Journal of Pediatric Surgery 55 (2020) 2284–2288

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Neonatal Conditions

Sutureless vs sutured abdominal wall closure for gastroschisis: Operative characteristics and early outcomes from the Midwest Pediatric Surgery Consortium

Jason D. Fraser [a,*], Katherine J Deans [b], Mary E Fallat [c], Michael A Helmrath [d], Rashmi Kabre [e], Charles M Leys [f], R Cartland Burns [g], Kristine Corkum [e], Patrick A. Dillon [h], Cynthia D. Downard [c], Samir K. Gadepalli [i], Julia E. Grabowski [e], Edward Hernandez [g], Ronald B. Hirschl [i], Kevin N. Johnson [i], Jonathan E. Kohler [f], Matthew P. Landman [g], Rachel M. Landisch [j], Amy E. Lawrence [b], Grace Z. Mak [k], Peter C. Minneci [b], Beth Rymeski [d], Thomas T. Sato [j], Madeline Scannell [h], Bethany J. Slater [k], Kathryn H Wilkinson [j], Tiffany N Wright [c], Shawn D. St. Peter [a], on behalf of the Midwest Pediatric Surgery Consortium

[a] Department of Surgery, Children's Mercy Kansas City, Kansas City, MO
[b] Center for Surgical Outcomes Research, The Research Institute at Nationwide Children's Hospital, Department of Surgery, University of Ohio, Columbus, OH
[c] Division of Pediatric Surgery, Hiram C. Polk, Jr., M.D. Department of Surgery, University of Louisville, Louisville, KY
[d] Division of Pediatric Surgery, Cincinnati Children's Hospital Medical Center, Cincinnati, OH
[e] Division of Pediatric Surgery, Department of Surgery, Feinberg School of Medicine of Northwestern University, Chicago, IL
[f] Division of Pediatric Surgery, Department of Surgery, University of Wisconsin School of Medicine and Public Health, Madison, WI
[g] Division of Pediatric Surgery, Department of Surgery, Indiana University School of Medicine, Indianapolis, IN
[h] Division of Pediatric Surgery, Department of Surgery, Washington University School of Medicine, St. Louis, MO
[i] Section of Pediatric Surgery, Department of Surgery, University of Michigan, Ann Arbor, MI
[j] Division of Pediatric Surgery, Department of Surgery, Medical College of Wisconsin, Milwaukee, WI
[k] Section of Pediatric Surgery, Department of Surgery, The University of Chicago Medicine, Chicago, IL

ARTICLE INFO

Article history:
Received 4 November 2019
Received in revised form 14 January 2020
Accepted 6 February 2020

Key words:
Gastroschisis
Silo
Sutureless closure
Ventilator
Anesthesia
Neonate

ABSTRACT

Purpose: To report outcomes of sutured and sutureless closure for gastroschisis across a large multi-institutional cohort.
Methods: A retrospective study of infants with uncomplicated gastroschisis at 11 children's from 2014 to 2016 was performed. Outcomes of sutured and sutureless abdominal wall closure were compared.
Results: Among 315 neonates with uncomplicated gastroschisis, sutured closure was performed in 248 (79%); 212 undergoing sutured closure after silo and 36 undergoing primary sutured closure. Sutureless closure was performed in 67 (21%); 37 primary sutureless closure, 30 sutureless closure after silo placement. There was no significant difference in gestational age, gender, birth weight, total days on TPN, and time from closure to initial oral intake or goal feeds. Sutureless closure patients had less general anesthetics, ventilator use/time, time from birth to final closure, antibiotic use after closure, and surgical site/deep space infections. Subgroup analysis demonstrated primary sutureless closure had less ventilator use and anesthetics than primary sutured closure. Sutureless closure after silo led to less ventilator use/time, anesthetics, and antibiotics compared to those with sutured closure after silo.
Conclusion: Sutureless abdominal wall closure of neonates with gastroschisis was associated with less general anesthetics, antibiotic use, surgical site/deep space infections, and decreased ventilator time. These findings support further prospective study by our group.
Level of Evidence: Level III.

