Pediatric Surgery International (2024) 40:246
https://doi.org/10.1007/s00383-024-05819-5

REVIEW

Improving outcomes for uncomplicated gastroschisis: clinical practice guidelines from the American Pediatric Surgical Association Outcomes and Evidence-based Practice Committee

Joanne Baerg[1] · Jarod McAteer[2] · Doug Miniati[3] · Stig Somme[4] · Mark Slidell[5] on behalf of the American Pediatric Surgical Association Outcomes and Evidence-based Practice Committee

Accepted: 10 August 2024

Abstract

Background The authors sought better outcomes for uncomplicated gastroschisis through development of clinical practice guidelines.

Methods The authors and the American Pediatric Surgical Association Outcomes and Evidenced-based Practice Committee used an iterative process and chose two questions to develop clinical practice guidelines regarding (1) standardized nutrition protocols and (2) postnatal management strategies. An English language search of PubMed, MEDLINE, OVID, SCOPUS, and the Cochrane Library Database identified literature published between January 1, 1970, and December 31, 2019, with snowballing to 2022. The Appraisal of Guideline, Research and Evaluation reporting checklist was followed.

Results Thirty-three studies were included with a Level of Evidence that ranged from 2 to 5 and recommendation Grades B–D. Nine evaluated standardized nutrition protocols and 24 examined postnatal management strategies. The adherence to gastroschisis-specific nutrition protocols promotes intestinal feeding and reduces TPN administration. The implementation of a standardized postnatal clinical management protocol is often significantly associated with shorter hospital stays, less mechanical ventilation use, and fewer infections.

Conclusions There is a lack of comparative studies to guide practice changes that improve uncomplicated gastroschisis outcomes. The implementation of gastroschisis-specific feeding and clinical care protocols is recommended. Feeding protocols often significantly reduce TPN administration, although the length of hospital stay may not consistently decrease.

Keywords Gastroschisis · Abdominal wall defect · Outcomes · Clinical care protocol · Simple gastroschisis

Abbreviations

TPN	Total parenteral nutrition
NICU	Neonatal intensive care unit
APSA OEBPC	American Pediatric Surgical Association Outcomes and Evidence-Based Practice Committee
AGREE	Appraisal of Guideline, Research and Evaluation checklist
MINORS	Methodological Index for Non-Randomized Studies
LOS	Length of stay
MRI	Magnetic resonance imaging
SMA	Superior mesenteric artery
OR	Odds ratio
NEC	Necrotizing enterocolitis
OCEBM	Oxford Centre for Evidence-Based Medicine criteria
LOE	Level of evidence

✉ Joanne Baerg
jbaerg@phs.org; jbaerg07@gmail.com

1 Division of Pediatric Surgery, Presbyterian Healthcare Services, Albuquerque, NM, USA

2 Division of Pediatric Surgery, Providence Sacred Heart Children's Hospital, Spokane, WA, USA

3 Division of Pediatric Surgery, Kaiser Permanente Northern California, Roseville, CA, USA

4 Division of Pediatric Surgery, University of Colorado School of Medicine, Aurora, CO, USA

5 Division of Pediatric Surgery, Johns Hopkins Children's Center, Baltimore, MD, USA

Published online: 30 August 2024

Introduction

Infants with gastroschisis consume a disproportionately greater share of resources when compared to other Neonatal Intensive Care Unit (NICU) groups [1]. Gastroschisis is estimated to occur between 2 and 6 in 10,000 live births. The incidence is increasing in every location where it is studied [2–4]. Uncomplicated gastroschisis involves no additional complications other than those stemming from bowel inflammation and irritation [5]. The definition of complicated gastroschisis includes intestinal atresia, volvulus, perforation, or necrosis present at birth [6–8]. Gastroschisis infants are at risk of poor outcomes from TPN administration, multiple anesthetics, mechanical ventilation, infections, prolonged hospital stay and mortality [9]. The key elements of a postnatal gastroschisis management strategy to optimize outcomes are not well-defined [10]. The authors sought to improve outcomes for infants with uncomplicated gastroschisis through development of enteral feeding and postnatal management guidelines.

Methods

The authors, in collaboration with the American Pediatric Surgical Association Outcomes and Evidence-based Practice Committee (APSA OEBPC), used an iterative process and chose two questions, a priori, for clinical practice guideline development.

