



Botulinum toxin, progressive pneumoperitoneum and RTL closure for ventral hernias secondary to giant omphalocele in children: a 10-patient series

Mario Javier Peña García¹ · Edgard Efren Lozada-Hernández² · Alejandro Alberto Peñarrieta Daher³ · Jaime Penchyna Grub¹ · Guillermo Jacobo Serrano Meneses⁴ · Ricardo Reynoso González⁵ · Ivan Vladimir Medina Lopez⁶

Received: 20 July 2026 / Accepted: 30 August 2026

© The Author(s), under exclusive licence to Springer-Verlag France SAS, part of Springer Nature 2026

Abstract

Introduction This study describes a pediatric strategy to repair complex ventral hernias secondary to giant omphaloceles, avoiding the use of mesh and component separation. The protocol combines prehabilitation with botulinum toxin (BT), selective preoperative progressive pneumoperitoneum (PPP) and midline closure by the reinforced tension line (RTL) technique, with the aim of evaluating its safety, feasibility and medium-term results.

Methods A retrospective, descriptive and multicenter case series was conducted in 10 patients under 18 years of age with ventral hernia secondary to giant omphalocele. All patients received BT; PPP was indicated in patients whose Tanaka index was $\geq 25\%$. Surgical closure was performed using the RTL technique, without prosthetic material. Clinical characteristics, dimensions of the defect, use of prehabilitation, complications, hospital stay, follow-up and recurrence were analyzed.

Results Ten patients were included, all of whom were female, with a median age of 3.7 years and a median weight of 12.7 kg. The median defect area was 60 cm². Four patients required progressive pneumoperitoneum. Primary fascial closure was achieved in 100% of cases, without mesh or separation of components. There were no intraoperative complications. The median hospital stay was 6.5 days, and the median follow-up was 19.8 months. No recurrences were documented.

Conclusions The combined protocol seems safe and technically viable in this initial series. It allowed primary fascial closure without mesh, without separation of components and without recurrences during follow-up. However, these results should be interpreted as preliminary evidence because of the retrospective design, small sample size and absence of a control group.

Keywords Complex ventral hernia · Giant omphalocele · Botulinum toxin · Progressive pneumoperitoneum · Reinforced tension line · Case series · Pediatric surgery

✉ Edgard Efren Lozada-Hernández
edgardlozada2@gmail.com

Mario Javier Peña García
drmario.ciruped@gmail.com

Alejandro Alberto Peñarrieta Daher
penarrietadaher@gmail.com

Jaime Penchyna Grub
penchyna@hotmail.com

Guillermo Jacobo Serrano Meneses
gjsmeneses@gmail.com

Ricardo Reynoso González
reynoso.cirugia@gmail.com

Ivan Vladimir Medina Lopez
Dr.Ivan.Vladimir@outlook.com

¹ Pediatric Surgery, Hospital Infantil de México Federico Gómez, Cuauhtémoc, Ciudad de México, México

² Hospital Regional de Alta Especialidad del Bajío, Servicios de salud del Instituto Mexicano del Seguro Social para el Bienestar (IMSS-BIENESTAR), León, Guanajuato 37660, México

³ Neonatal Surgery, Hospital Infantil de México Federico Gómez, Cuauhtémoc, Ciudad de México, México

⁴ Neonatal Surgery, Servicios de Salud del Instituto Mexicano del Seguro Social para el Bienestar (IMSS-BIENESTAR), Hospital Pediátrico Moctezuma, Ciudad de México, México

⁵ General Surgery, Hernia Care, Ciudad Satélite, México

⁶ Pediatric Surgery, Hospital General Uruapan, Michoacán, México

Introduction

Giant omphaloceles (defects greater than 5 cm or with liver involvement in the sac) occur in approximately 1 in 4,000–6,000 live births and are associated with high perinatal mortality and frequent comorbidities [1]. Regardless of the initial treatment strategy used, a relevant proportion of patients will develop secondary ventral hernias. According to data from a multinational survey of pediatric surgeons with experience in giant omphalocele, the rates of residual hernia vary significantly according to the approach: primary closure is associated with a rate of 58%, staged closure is associated with a rate of 18%, and delayed nonoperative management is associated with a rate of 9% [2]. These findings have been replicated and confirmed in a subsequent systematic review [3]. These hernias represent a major surgical challenge, conditioned by the loss of domain, dense adhesions, distortion of the wall and scarcity of viable autologous tissue [1, 4].

In adult surgery, prehabilitation of the wall with botulinum toxin (BT) [5–8] and preoperative progressive pneumoperitoneum (PPP) [9] have allowed primary closure to be achieved without meshes in complex defects, with the combined approach showing superior results compared to either technique alone [10, 11]. In pediatrics, however, this combination has been reported in only three case reports with favorable results [12–14], without systematic evidence to guide management.