The prevalence of gastroschisis appears to be increasing, especially in younger mothers, and is now estimated to be 4.5 per 10,000 live births in the United States [1]. The surgical management of gastroschisis has traditionally involved primary or staged reduction of the viscera followed by sutured closure of the fascial defect and skin. Staged closure is required when the surgeon is unable to reduce the entire viscera without excessive intra-abdominal pressure. In such cases, a silo is applied to achieve progressive reduction.

In 2004, a "sutureless" abdominal wall gastroschisis closure was described [2]. First, the umbilical cord is left long at the time of birth so it may be used as a biological dressing. Next, intestine and other eviscerated organs are reduced. The umbilical cord is cut to fit the opening

* Corresponding author at: 2401 Gillham Road, Kansas City, MO 64108. Tel.: +1 8160 234 3575.
E-mail address: jdfraser@cmh.edu (J.D. Fraser).

https://doi.org/10.1016/j.jpedsurg.2020.02.017
0022-3468/

and is used to cover the defect along with plastic adhesive dressings to reinforce the defect. These plastic adhesive dressings are later removed, and the umbilical cord is allowed to dry while the fascial defect closes by secondary circumferential healing [2].

Given the simplicity of this technique, both interest and use of sutureless closure has become more popular. The potential advantages over sutured closure include better cosmetic outcomes, transfer of the procedure from the OR to the bedside, and lower hospital cost. However, there have been few large cohort studies comparing sutureless closure to the traditional methods.

The purpose of the present study is to examine and compare the short-term outcomes of sutureless to sutured abdominal wall closure in infants with gastroschisis across a large regional cohort in the United States.

1. Methods

1.1. Patients and study design

Following individual and reliance institutional review board approval, a retrospective cohort of infants with gastroschisis born between 2013 and 2016 was identified across 11 participating children's hospitals of the Midwest Pediatric Surgery Consortium (www.mwpsc.org). Patients were identified from administrative hospital databases as well as practice databases. Patients with complex gastroschisis (atresia, perforation, necrosis, death) were excluded.

Study data were collected and managed using REDCap (Research Electronic Data Capture) software hosted at the primary site. All study data entered were validated both centrally and at each individual institution for completeness of data entry and accuracy.

2. Methods

Consensus in identifying and defining relevant data elements for collection and analysis across the 11 institutions was obtained. Sutured abdominal wall closure was defined as closure in the operating room using sutures to close the fascial defect. Sutureless closure was defined as any other closure method that did not use sutures to close the fascia, which was most commonly the technique depicted in Fig. 1. This typically placing the umbilical cord or and/or a non-adherent dressing over the remaining exposed bowel. This was then routinely covered with and adhesive plastic dressing. As this was a retrospective study, each institution performed the sutureless closure according to their local protocols – including dressing, sedation, medication use, etc. Perioperative data collection included demographics, prenatal information when available, method and location of abdominal wall closure, silo use, time from birth to final closure, general anesthetic and ventilator use, significant comorbidities, antibiotic management, perioperative complications, total parenteral nutrition (TPN) utilization, peripherally inserted central catheter (PICC) use and complications, feeding characteristics and length of stay.

Fig. 1. Photo of typical method of sutureless closure.

Patients were initially divided into two groups: sutureless and sutured closure. Recognizing that the use of a silo may act as a confounder, the groups were then broken up into subgroups for more detailed analysis: patients that had a silo then underwent a sutureless closure were compared with those that had a silo then had a sutured closure. Patients that had a primary sutureless closure were compared with those that had a primary sutured closure.