1. Do standardized nutrition protocols facilitate early enteral feeding and improve outcomes?
2. Have any postnatal management strategies demonstrated superior outcomes such as reduced hospital stay, anesthesia and mechanical ventilation use, infection incidence and mortality rates?

Data sources

On July 1, 2020, a healthcare librarian utilized Covidence software to perform an English language search of PubMed, MEDLINE, OVID, SCOPUS, and the Cochrane Library database [11]. The Medical Subject Headings (MeSH) included "gastroschisis" and "abdominal muscles/abnormalities." The search identified publications between January 1, 1970, and December 31, 2019. The initial 1340 abstracts were collected and evaluated by the authors (JB, DM, JM, SS, MS). Non-unanimous decisions were evaluated by a second review and a majority opinion about exclusion or inclusion was applied. After initial screening, 518 articles were selected for manuscript review. The snowballing technique captured the most recent, applicable studies to 2022 (Fig. 1).

The level of evidence (LOE) and grade of recommendation were assigned based on the Oxford Centre for Evidence-Based Medicine (OCEBM) criteria (OCEBM levels of evidence working group, 2011). Guideline development followed the international Appraisal of Guideline, Research and Evaluation (AGREE) reporting checklist (Appendix A. AGREE Reporting Checklist in Supplementary) [12]. The Methodological Index for Non-randomized Studies (MINORS) criteria were recorded for each study to evaluate the potential impact of bias (Appendix B in Supplemental Table) [13].

Exclusion criteria

Non-English publications, animal studies, case reports, studies with incomplete data, and abstracts without a corresponding manuscript were excluded. Studies that included infants with complicated gastroschisis were excluded.

Results

Question 1

Do standardized nutrition protocols facilitate earlier enteral feeding and improve outcomes?

Nine studies that evaluated uncomplicated gastroschisis were evaluated. Hobson et al. obtained survey data from NICU clinicians and reported the primary barriers to feeding protocol standardization in one NICU were (i) clinician-specific practice and (ii) an emphasis on gastric residuals to determine volume and timing of feeding advancements. Survey data of clinician practice were utilized to develop a gastroschisis-specific feeding protocol. Trophic feeds were introduced earlier, and residual volumes were ignored. The protocol appeared to facilitate faster discharge, without any increase in complications. The study concluded more comparative data are needed [10].

Table 1 illustrates eight studies that evaluated the impact of feeding protocol implementation on outcomes. Six documented outcomes after implementation of a specific feeding protocol [14–19]. Two reported outcomes after feeding protocols were implemented as part of broader clinical care pathways (Table 1) [20, 21].

One multicenter study compared outcomes of infants from eleven institutions that were fed with and without a protocol; no two protocols were identical (Table 1) [17].

Five of eight studies reported that the implementation of a feeding protocol resulted in significantly fewer days of TPN administration [14–16, 18, 21]. However, five studies