The use of mesh in children, which is standard in adults, leads to secondary hernia rates greater than 50% after its removal [3], prompting many groups to avoid it in this population [4]. This requires the exploration of closure techniques without the use of prosthetic materials. The *reinforced tension line* (RTL) technique outperforms primary closure [15] and the *small bites* technique in incisional hernia reduction [16], and in a network meta-analysis of 3,540 patients, it showed the best overall performance, with a number needed to treat (NNT) of 3 [17]. However, its use as a hernia treatment is limited to a single favorable report [18].

Based on these considerations, a combined prehabilitation protocol with BT and, when indicated by loss of domain, PPP was designed and implemented across the participating institutions, followed by midline closure with RTL. The objective of the present study is to describe our initial experience with this protocol in a series of 10 pediatric patients with complex ventral hernias secondary to giant omphaloceles and to evaluate its safety, feasibility and medium-term results.

Materials and methods

Type of study

An observational, retrospective and descriptive study of a multicenter case series was conducted (pediatric surgery service of the Hospital Infantil de Mexico Federico Gómez, IMSS-Bienestar Hospital Pediátrico Moctezuma in Mexico City and the Regional Hospital of High Specialty of Bajío-IMSS Bienestar). The report was written following the recommendations of the PROCESS, Preferred Reporting Of CasE Series in Surgery [19]. The protocol was approved by the Research Ethics Committee and the Research Committee of the Hospital Regional de Alta Especialidad del Bajío-IMSS Bienestar, with registration numbers CEI-011-2026 and CI/HRAEB/009/2026, respectively.

Selection criteria

The inclusion criteria were patients under 18 years of age with a documented history of giant omphalocele and a diagnosis of secondary ventral hernia who were treated with a combined prehabilitation protocol (BT and/or PPP) and underwent surgical closure with the RTL technique. The exclusion criterion was patients whose clinical records were incomplete, preventing the recovery of the variables of interest. No patient was excluded from the series for this reason.

Prehabilitation protocol and surgical closure

1. Botulinum toxin (BT)

BT infiltration was performed in the outpatient procedure room under continuous monitoring with an anesthesia machine and sedation. After asepsis and antisepsis of the abdominal wall, the vial was reconstituted (100 IU in 10 mL of 0.9% isotonic saline solution, resulting in a concentration of 10 IU/mL). Under ultrasound guidance, 100 IU was infiltrated per side at five puncture sites (2 mL per site, 20 IU per point), located between the costal margin and the iliac crest, in the corridor between the anterior axillary line and the midaxillary line: two points in the external oblique muscle, two in the internal oblique, and one in the transversus abdominis. The total dose per event was 200 IU of onabotulinumtoxinA (Botox®) or incobotulinumtoxinA (Xeomin®), or 500 IU of abobotulinumtoxinA (Dysport®) (250 IU per side), which is equivalent to 13–16 IU/kg of

