medialization should be the goal in all hernia repair surgeries, however, due to large defect size and muscle retraction this might not always be attainable [2]. Myofascial release (MFR) techniques encompass anterior or posterior component separation and have been described in literature to accomplish fascial medialization. However, these techniques are associated with higher surgical site morbidity, such as surgical site occurrences, wound morbidity, pneumonia, and ileus [3, 4, 15].

It has been theorized that chemical paralysis of lateral abdominal wall musculature could be a valuable adjunct in the repair of complex abdominal wall hernias [5]. Prehabilitation of the abdominal wall musculature to aid fascial medialization can be achieved by injecting Botulinum Toxin type A (BTA) into the lateral abdominal wall muscles (LAWM). When injected into muscle, BTA causes temporary muscle paralysis [6, 7]. This is ascribable to the blocking of neurotransmitter acetylcholine release, resulting in flaccid paralysis and elongation of lateral abdominal wall muscles,

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increasing the rate of fascial closure during complex abdominal wall reconstruction (CAWR) [8]. The therapeutic effect is known to last for 2–12 weeks after injection. Recent literature shows possible elongation of the LAWM of up to 4.7 cm per side [4, 9, 10]. Reported primary fascial closure rate after BTA prehabilitation is high, up to 75%, avoiding component separation techniques in two-third of the patients [11, 12]. BTA prehabilitation is considered a safe abdominal wall stretcher, to optimize preoperative conditions [13].

The aim of this study was to determine the effect of BTA prehabilitation on the length of lateral abdominal wall muscles, and on the need for component separation techniques (CST), in patients scheduled for complex abdominal wall reconstruction.

Methods

The performed study was a retrospective study in a tertiary referral center for CAWR. Patients who underwent complex abdominal wall reconstruction and were prehabilitated with BTA 4–6 weeks prior to surgery were included. Patients with preoperative progressive pneumoperitoneum (PPP) were excluded.

All patients were discussed at least once in a multidisciplinary team meeting (MDT) by an abdominal wall surgeon, pulmonologist, ICU physician, anesthesiologist, and physiotherapist, and assays such as a CT-scan, pulmonary testing, an EKG, blood tests for hemoglobin, HbA1c and albumin were performed.

At the MDT, a traffic light color code is allocated. Patients who are allocated green, are considered fit for surgery, and have no (increased) per-operative risk factors. Patients who are allocated orange, are eligible for surgery, only after prehabilitation measurements are taken. After prehabilitation, the patient is again discussed in the MDT, and if prehabilitation is successful, the color code will shift from orange to green [13]. Prehabilitation measures could consist of physical therapy, dietary advice, glycemic control, pulmonary preparations: in other words, optimization of all risk factors preoperatively [14].

Patients who are allocated red will not follow the complex hernia care pathway for surgical repair due to unmodifiable risk factors. Nor will they principally ever be operated on, due to the extremely high estimated morbidity and mortality risk.

BTA prehabilitation was considered necessary if the defect width was greater than 10 cm, if there was a great amount of evisceration, or in specific cases if the MDT participants considered it to be a valuable addition.

All patients selected for BTA prehabilitation were administered pre-operative BTA 4–6 weeks prior to abdominal wall repair surgery as an outpatient procedure. Injection was executed by a surgeon or nurse practitioner and a radiologist, using ultrasonography to visualize the three lateral muscle layers. BTA was injected on 6 different injection sites: 3 in the left LAWM and 3 in the right LAWM. Per injection, a dilution of 17 Units BTA was used in a syringe of 12.5 cc, which was fully injected: approximately 4 cc in each muscle layer (transversus abdominis muscle, internal oblique muscle, external oblique muscle).

CT scans were made prior to BTA injection and on the day of surgery, to determine length of abdominal wall muscles, as well as to calculate the volume of incisional hernia, and volume of abdominal cavity (Fig. 1).

During surgery, the necessity for CST was estimated by the performing surgeon. All patients underwent open CAWR surgery with retromuscular mesh augmentation. If CST was assessed required to close the midline fascia, either endoscopically assistant component separation (eCST) or transversus abdominis release was executed.