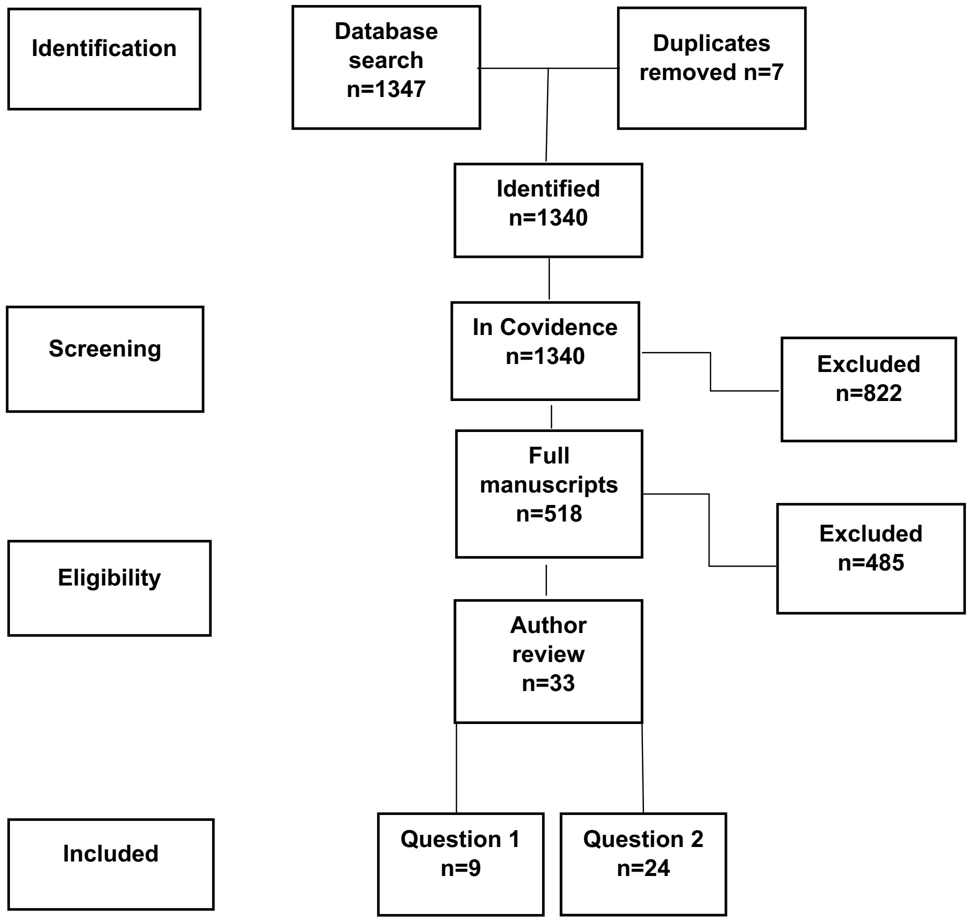

Fig. 1 Study selection and data extraction, articles selected between 1990 and 2022

also reported no significant decrease in LOS [14] [16, 17, 20, 21]. Three studies compared data from historical controls to prospective data from infants fed according to a prospective protocol [19–21].

One protocol commenced feeding volumes at 5 mL every 3 h, with advancement by 5 mL per day as tolerated until the volume of 30 mL was achieved. At 30 mL, approximating half-goal volume, infants were fed as tolerated. Advancement volumes of up to 30 mL/kg/day were considered compliant with the protocol. After protocol implementation, infants undergoing delayed defect closure achieved enteral feeds significantly faster ($P=0.04$) [19].

One protocol commenced breast milk or Pedialyte within 48 h after nonbilious gastric output was observed. Feeds were advanced at 20 ml/kg/day as tolerated, to goal. The time to initiate feeds was significantly reduced, but no change in LOS was observed [20].

Others commenced nasogastric tube clamping for three consecutive days after non-bilious output was observed [21]. When the total drainage was below 40 ml/day, feeds were initiated at 20 ml/kg/day and increased by 24 ml/kg/day until goal. The volume of 40 ml/day was arbitrary. Cisapride was administered in all infants and TPN was discontinued when the oral volume was 120 ml/kg/day [20]. No significant reduction in LOS was observed. However, the days of TPN administration were significantly reduced in the protocol group ($P=0.026$), as was the incidence of surgical site infections ($P=0.009$) [21]. It must be noted that Cisapride is not available in the United States, and therefore, the protocol may not generalize in its entirety.

Passaro et al. compared three protocols [14]. One advanced feeding volume by 12 ml/kg/day, one advanced by 12 ml/kg every 3 days, and one gastroschisis-specific protocol advanced by 12 ml/kg every 48 h until 50% of goal was met, after which, there were daily increases. The gastroschisis-specific protocol appeared to reduce practice variation. There were three cases of NEC in the first group (10%) with daily advancements and none in the gastroschisis-specific protocol group ($P<0.01$)[14].

With a protocol of cycling between increasingly longer intervals of increased human milk volume, and a shorter orogastric tube decompression time, Lemoine et al. reported improved outcomes such as a decreased time to initiate feeds, decreased LOS, and reduced sepsis incidence [15]. Like previous reports, the study demonstrated that early minimal enteral feeding and advancement at 12 ml/kg/day, at 5 days after closure, may improve outcomes by significantly reducing total days of TPN administration ($P=0.004$) [15].