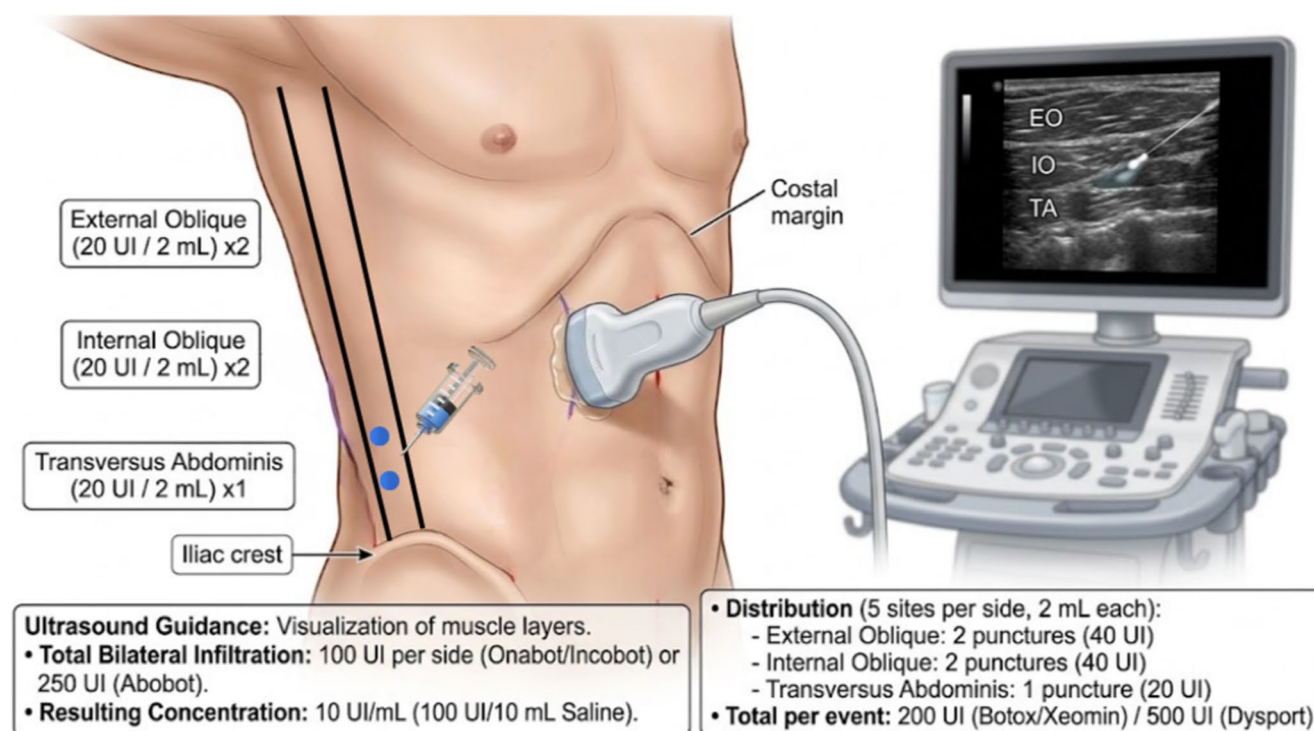


Fig. 1 Methodology for ultrasound-guided botulinum toxin infiltration in the abdominal wall

onabotulinumtoxinA in most patients, with a conversion ratio of 3:1. The protocol was scheduled with an interval of four weeks between infiltration and definitive surgery (Fig. 1).

2. Preoperative progressive pneumoperitoneum (PPP)

PPP was indicated in patients with a Tanaka index equal to or greater than 25%, a criterion that was met in four patients (indices of 32%, 70%, 85% and 100%). The procedure was performed in the operating room under local anesthesia and sedation. Through minilaparotomy, an Arrow 7 French catheter was placed in the peritoneal cavity, which was kept in situ until the day of definitive surgery. From the first day, daily air insufflation was performed at a fixed dosage of 20 mL/kg/day, without a preestablished maximum volume. The protocol was maintained until the date of definitive surgery, for a maximum of 10 days; the catheter was removed with the same surgical procedure. The total cumulative insufflated volume in the four patients was 1,200, 1,330, 1,800 and 2,600 mL, in agreement with the Tanaka index of each patient.

3. Reinforced tension line (RTL)

Abdominal wall closure was performed in all patients using the RTL technique. Under general anesthesia, a midline incision was made with perilesional dissection of the hernia

sac. Once the hernia content was reduced and the adhesions were released, fascial closure was performed in two stages. First, two longitudinal and parallel suture lines were placed, one on each aponeurotic edge, using a PDS Plus II suture number 0 CT-1 taperpoint needle (1/2 circle and 36 mm). Each line began at one end of the wound, with the needle entering and exiting at 1 cm intervals, remaining 0.5–0.8 cm from the edge of the aponeurosis. Upon reaching the opposite end, the process was repeated on the contralateral edge. The ends of both sutures were knotted at the angles of the wound, thus leaving two lines of longitudinal reinforcement on the aponeurotic edges. Subsequently, definitive closure of the aponeurosis was achieved via continuous suture, ensuring that each stitch included and anchored the two longitudinal reinforcing strands. A 1/8" Drenovac supra-aponeurotic drain was placed in all patients, which was maintained for a period of 4 to 5 days (Fig. 2).

Variables analyzed

The following variables were analyzed: demographic variables (age and weight at the time of surgery), hernia defect variables (dimensions of the fascial defect by computed tomography and the Tanaka index, calculated in the nine patients with available CT imaging), prehabilitation protocol variables (number of BT infiltration events, the total dose administered per event (IU/kg), use of PPP, days of insufflation and total accumulated volume), primary