2.1. Statistical analysis

Missing data were recollected to ensure accuracy when possible; patients with missing data were excluded from the analysis. Continuous data were expressed as medians and interquartile ranges and discrete variables were expressed as percentages. For discrete variable comparisons, Pearson's chi-square test was used. Fisher's exact test was used for associations of two binary variables which had small cell sizes. A *p*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Study cohort and demographics

Over the 3-year study period, 394 infants with gastroschisis were identified. Seventy-nine patients with complex gastroschisis were excluded, leaving 315 patients for analysis (Fig. 2). The median gestational age at birth was 36 weeks (IQR 35, 37), the median birth weight was 2.4 kg (IQR 2.1, 2.8), and there were 157 males (49.8%). There were no significant differences in gestational age, birth weight, and gender between patients that had a sutured closure compared to those that had a sutureless closure (Table 1).

3.2. Operative management

Sutured abdominal wall closure was performed in 248 (79%), of which 212 were closed after the use of a silo and 36 were closed primarily. Sutureless closure was performed in 67 patients, 37 after the use of a silo and 30 were closed primarily without a silo. The median time from birth to final closure was 104.6 h (IQR 47–145.5) for the entire cohort. The time from birth to closure in those that underwent sutureless closure was 52 h (IQR3.7–120.8) compared to 115 h (IQR 62–164) for those that underwent sutured closure ($p = 0.0003$).

Two patients (2/30, 6.7%) that had primary sutureless closure failed this approach due to concerns for abdominal compartment syndrome. Both had the plastic closure removed and were placed in a silo. One went on to sutured fascial closure with a length of stay 29 days, and the other required a patch to obtain fascial closure requiring a 54-day hospitalization.

3.3. Post-operative management

3.3.1. Enteral and parenteral nutrition

In the cohort analyzed, 204 patients (65%) were fed via an institutional protocol. There were no significant differences in total days of TPN, use of protocol feeding, time from closure to initial oral intake, or time to goal feeds between the sutureless and sutured groups (Table 1).

3.3.2. Antibiotic usage and infections

Patients with sutureless closure had less total antibiotic use after closure (67% vs 83%, $p = 0.004$) and fewer surgical site/deep space infections (3% vs 13%, $p = 0.02$). There was no significant difference in antibiotic use prior to closure or days of antibiotics after closure between the two groups (Table 1).

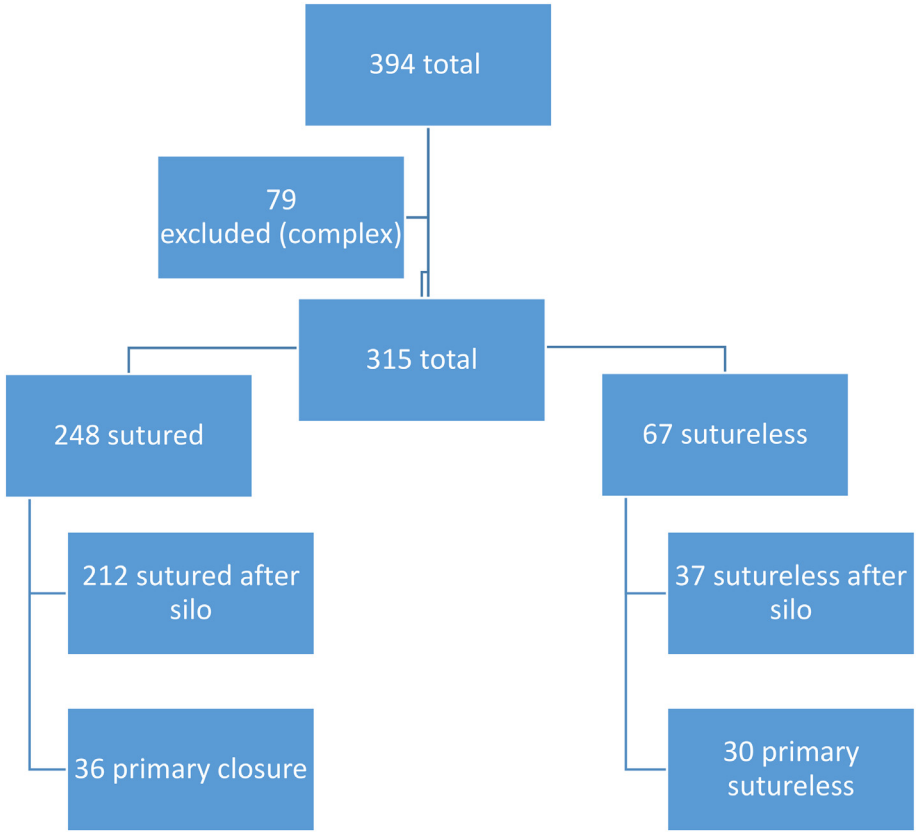

Fig. 2. Study cohort.