A prospectively obtained database was used for analysis. Data acquired were patient characteristics, hernia characteristics pre- and post-BTA (most importantly defect width, loss of domain (LOD) (calculated with the Tanaka method) [16] in percentage, length of lateral abdominal wall musculature (LAWM)), and prediction of necessity for CST. Peri- and postoperatively collected data were length of operation time, CST needed, occurrence of complications.

Primary outcome measures were pre- and post-BTA length of the muscles, difference in loss of domain, and myofascial release performed. Secondary outcome measures were postoperative complications, length of operation time, and length of hospital stay.

CT scans were viewed by an experienced radiologist and muscle lengths were measured (Fig. 1). CT scans were viewed retrospectively, all at once.

All patients who underwent BTA prehabilitation were propensity matched to patients in an already existing database of all who underwent complex abdominal wall surgery. This was a prospectively maintained database, updated by a coordinating physician.

Data collected in this database is comparable to data as described above. The only noteworthy difference was the absence of a measured length of abdominal wall musculature.

Patients were propensity matched firstly using logistic regression to calculate their individual propensity scores, in Microsoft Excel. Covariates used in this calculation were age, mean BMI, hernia width and loss of domain > 20% (LOD). Patients were matched using a caliper of 0.02 for all parameters. Furthermore, a 1:2 (exposed: not exposed) matching ratio was used. Covariate balance was checked in both groups. The historical control group of subjects to choose from consisted of 135 patients.

Fig. 1 Pre- and post- BTA CT scan

Statistical analysis was executed using Microsoft Excel, with XLSTAT extension. Analysis was overseen by a statistic.

Ethical approval was not necessary given the retrospective nature of the study. No changes were made in the original care pathway for patients.

Results

A total of 13 patients underwent BTA prehabilitation prior to CAWR, between July 2020 and September 2022.

All prehabilitated patients underwent a pre- and post-BTA CT scan. Pre-BTA, a mean hernia width of 14.15 cm was seen. Median time from BTA injection to surgery was 4 weeks, median time from BTA injection to post-BTA CT scan was 4 weeks.

Mean muscle length was statistically significantly decreased for all muscles (Table 1).

LOD was considered > 20% in 3 (23%) Patients pre-BTA, and in 2 (15%) patients post-BTA ($p = 0.624$) (Table 1).

In a total of 13 patients, CST was estimated to be necessary at the MDT, whereas in 7 patients, CST was executed (46% reduction). In 13 (100%) patients, primary fascial closure was achieved. In the 6 patients who did not require CST, a mean muscle elongation (MME) of 4.01 cm was seen, whereas in the 7 patients who required CST, a mean muscle elongation of 2.10 cm was seen ($p = 0.0025$) (Table 2) (Graph 1).

Eight (62%) BTA prehabilitated patients developed postoperative complications, of which 2 (15%) were DINDO > 2. In propensity matched subjects, fifteen (58%) patients developed postoperative complications, of which 3 (12%) were DINDO > 2 (p = 0.735).

Table 1 Hernia and muscle characteristics pre- and post-BTA prehabilitation

	Pre BTA	Post BTA	Δ	*p*
n	13	13		
m. Obliquus externus (r) (cm)	11.92	15.04	**− 3.1230769**	**0.000054**
m. Obliquus externus (l) (cm)	12.53	14.83	**− 2.2916667**	**0.013619**
m. Obliquus internus (r) (cm)	11.70	15.68	**− 3.9769231**	**0.000473**
m. Obliquus internus (l) (cm)	12.11	15.12	**− 3.0083333**	**0.003539**
m. Transversus abdominis (r) (cm)	9.99	13.43	**− 3.4384615**	**0.000996**
m. Transversus abdominis (l) (cm)	10.22	12.45	− 2.2333333	0.102161
LOD (%)	15.00	12.00	3	0.258383

Bold indicates significant values

LOD = loss of domain

Table 2 Mean muscle elongation in patients who underwent CST compared to patients who did not need CST

	CST	No CST	*p*
n	7	6	
Muscle elongation (mean)	2.10	4.01	**0.002538673**
m. Obliquus externus (*r*) (cm)	2.37	4.00	
m. Obliquus externus (*l*) (cm)	3.07	5.03	
m. Obliquus internus (*r*) (cm)	2.13	4.97	
m. Obliquus internus (*l*) (cm)	0.83	3.75	
m. Transversus abdominis (*r*) (cm)	2.25	3.77	
m. Transversus abdominis (*l*) (cm)	1.92	2.55	
Time between BTA and surgery (weeks, mean)	4	4,5	0.258

Bold indicates significant values

The 13 patients who underwent BTA prehabilitation were consequently matched to 26 patients from the pre-existent database (Table 5, supplementary material). Covariates were equally divided (Fig. 2) and there were no statistically significant differences between the two groups on baseline level (Table 3) or in intraoperative characteristics (Table 4).