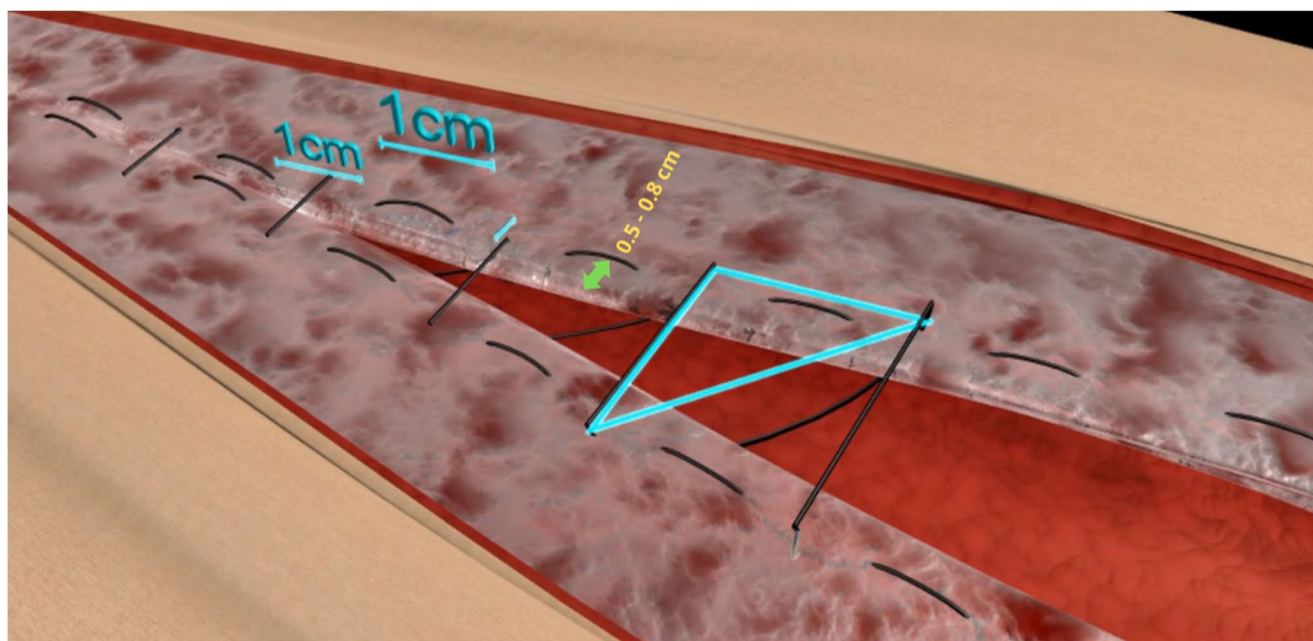


Fig. 2 Abdominal wall closure using the reinforced tension line (RTL) technique

outcome variables (rate of hernia recurrence, defined as clinical recurrence or recurrence on imaging of the defect at postoperative follow-up, and the presence of major postoperative complications) and secondary outcome variables (days of postoperative hospitalization and complications associated with the prehabilitation protocol).

Statistical analysis

The statistical analysis was descriptive. Continuous variables were expressed as medians and ranges, given the nonparametric distribution expected in small samples. Additionally, the mean and standard deviation were reported when clinically relevant. Categorical variables were expressed as absolute frequencies and percentages. Statistical inference

tests were not performed given the sample size. The analysis was performed in the R environment version 4.4.0 (R Foundation for Statistical Computing) using RStudio.

Results

Ten pediatric patients, all of whom had a diagnosis of ventral hernia secondary to a giant omphalocele, were included. At the time of surgery, the median age of the patients was 3.7 years (range 2.0–17.0), and the median weight was 12.7 kg (range 8.5–45.0). The baseline characteristics of each patient are detailed in Table 1.

Preoperative tomographic evaluation was performed in 9 of the 10 patients; in the remaining case, it was not

Table 1 Baseline patient characteristics

Pt.	Age (years)	Weight (kg)	CT defect size (cm)	Area (cm ²)	Tanaka index	PPP
1	7.0	15.0	9.5 × 9.8	93.1	85%	Yes
2	5.8	16.0	7.0 × 9.5	66.5	NC	No
3	3.4	12.5	7.0 × 8.0	56.0	NC	No
4	3.0	13.0	5.4 × 4.3	23.2	32%	Yes
5	2.8	10.2	NA†	NA	NC	No
6	2.0	8.5	9.8 × 9.5	93.1	100%	Yes
7	2.0	9.5	4.9 × 5.4	26.5	70%	Yes
8	8.8	26.5	6.0 × 10.0	60.0	NC	No
9	4.0	12.9	6.0 × 10.0	60.0	NC	No
10	17.0	45.0	7.0 × 8.0	56.0	NC	No
Median	3.7	12.7		60.0		
Range	2.0–17.0	8.5–45.0		23.2–93.1		

NC not calculated (CT available, but the Tanaka index was not documented). NA not available. †Clinically evident defect without loss of domain; CT was not performed

considered necessary since the defect was clinically evident without signs of loss of domain. The median area of the fascial defect was 60.0 cm² (range 23.2–93.1). In two patients, protrusion of the left hepatic lobe was documented through the defect.

Prehabilitation protocol

All patients received at least one BT infiltration event (Table 2). The median dose was 14.4 IU/kg, which is equivalent to that of onabotulinumtoxinA (range 3.7–23.5). Five patients required more than one infiltration event: three received two events, and two received three events; in all cases, these events were due to administrative delay in surgical scheduling and not due to clinical criteria of insufficient response.