3.3.3. Ventilator and anesthetic management

There were significantly fewer general anesthetics in the sutureless group (0 (IQR 0–1) vs 1 (IQR 1–2), $p < 0.001$) as well as less ventilator use (48% vs 78%, $p < 0.001$) and median time on the ventilator (0d (IQR 0–3) vs 3 (IQR 1–6), $p < 0.001$ (Table 1).

3.4. Subgroup analysis

Recognizing that the use of a silo may act as a confounder, subgroup analysis was performed: primary sutured closure was compared with primary sutureless closure and sutured closure after a silo was compared with sutureless closure after a silo.

3.4.1. Primary closure comparison

Comparing those who underwent primary abdominal wall closure with a sutureless vs sutured closure, there were no differences in gestational age, birth weight, gender, time from birth to final closure, or length of stay. Moreover, there were no differences in time to first oral intake or time to goal feeds, ventilator days, infections, antibiotic use and length of stay. Primary sutureless closure yielded less ventilator use (46% vs 83%, $p = 0.001$), and anesthetics [0 (IQR 0–1) vs 1 (IQR 1–1), $p < 0.001$]. However, there were more days of TPN than primary closure [24d (IQR 17–31) vs 18 (IQR 14–23), $p < 0.001$] (Table 2).

3.4.2. Silo assisted closure comparison

In analyzing the subgroups that had a silo then underwent a sutureless closure compared to sutured closure, similar differences were seen. There was less ventilator use (50% vs 77%, $p = 0.001$) and time [0.5d (IQR 0–4.75) vs 4d (IQR 1–7), $p = 0.007$], median number of anesthetics [0 (IQR 0–1 vs 2 (IQR 1–2), $p < 0.001$], and antibiotic use after closure (60% vs 84% $p = 0.001$) for those who had a silo then

Table 1
Demographic characteristics and outcomes.

	Cohort (n = 315)	Sutureless (n = 67)	Sutured (n = 248)	p
Median LOS (days)	33 (24–46)	32 (25–46)	33 (24–47)	0.50
Gestational age (weeks)	36 (35–37)	36 (35–37)	36 (35–37)	0.66
Gender (n)	157 (50%)	33 (49%)	(50%)	0.91
Birth Weight (kilograms)	2.43 (2.1–2.8)	2.45 (2–2.9)	2.4 (2.1–2.8)	0.9
Total days TPN	24 (17–35)	25 (18–36)	24 (17–34)	0.99
Time from closure to first PO (d)	11 (8–16)	12 (8–17)	11 (8–15.5)	0.35
Time from closure to goal feeds (d)	23 (17–33)	25 (18.25–33.5)	23 (17–33)	0.55
Surgical site/deep infections	N = 34 (11%)	N = 2 (3%)	N = 32 (13%)	**0.02**
Antibiotic days after closure	2 (1–7)	2 (1–5)	3 (1–7)	0.055
Antibiotics prior to closure	N = 297 (94%)	N = 60 (90)	N = 237 (96%)	0.27
Antibiotics used after closure	N = 251 (80%)	N = 45 (67%)	N = 206 (83%)	**0.004**
Any general anesthetic received (n)	1 (1–2)	0 (0–1)	1 (1–2)	<**0.001**
Number of general anesthetics given (n)	256 (81%)	18 (27%)	238 (97%)	<**0.001**
Ventilator use outside of OR (n)	226 (72%)	32 (48%)	194 (78%)	<**0.001**
Time on ventilator (d)	2 (0–6)	0 (0–3)	3 (1–6)	<**0.001**

Table 2
Outcomes of primary sutureless vs primary sutured abdominal wall closure.