Compared to propensity matched subjects, an absolute risk reduction (ARR) of 27% [95%-CI 14.57–39.43%, $p = 0.078$] was found, and a NNT of 3.7 [95%-CI 2.5–6.9] was calculated.

There was a non-significant decrease in surgery time (179.6 min vs 161.9 min), and a non-significant decrease in admission time was witnessed (9 days vs 6.2 days).

No difference was objectified in complications, admission time or hernia recurrence between the propensity matched groups (Table 4).

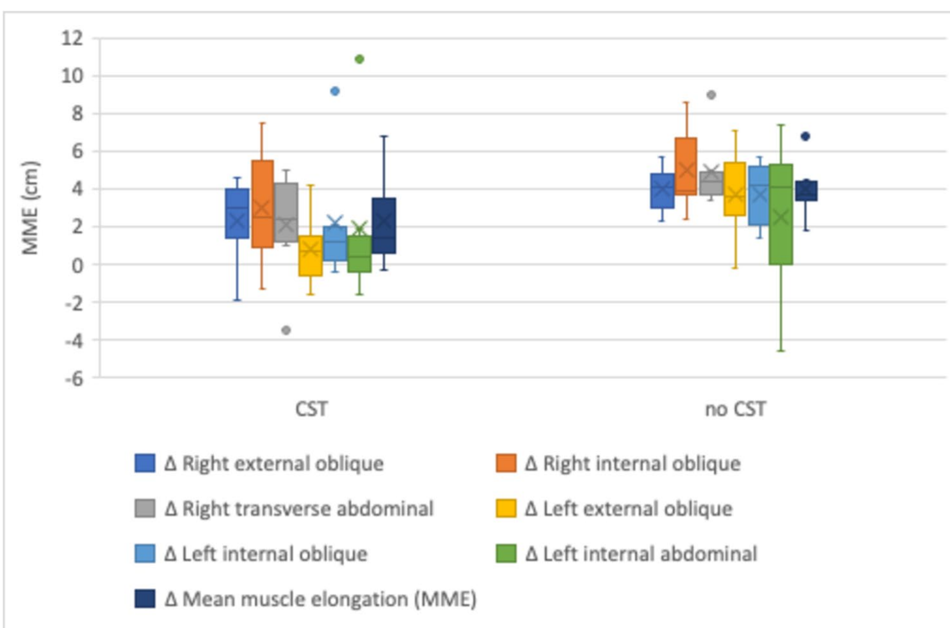
Discussion

There are only few studies reporting on the exact effect of the prehabilitation with BTA in the LAWM. Literature states the primary fascial closure rate appears high due to the temporary paralysis of the muscles, allowing the surgeon to close the anterior as well as the posterior fascia tension-free.

However, evidence is lacking on the effect of BTA on the prevention of CST. Furthermore, only Timmer et al. [4] describe an estimated effect of BTA on muscle elongation and LOD.

This study determined a favorable effect of BTA prehabilitation on the length and mass of LAWM, and on the need for CST (compared to patients without prehabilitation, propensity scored), in patients scheduled for CAWR.

Overall effects of BTA were favorable, and in 6 cases, CST was prevented by BTA prehabilitation.