The Tanaka index was calculated in the nine patients with available CT imaging. Four patients (40%) had an index equal to or greater than 25% (32%, 70%, 85% and 100%) and were indicated for PPP (Table 3); the remaining

Table 2 Botulinum toxin protocol

Pt.	Formulation	Total U/session	Equiv- alent U/kg*	No. of ses- sions
1	Botox®/Xeomin®	200	13.3	3
2	Xeomin®	200	12.5	2
3	Botox®	200	16.0	2
4	Botox®	200	15.4	1
5	Botox®/Xeomin®	200	19.6	2
6	Botox®	200	23.5	3
7	Botox®	200	21.1	1
8	Botox®	200	7.5	1
9	Dysport®	500 (≈ 167 equiv.)	12.9	1
10	Dysport®	500 (≈ 167 equiv.)	3.7	1
Median	—	—	14.4	1.5
Range	—	—	3.7– 23.5	1–3

*U/kg values are expressed as onabotulinumtoxinA equivalents. For Dysport®, a 3:1 conversion ratio was applied

Table 3 Progressive preoperative pneumoperitoneum (*n*=4)

Pt.	Tanaka index (%)	Insufflation days	Cumulative volume (mL)
1	85	6	1800
4	32	10	1200
6	100	8	2600
7	70	7	1330
Median	77.5	7.5	1565
Range	32–100	6–10	1200–2600

PPP was indicated for a Tanaka index ≥ 25%. Daily insufflation was continued until limited by patient tolerance (abdominal pain). Cumulative volume represents the total volume administered throughout the protocol

five patients had an index below 10%. The median number of days of insufflation was 7.5 days (range 6–10), and the median cumulative volume was 1,565 mL (range 1,200–2,600). In all patients, the catheter was removed during the final surgical procedure, without complications associated with the insufflation procedure.

Surgical closure

All patients underwent abdominal wall closure with the RTL technique. No patient required the use of prosthetic material (0/10, 0%). In three patients, umbilicoplasty was performed as a concomitant procedure.

Postoperative evolution and follow-up

No intraoperative complications were recorded for any patient. The median duration of hospitalization was 6.5 days (range 4–27). The case with the longest stay corresponded to a patient who presented with pneumonia due to respiratory syncytial virus during the immediate postoperative period, an intercurrent complication unrelated to the surgical technique (Clavien–Dindo IIIa); excluding this case, the median hospitalization was 6.0 days (range 4–17).

The median follow-up was 19.8 months (range 16.4–47.7), and the cumulative follow-up was 242.2 months. Hernia recurrence was not documented in any patient during the follow-up period (0/10, 0%). Figure 3 shows a representative case with a Tanaka index of 100%, including the preoperative appearance, the immediate postoperative result, and the 6-month follow-up.

Discussion

The present study reports the largest multicenter series to date of the combined protocol of prehabilitation with BT, selective PPP and closure with the RTL technique in pediatric patients with ventral hernias secondary to a giant omphalocele. The only direct antecedents in the literature are three case reports (12–14), which underscore the scarcity of evidence in this specific scenario and the relevance of the present series.

Prehabilitation with BT and pneumoperitoneum

The physiological basis of BT as a prehabilitation strategy lies in its ability to produce temporary chemical paralysis of the lateral abdominal musculature, facilitating fascial medialization and reducing midline tension. A meta-analysis of 23 studies with 995 patients revealed that bilateral



Fig. 3 Surgical progression of a complex Tanaka defect

injection of BT resulted in significant elongation of the lateral abdominal wall (3.2 cm per side; 6.3 cm total), with a reduction in the transverse width of the hernia defect and a significant increase in the fascial closure rate (RR 1.08; 95% CI 1.02–1.16; $p = 0.02$) (7). In our series, the rate of primary fascial closure was 100%, without the need for prior separation of components or transversus abdominis release (TAR) in any case, which is consistent with the data of that meta-analysis and with a retrospective cohort study that demonstrated that BT prehabilitation significantly reduced the need for component separation techniques in giant hernias, from 84% to 46% compared with patients without prehabilitation ($p < 0.001$) [20].