	Primary Sutureless (n = 37)	Primary Sutured (n = 36)	p
Median LOS (d)	29 (23–41)	23 (18.75–33)	0.08
Gestational age (weeks)	36 (35–36.4)	36.5 (36–37)	0.18
Gender (male)	19 (51%)	17 (47%)	0.72
Birth Weight (median)	2.4 (IQR 1.95–2.85)	2.6 (IQR 2.3–2.9)	0.3
Total days TPN	24 (17–31)	18 (14–23)	**0.02**
General anesthetics (n)	0 (0–1)	1 (1–1)	<**0.001**
General anesthetic given (n)	10 (27%)	34 (94%)	**0**
Time from close to first PO (d)	11 (5–15)	10.5 (9–14.25)	0.22
Time from close to goal feed (d)	23.5 (18–29.75)	20.5 (16–26.75)	0.06
Ventilator use outside of OR (n)	17 (46%)	30 (83%)	**0.001**
Time on ventilator (d)	0 (0–2)	2 (1–3)	0.2
Birth to final closure (h)	4 (2.7–7)	3.9 (2.88–6)	0.93
Surgical site/deep infections (n)	1 (3%)	3 (8%)	0.29
Antibiotic days after closure	2 (1–4.25)	2 (1–3)	0.46
Antibiotics used after closure (n)	27 (73%)	27 (75%)	0.84

a sutureless closure compared to those who had a silo then underwent a sutured closure. There was no difference in antibiotic days after closure, infections, time from birth to final closure, time to first oral intake or goal feeds, days on TPN, birth weight, gender, gestational age, or length of stay (Table 3).

4. Discussion

In this large cohort comparison of neonates who have undergone sutureless closure, we found that infants closed with a sutureless technique had similar time to initiation of feeds and time to goal feeds; which resulted in a similar length of stay. These findings remained constant in the subgroup analysis. Patients that had sutureless closure, with or without silo, had fewer general anesthetics, less ventilator use and time, shorter time from birth to final closure, less antibiotic use after closure, and fewer surgical site/deep space infections than those who underwent sutured closure. The subgroup analysis demonstrated patients that had a primary sutureless closure had less ventilator use and fewer anesthetics than primary sutured closure. After silo placement, sutureless closure was associated with less ventilator use/time, fewer anesthetics, and less antibiotics after closure compared to those who had a sutured closure. The short- and long-term cosmetic results were subjectively good with sutureless closure.

First published in 2004, a case series described the sutureless closure in 10 children with excellent results [2]. Six were closed with primary reduction and sutureless closure, 2 were closed with a sutureless closure after bowel resection, and 2 were closed after use of a silo. A retrospective case-matched study compared sutureless closure to primary surgical and staged silo closure and included 11 subjects in each arm. The results showed no difference in any of the outcomes examined other than a higher incidence of umbilical hernias after sutureless closure [3].

Most recently, a retrospective case–control study of sutureless versus sutured gastroschisis closure reported that sutureless closure resulted in significantly less time on the ventilator. Less time to enteral feeds and to discharge were also described along with self-resolving umbilical hernias in all patients with sutureless closure. No differences in the incidence of serious complications were found [4].