Graph 1 Muscle elongation in patients with versus without CST. Explanation pictograms: middle line = median, x = mean, bottom line box = median IQR 1, top line box = median IQR 3, vertical lines = minimum and maximum values, dot = outlier

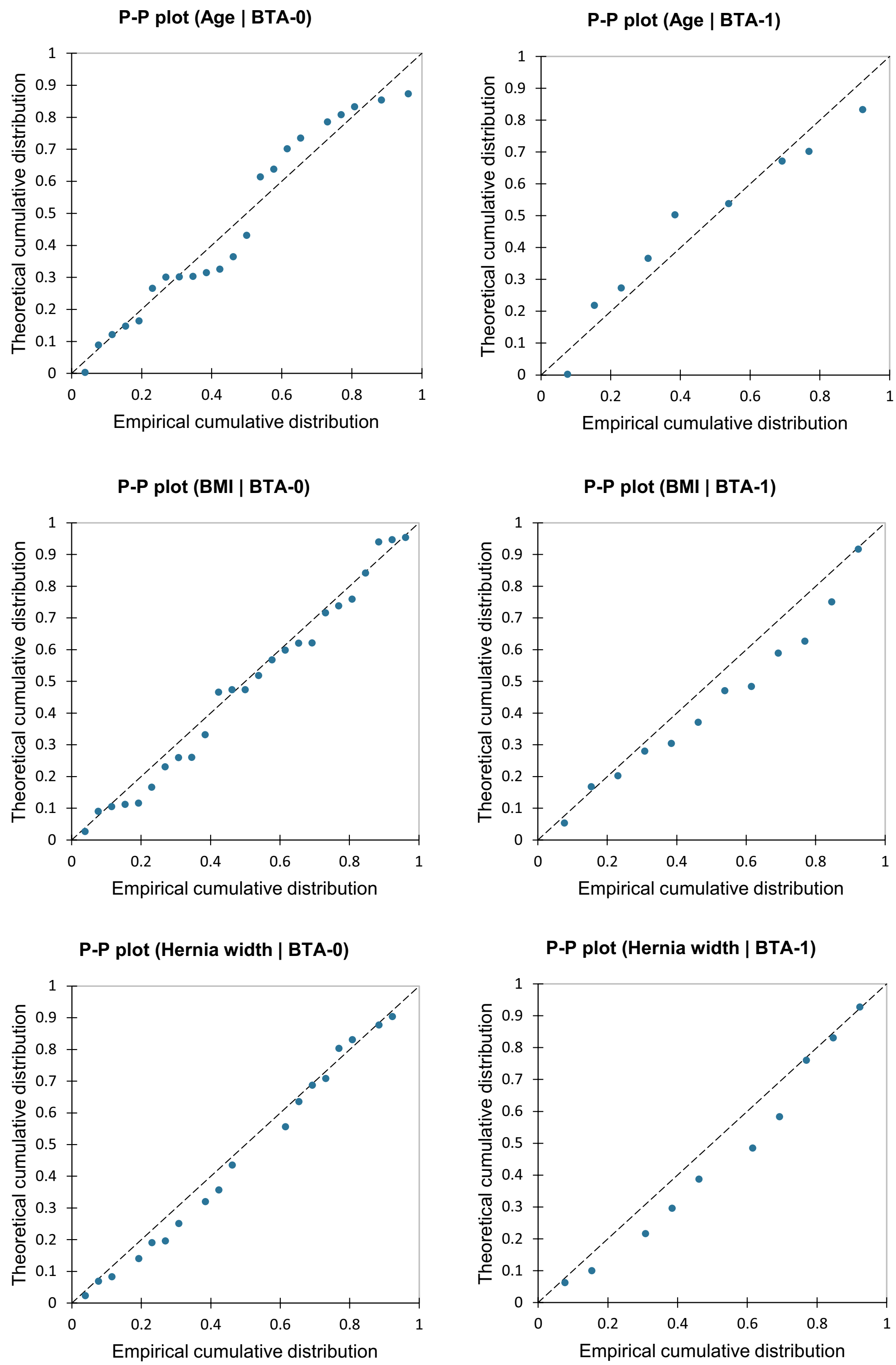


Fig. 2 Normality of covariates

Several studies have shown advantageous effects of BTA on the elongation of LAWM [4, 9, 10]. Our research findings are in line with these studies: BTA stretches these muscles up to 34% (Table 1). However, there were no previous studies reporting on the effect of BTA on the prevention of CST, whereas this study showed a significant decrease in the use of CST compared to the historical control group.