This point is clinically relevant. Both anterior component separation (CAS) and TAR are associated with nonnegligible rates of wound complications. A recent meta-analysis of 2,293 patients revealed that compared with TAR, CAS is associated with twice the incidence of wound complications (OR 2.58, $p = 0.004$), and even TAR (the current preferred technique in adults) has surgical site infection rates ranging from 14 to 19% in contemporary series [21, 22]. In the pediatric population, these complications have an additional dimension: the sectioning of muscle planes in a growing child compromises the functional development of the abdominal wall in the long term. In the most complete functional follow-up available for children who underwent CAS for giant omphaloceles, Van Eijck et al. documented diastasis recti in 7 of 8 patients and difficulty in active control of the abdominal musculature at a mean follow-up of 4.5 years, although without clinically significant functional repercussions [23]. Our protocol completely avoids this dissection by achieving closure by chemical prehabilitation and suture reinforcement, fully preserving the muscle architecture.

PPP was indicated in the four patients with a Tanaka index equal to or greater than 25%, corresponding to patients with greater loss of domain. The combination of BT and PPP as a sequential strategy has shown superior results to each technique separately in complex hernias with loss of domain in adults [9, 10]. In our series, the insufflation dose was fixed at 20 mL/kg/day in all cases, which is analogous to pediatric peritoneal dialysis exchanges and is considered safe and reproducible without the need for titration by symptomatology, as occurs in adults [24]. The differences in the cumulative volume between patients reflect the interaction between the body weight of each patient and the number of days of insufflation completed, not adjustments in the intensity of the protocol. The Tanaka index guided the indication of PPP, not the daily dose, although its usefulness as a selection criterion in pediatrics deserves prospective evaluation given the sample size of this series.

Closure with RTL and the absence of mesh

The decision to forgo using prosthetic material was deliberate and well-founded. In the pediatric population, the use of synthetic mesh implies its subsequent surgical removal in most cases, with rates of secondary hernia greater than 50% after its removal [2, 3]. RTL, evaluated until now mainly as a technique for the prevention of incisional hernia in adults, was demonstrated in a network meta-analysis that included 3,540 patients to be the modified closure technique with the best overall performance, the only technique that simultaneously reduced incisional hernia and wall dehiscence, with an NNT of 3 [17]. Its use as a treatment for established hernia is limited to a single favorable report [18], and the present series constitutes the first systematic evaluation of its application in children with complex secondary hernias, with a recurrence rate of 0% at a median follow-up of 19.8 months (range 16.4–47.7; cumulative follow-up 242.2 months).

These results are comparable to those of van Eijck et al. (2008), who reported a recurrence rate of 0% at a median follow-up of 23.5 months (range 3–39 months) with a component separation technique without prosthetic material in 10 pediatric patients with hernia secondary to a giant omphalocele [25]. These findings compare favorably with those reported by Beres et al. (2012), who documented a recurrence rate of 38% at a median follow-up of 60 months (range 10–90 months) in 13 patients treated with porcine intestinal submucosa biological mesh (Surgisis) for abdominal wall defects [26].

Protocol safety

No intraoperative complications were recorded for any patient. The only major postoperative complication was respiratory syncytial virus pneumonia in a patient with greater clinical complexity (Tanaka index 100%), an intercurrent complication unrelated to the surgical technique (Clavien–Dindo IIIa). The median hospitalization duration for the overall cohort was 6.5 days, comparable to that reported in reference pediatric series.

Limitations

This study has limitations inherent to its design. This is a retrospective, multicenter case series, but without a control group, with a sample size of 10 patients and heterogeneous follow-up. The variability in the indication of PPP, the number of BT infiltration events (conditioned in some cases by administrative factors and not by clinical criteria) and the absence of a standardized functional evaluation of the abdominal wall in the long term are aspects that should be studied in the future. The fixed per-site botulinum toxin dosing regimen also resulted in considerable variability

in per-kilogram exposure (median 14.4 IU/kg, range 3.7–23.5); a weight-adjusted regimen could reduce this variability and should be evaluated in future protocols. However, given the rarity of this entity and the absence of previous systematic series, these results constitute the most complete evidence available to date and offer a basis for the design of multicenter studies with greater statistical power.

Conclusions

The combined protocol of prehabilitation with BT, selective PPP and closure with the RTL technique proved to be a safe and technically viable strategy for the repair of complex ventral hernias secondary to giant omphaloceles in pediatric patients. In this multicenter series of 10 patients, primary fascial closure was achieved in 100% of patients without the need for component separation or the use of prosthetic material, with a recurrence rate of 0% at a median follow-up of 19.8 months and an acceptable surgical complication profile.

Given the limitations inherent to the retrospective design, sample size and absence of a control group, the results should be interpreted as preliminary evidence that justifies the design of multicenter prospective studies with greater statistical power and long-term standardized functional follow-up.

Author contributions MJPG and EELH: Conceptualization, Data curation, Methodology, Writing & Editing, Visualization. AAPD, JPG, GJSM, RRG and IVML: Conceptualization, Methodology, Writing Review & Editing, Visualization.

Funding None.

Data availability The authors confirm that the data supporting the findings of this study are available upon reasonable request.