A pilot prospective randomized trial compared sutured with sutureless closure with 19 patients in the sutureless arm and 20 patients in the sutured arm. The authors found that there was an increase in the time to full feeds and time to discharge in the sutureless group [5]. Interestingly, the authors reported a median time to discharge of 28 days in the sutured group compared to 43 days in the sutureless group. In our cohort, the group of patients that had a sutured closure had a median length of stay of 33 days compared to 32 days in the sutureless group. The same study reported a median time to full enteral feeds of 23 days for sutured and 39 for sutureless patients, compared to our finding of 23 days for sutured and 23 for sutureless patients. Overt reasons for these differences are not clear, however, this comparison study was conducted early in the experience with sutureless closure. Our data showed an increase in median TPN days for those who had a primary sutureless closure compared to primary sutured closure (24 vs 18 days, p = 0.02). The above authors reported the use of intubation, extubation, and feeding protocols. These use of feeding protocols has been shown to decrease time to full enteral feeds but without change in hospital stay [6]. Institution-specific feeding protocols were used in 204 of the 315 patients analyzed in our study. We did not specifically examine the use of intubation or extubation protocols.

Table 3
Outcomes of silo then sutureless closure vs silo then sutured closure.

	Silo then Sutureless (n = 30)	Silo then Sutured (n = 212)	p
Median LOS (d)	36 (28.25–45.75)	33.5 (25–49)	0.85
Gestational age (weeks)	36 (35–37)	36 (35–37)	0.56
Gender (male)	14 (47%)	107 (50%)	0.70
Birth Weight (median)	2.5 (2.2–2.9)	2.4 (2.1–2.8)	.057
Total days TPN	27 (22.5–38)	25 (18–36)	0.73
General anesthetics (n)	0 (0–1)	2(1–2)	< **0.001**
General anesthetic given (n)	8 (27%)	205 (97%)	**0**
Time from close to first PO (d)	12.5 (7.5–17.75)	11 (7–16)	0.71
Time from close to goal feed (d)	26 (21.25–36.75)	23.5 (17–34.5)	0.59
Ventilator use outside of OR (n)	15 (50%)	164 (77%)	**0.001**
Time on ventilator (d)	0.5 (0–4.75)	4 (1–7)	**0.007**
Birth to final closure (h)	120 (93–144)	120 (85.5–168)	0.41
Surgical site/deep infections (n)	1 (3%)	29 (14%)	0.11
Antibiotic days after closure	2 (0–5)	4 (1–8)	0.15
Antibiotics used after closure (n)	18 (60%)	179 (84%)	**0.001**

A recent single institution cohort study demonstrated some similar findings to ours. In 90 consecutive patients with gastroschisis, 50 sutured and 40. They found no differences in hospital stay, time to full feeds, duration of TPN, wound infection rates, or readmission rates. The sutureless group had fewer days of antibiotics, days intubated, days receiving intravenous analgesia, and silo reductions. There were more umbilical hernias in the sutureless group [7]. We did not examine readmission rates, only in-hospital events and outcomes, nor did we examine analgesia use. On initial analysis, our study showed decreased surgical site and deep space infection rates, but once the groups were broken down into silo assisted closure and primary closure, no differences were found; but this may be due to a decreased power form the subgroup analysis. Moreover, other studies have shown that sutureless closure may decrease infectious complications in patients with gastroschisis [8, 9]. This may be due to less days on the ventilator and the lack of direct operative trauma to the sensitive neonatal tissues. Data from our cohort demonstrated that patients that had a closure with the sutureless technique had significantly fewer ventilator days. This has been shown in other retrospective series [7, 10, 11].

Interestingly, two patients in the sutureless group had abdominal compartment syndrome after placement of the plastic dressing. In both the dressing was removed, and sutured repair was ultimately achieved, however one patient required patch placement for fascial closure. This highlights the importance of patient selection, but also demonstrates that serial physical examinations and close monitoring of these patients is necessary even after the defect is closed with just a dressing.

We did not examine long-term outcomes, specifically the need for umbilical hernia repair in this study. However, rates of umbilical hernia have been reported in smaller series as 5/11 in primary sutured closure, 1/11 in silo then sutured closure, and 9/11 in sutureless closure. Of those with umbilical hernias however, the only ones that required repair at the time of publication were 2/5 in the primary sutured closure group [3]. The next phase of our multi-institutional retrospective study will be to gather and report this information on this same cohort.