Studies have shown that abdominal wall hernias with LOD greater than 20% are at high risk for the need of a myofascial release [2]. Since CST is associated with higher postoperative (wound) morbidity, prevention could be favorable considering patients' recovery trajectory. It has been theorized that CST could be prevented by injecting BTA in the LAWM, hypothetically reducing LOD. The performed study

Table 3 Baseline characteristics BTA-prehabilitated patients versus historical control group

	Control		BTA		*p* value
n	26	100%	13	100%	
Sex					
Male	11	42%	5	38%	0.8179
Female	15	58%	8	62%	
Age (mean, SD)	63.99	11,64	63.923	11,934	0.9867
BMI (mean, SD)	27.431	3894	27.458	3064	0.9827
COPD	6	23%	3	23%	1.000
Diabetes	4	15%	3	23%	0.555126
Hernia width (mean, SD)	14.308	5013	14.154	4180	0.9246
Recurrent hernia	6	23%	4	31%	0.604027
LOD > 20%	6	23%	3	23%	1.000

Table 4 Intra- and postoperative results of BTA-prehabilitation compared to historical control group in patients planned for CST

	Control		BTA		*p* value
n	26	100%	13	100%	
Myofascial release executed	21	81%	7	54%	0.0781
Surgery time (mean, SD)	179.615	62.519	161.923	51,302	0.3840
Admission time (mean, SD)	9.077	6.203	7.154	1951	0.2850
Complication	15	58%	8	62%	0.9732
Complication > DINDO 2	3	12%	2	15%	0.7348
Mortality	0	0%	0	0%	1.000
Recidive	1	4%	1	8%	0.6077

showed a decrease of LOD of 3%, not statistically significant. Moreover, more importantly, this study highlights the effect of BTA on the elongation of LAWM. Lengthening or loosening these muscles could facilitate primary fascial closure, as is seen in the CST rate in BTA prehabilitated group compared to the historical control group: a 27% decrease was established. There was no correlation found between time before surgery (after BTA injection) and the prevention of CST.

BTA prehabilitation is described as a safe abdominal wall stretcher, to optimize preoperative conditions [13]. This study is in line with these previous findings, since no adverse effects on the BTA occurred during or after the procedures.

This is the first study in this field that compares patients who underwent prehabilitation with BTA to a historical control group using a propensity score to mimic a randomized controlled trial. It is therefore the first study that can quantify the effect on the necessity for CST.

Furthermore, this research sought to observe and objectify the effect of BTA administration on the muscle characteristics and was trying to seek a causality between the measured effect of BTA and the necessity for CST.

Moreover, a propensity matched historical control group was used to demonstrate the effect of BTA on the prevention off CST. Since the study was retrospective, and conduction of an RCT was unmanageable, propensity matching appeared to be the appropriate choice, and vigorously increases the weight of the evidence obtained from this data.

While these are useful findings, they are limited by the study's numbers. Because of the explorative nature of the use of BTA in CAWR, there are only small populations appropriate to conduct research on. Furthermore, the study population was, partly because of its size, a heterogenous group. This translates into a post-hoc power of only 42.7%, resulting in required caution whilst interpretating and applicating these findings. Although characteristics between both groups are not significantly different, patient characteristics could have been very different when compared individually.

Additionally, the requirement for CST was estimated by the operating surgeon at the time of surgery, meaning besides expertise, there was no guideline or standardized value for this.

Thirdly, since the hospital where this study was acquired was initially new to the process of BTA administration, a learning curve must be considered, possibly causing underestimation of the actual effect of BTA.

Moreover, the exact effect of BTA could differ in individual patients. Although BTA is supposed to have the elongating and weakening effect on the muscles it is injected in by blocking neurotransmitter acetylcholine release, there is no evidence stating the consistency of this effect on an individual patient level.

Finally, the choice to execute a myofascial release is always made intraoperatively, meaning the operating surgeon is determining whether there is a possibility of tension-free midline closure without the use of CST. Since this is a choice based on experience and expertise, there could be different "cutoff points" between surgeons for the use of CST. However, only three surgeons, FEBS-AWS certified, were operating these BTA-prehabilitated patients, so the difference is expected to be negligeable.

Conclusion

There is a tendency for decrease of hernia width by preoperatively administered BTA and necessity for CST in patients with complex abdominal wall defects. Although small, as this study used propensity matched comparison, further exploration of BTA should be encouraged.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10029-023-02929-2.

Data availability The data that support the findings of this study are not openly available due to reasons of privacy and are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Not necessary given the retrospective nature of the study. No changes were made in the original care pathway for patients.

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