Declarations

Informed consent For this observational study with anonymized data, formal consent is not required.

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Generative AI and AI-assisted technologies in the writing process During the preparation of this work the authors did not use any tool or service to modify/adapt/revise its content.

References

- Akinkuotu AC, Sheikh F, Olutoye OO, Lee TC, Fernandes CJ, Welty SE, Ayres NA, Cass DL (2015) Giant omphaloceles: surgical management and perinatal outcomes. *J Surg Res* 198:388–392. <https://doi.org/10.1016/j.jss.2015.03.060>
- van Eijck FC, Aronson DA, Hoogveen YL, Wijnen RM (2011) Past and current surgical treatment of giant omphalocele: outcome of a questionnaire sent to authors. *J Pediatr Surg* 46:482–488. <https://doi.org/10.1016/j.jpedsurg.2010.08.050>
- Bauman B, Stephens D, Gershon H, Bongiorno C, Osterholm E, Acton R, Hess D, Saltzman D, Segura B (2016) Management of giant omphaloceles: A systematic review of methods of staged surgical vs. nonoperative delayed closure. *J Pediatr Surg* 51:1725–1730. <https://doi.org/10.1016/j.jpedsurg.2016.07.006>
- Ghattaura H, Ross A, Aldeiri B, Mutanen A, Saxena A (2024) Managing giant omphalocele: A systematic review of surgical techniques and outcomes. *Acta Paediatr* 113:2459–2465. <https://doi.org/10.1111/apa.17346>
- Ibarra-Hurtado TR, Nuño-Guzmán CM, Echeagaray-Herrera JE, Robles-Vélez E, de Jesús González-Jaime J (2009) Use of botulinum toxin type a before abdominal wall hernia reconstruction. *World J Surg* 33:2553–2556. <https://doi.org/10.1007/s00268-009-0203-3>
- Espinosa-de-Los-Monteros A, Meza-Medina CA, Lopez-Zamora Z, Solís-Reyna RA, Carrillo-Vidales J (2024) Effects of botulinum toxin in two indicators of loss of domain and hernia size among patients with large ventral hernias. *World J Surg* 48:881–886. <https://doi.org/10.1002/wjs.12112>
- Timmer AS, Claessen JJM, Atema JJ, Rutten MVH, Hompes R, Boermeester MA (2021) A systematic review and meta-analysis of technical aspects and clinical outcomes of botulinum toxin prior to abdominal wall reconstruction. *Hernia* 25:1413–1425. <https://doi.org/10.1007/s10029-021-02499-1>
- Weissler JM, Lanni MA, Tecce MG, Carney MJ, Shubinets V, Fischer JP (2017) Chemical component separation: a systematic review and meta-analysis of botulinum toxin for management of ventral hernia. *J Plast Surg Hand Surg* 51:366–374. <https://doi.org/10.1080/2000656X.2017.1285783>
- Martínez-Hoed J, Bonafe-Diana S, Bueno-Lledó J (2021) A systematic review of the use of progressive preoperative pneumoperitoneum since its inception. *Hernia* 25:1443–1458. <https://doi.org/10.1007/s10029-020-02247-x>
- Bueno-Lledó J, Carreño-Saenz O, Torregrosa-Gallud A, Pous-Serrano S (2020) Preoperative botulinum toxin and progressive pneumoperitoneum in loss of domain hernias-our first 100 cases. *Front Surg* 7:3. <https://doi.org/10.3389/fsurg.2020.00003>
- Eltner KE, Read JW, Rodríguez-Acevedo O, Ho-Shon K, Magnussen J, Ibrahim N (2017) Preoperative progressive pneumoperitoneum complementing chemical component relaxation in complex ventral hernia repair. *Surg Endosc* 31:1914–1922. <https://doi.org/10.1007/s00464-016-5194-1>
- Rombaldi MC, Barreto CG, Peterson CA, Cavazzola LT, Santis-Isolan PMB, Fraga JC (2021) Complex ventral hernia repair in a child: An association of botulinum toxin, progressive pneumoperitoneum and negative pressure therapy. A case report on an arising surgical technique. *Int J Surg Case Rep* 81:105828. <https://doi.org/10.1016/j.ijscr.2021.105828>
- Rombaldi MC, Neto WFS, Holanda FC, Cavazzola LT, Fraga JC (2020) Ventral hernia secondary to giant omphalocele in a child: combined approach of botulinum toxin and preoperative progressive pneumoperitoneum. *Hernia* 24:1397–1400. <https://doi.org/10.1007/s10029-019-02084-7>
- Peña García MJ, Peñarrieta Daher AA, Medina López I, Brenes Guzmán S, Zalles Vidal C, Teyssier Morales G, Penchyna Grub J, Nieto Zermeño J, Reynoso González R (2023) Complex ventral hernia secondary to giant omphalocele managed by preoperative pneumoperitoneum and botulinum toxin: A case report. *J Pediatr Surg Case Rep* 97:102699. <https://doi.org/10.1016/j.epsc.2023.102699>
- Lozada-Hernández EE, Mayagoitia-González JC, Smolinski-Kurek RL, Montiel-Hinojosa L, Hernández-Villegas L,