While we excluded patients with complex gastroschisis, the application of the sutureless closure technique in this population is possible, either initially or after silo placement. In the initial description of the sutureless closure, it appears that two patients required an enteric anastomosis prior and went on to sutureless closure [2]. Furthermore, sutureless repair was demonstrated to be feasible in patients with complex gastroschisis (atresia and perforation) in 3 of 20 patients managed with sutureless closure in a retrospective cohort study [11].

This study has several limitations that should be taken into consideration. First due to the retrospective and in-hospital nature, comparisons that have been made in other studies, such as umbilical hernia rates and repair, were not performed. The next phases of this study will examine these same patients contemporaneously across the MWPSC to define their true risk of umbilical hernia in the short and long term. We will also examine readmissions, growth, and need for operative intervention. The goal of this will be to examine long-term outcomes and safety of patients who had a sutured and sutureless closure in a retrospective manner. As this is also a multi-institutional retrospective study, there is a possibility of selection bias in each of the patient populations, both due to surgeon's own bias or patient defined. It is possible that patients that are more well-suited for a sutureless repair are selected more frequently for this approach and therefore there is a possibility of selection bias in this data set; that is, patients with more favorable bowel patterns may have been more likely to have been selected to undergo sutureless closure Attempts to control for some of these factors was done by performing the subgroup analysis, but it is important to interpret the results within this context. While the sutureless approach was associated with improved outcomes in several markers as noted, the nature of this study means that definitive conclusions of causation are not possible. Therefore, we plan to implement a prospective sutureless protocol across our Consortium with the goal of improving the objective outcomes documented in this experience.

5. Conclusion

The sutureless abdominal wall closure in neonates with gastroschisis is associated with fewer general anesthetics, less antibiotic use, less surgical site/deep space infections, and decreased ventilator time with similar time to initial feeds, time to goal feeds, and hospital stay in selected patients. Further longitudinal study of this cohort in planned to examine the long-term outcomes and complications. Moreover, these findings justify further prospective study of the sutureless closure method.

References

[1] Kirby RS. The prevalence of selected major birth defects in the United States. Semin Perinatol 2017;41:338–44.
[2] Sandler A, Lawrence J, Meehan J, et al. A "plastic" sutureless abdominal wall closure in gastroschisis. J Pediatr Surg 2004;39:738–41.
[3] Bonnard A, Zamakshary M, de Silva N, et al. Non-operative Management of Gastroschisis: a case-matched study. Pediatr Surg Int 2008;24:767–71.
[4] Riboh J, Abrajano CT, Garber K, et al. Outcomes of sutureless gastroschisis closure. J Pediatr Surg 2009;44:1947–51.
[5] Bruzoni M, Jaramillo JD, Dunlap JL, et al. Sutureless vs sutured gastroschisis closure: a prospective randomized controlled trial. J Am Coll Surg 2017;224:1091–6.
[6] Passaro RC, Savoie KB, Huang EY. Use of a gastroschisis feeding guideline to improve standardization of care and patient outcomes at an urban Children's hospital. Nutr Clin Pract 2018;33:545–52.
[7] Witt RG, Zobel M, Padilla B, et al. Evaluation of clinical outcomes of Sutureless vs sutured closure techniques in gastroschisis repair. JAMA Surg 2019;154:33–9.
[8] Schleuter RK, Azarow KS, Hines AG, et al. Identifying strategies to decrease infectious complications of gastroschisis repair. J Pediatr Surg 2015;50(1):98–101.
[9] Orion KC, Krein M, Liao J, et al. Outcomes of plastic closure in gastroschisis. Surgery 2011;150:117–85.
[10] Dariel A, Poochareoen W, de Silva, et al.. Secondary plastic closure of gastroschisis is associated with a lower incidence of mechanical ventilation. Eur J Pedatric Surg 2015;25:34–40.
[11] Grabski DF, Hu Y, Vavolizza RD, et al. Sutureless closure: a versatile treatment for the diverse presentations of gastroschisis. J Perinatol 2019 Jan;28 [Epub ahead of print].