- Morales-Vargas JM, Pérez-Sánchez KD, Orozco-Mosqueda A, Cano-Rosas M (2022) Prevention of incisional hernia with a reinforced tension line (RTL) versus primary suture only in midline laparotomies: 3-year follow-up in a randomized clinical trial. *Hernia* 26:447–456. <https://doi.org/10.1007/s10029-020-02338-9>
16. Wenzelberg CL, Rogmark P, Ekberg O, Petersson U (2024) Reinforced tension-line suture after laparotomy: early results of the Rein4CeTo1 randomized clinical trial. *Br J Surg* 111:znae265. <https://doi.org/10.1093/bjs/znae265>
 17. Lozada Hernández EE, Hernández Bonilla JP, Hinojosa Ugarte D, Magdaleno García M, Mayagoitia González JC, Zúñiga Vázquez LA, Obregón Moreno E, Jiménez Herevia AE, Cethorth Fonseca RK, Ramírez Guerrero P (2023) Abdominal wound dehiscence and incisional hernia prevention in midline laparotomy: a systematic review and network meta-analysis. *Langenbecks Arch Surg* 408:268. <https://doi.org/10.1007/s00423-023-02954-w>
 18. Hollinsky C, Sandberg S, Kocijan R (2007) Preliminary results with the reinforced tension line: a new technique for patients with ventral abdominal wall hernias. *Am J Surg* 194:234–239. <https://doi.org/10.1016/j.amjsurg.2006.09.045>
 19. Mathew G, Sohrabi C, Franchi T, Nicola M, Kerwan A, Agha R, PROCESS Group (2023) Preferred reporting of case series in surgery (PROCESS) 2023 guidelines. *Int J Surg* 109:3760–3769. <https://doi.org/10.1097/JS9.0000000000000940>
 20. Zamkowski M, Lerchuk O, Porytsky A, Ushnevych Z, Khomyak V, Śmietański M (2024) The impact of botulinum toxin A application on reducing the necessity for component separation techniques in giant incisional hernias: a dual-center, polish-ukrainian, retrospective cohort study. *Pol Przegl Chir* 96:12–19. <https://doi.org/10.5604/01.3001.0054.4919>
 21. Mohamedahmed AY, Issa MT, Zaman S, Mohammed S, Mohamedahmed MY, Hamid M, Muhammed AKA, Odogwu S, Kabir SA (2025) Outcomes of anterior component separation versus posterior component separation with transversus abdominis muscle release for large incisional hernias: a systematic review and meta-analysis. *Hernia* 29:289. <https://doi.org/10.1007/s10029-025-03487-5>
 22. Dries P, Verstraete B, Allaeys M, Van Hoef S, Eker H, Berrevoet F (2024) Anterior versus posterior component separation technique for advanced abdominal wall reconstruction: a proposed algorithm. *Hernia* 28:895–904. <https://doi.org/10.1007/s10029-024-03039-3>
 23. van Eijck FC, van Vlimmeren LA, Wijnen RM, Klein W, Kruijen I, Pillen S, Nijhuis-van der Sanden MW (2013) Functional, motor developmental, and long-term outcome after the component separation technique in children with giant omphalocele: a case control study. *J Pediatr Surg* 48:525–532. <https://doi.org/10.1016/j.jpedsurg.2012.08.010>
 24. Nourse P, Cullis B, Finkelstein F, Numanoglu A, Warady B, Antwi S, McCulloch M (2021) ISPD guidelines for peritoneal dialysis in acute kidney injury: 2020 Update (paediatrics). *Perit Dial Int* 41:139–157. <https://doi.org/10.1177/0896860820982120>
 25. van Eijck FC, de Blaauw I, Bleichrodt RP, Rieu PN, van der Staak FH, Wijnen MH, Wijnen RM (2008) Closure of giant omphaloceles by the abdominal wall component separation technique in infants. *J Pediatr Surg* 43:246–250. <https://doi.org/10.1016/j.jpedsurg.2007.09.051>
 26. Beres A, Christison-Lagay ER, Romao RL, Langer JC (2012) Evaluation of Surgisis for patch repair of abdominal wall defects in children. *J Pediatr Surg* 47:917–919. <https://doi.org/10.1016/j.jpedsurg.2012.01.046>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.