Table 1 Comparison of feeding protocols for uncomplicated gastroschisis [14–21]

Author *N* LOE	Method comparative groups	Feeding protocol	Outcomes	Data median	*P* value	Conclusions
DeUgarte et al. [20] *N* = 238 MULTICENTER LOE II/III	Prospective 2015–2018 (*N* = 70) vs. Historical controls 2007–2012 (*N* = 168)	Initiate feeds ≤ 48 h after gastric output nonbilious Breast milk if available (or Pedialyte®) Aim to advance by 20 cc/kg/day as tolerated	Time to full feeds (days) LOS (days)	9 vs. 8.5 29 vs. 28	0.94 0.70	LOS and time to feed not impacted Protocol demonstrated reduction of: 1. Ventilator days 2. Anesthesia 3. Antibiotics 4. Opioids (Table 2) Intrinsic intestinal dysmotility is rate limiting factor to establish feeds
Zalles-Vidal et al. [21] **N = 92** SINGLE CENTER LOE III	Prospective 2014–2016, (*N* = 46) vs. 2010–2014(*N* = 46)	Output non-bilious, clamp NG for 3 days Output < 40 cc/day, start at 20 cc/kg/day and advance 24 cc/kg/day to goal Cisapride in all D/C TPN when 120 cc/kg/day tolerated	TPN (days) LOS (days)	27 vs. 21 41 vs. 32	**0.026** (NPO time-unchanged) 0.146	LOS not impacted Protocol demonstrated reduction of: 1. Ventilator days 2. Anesthesia 3.TPN days 4. Sepsis 5. Mortality (Table 2)
Passaro et al. [14] **N = 60** RETROSPECTIVE LOE III	2009–2013 1 day advance (*N* = 29) 3 day advance (n=14)vs.2013-2015Gastroschisis specific feeding protocol (n=17)	2009–2013 1 ml q3h for 3 days, then continuous feed, advance by 12 ml/kg q3 days. < 1500 g: continuous > 1500 g: consider bolus vs. 2013–2015 GS specific-advance 12 ml/kg every 48 h to 50% of goal, then advance daily by same volume	Time to full feeds (days) NEC Weight gain (g) LOS (days) Guideline adherence (%)	GS spec-18 days 3/29 (10%) vs. 0 72 vs 94	**0.01** NS NS **< 0.01**	LOS and weight gain not impacted 2013–2015 GS specific protocol: 1.Reduced variation in median time to full feeds 2. Zero NEC 3.Guideline adherence-significantly better with the GS-specific protocol
Lemoine et al. [15] **N = 32** RETROSPECTIVE LOE III	2010–2012 vs. 2007–2009	New early feeding protocol introduced in 2010 and compared to traditional feeding (clinician variation)	Time to full feeds (days) Time to first feed (days) LOS (days) Sepsis (*n* %)		**< 0.001** 0.72 **0.022** **0.036**	1.Time to achieve full enteral feedings, not the timing of feed initiation, associated with significantly reduced LOS 2.Sepsis reduced

Table 1 (continued)

Author *N* LOE	Method comparative groups	Feeding protocol	Outcomes	Data median	*P* value	Conclusions
Walter, Nicolet et al. [16] **N = 73** MULTIVARIATE ANALYSIS Prospective case control LOE III	Prospective case control Prospective (n = 22) vs.Historical controls (n = 51)	Early Minimal Enteral Feeds (MEF)—feed 5 days after closure, 12 ml/kg/day vs. Historical group (feed at ileus resolution–clinician specific)	TPN (% TPN dc by day 60)	100 vs. 30	**0.004**	Multivariate analysis Nutritional protocol-independent association with reduced TPN days **(P = 0.04)**
			LOS (days)	40 vs 54.5	0.08	
			Time to first feed (days)	5 vs 11.5	**0.005**	
			Sepsis (n,%)	9 vs. 40	**0.016**	
Dekonenko et al. [17] **N = 315** MULTICENTER RETROSPECTIVE LOE III	Protocol group *N* = 204 vs. No Protocol *N* = 111 SUBGROUP ANALYSIS (Immediate vs. delayed closure and Sutured vs. sutureless closure)	Feeding protocols from 11 Midwest Children's Hospitals None were identical	TPN (days)	NS		SUBGROUP ANALYSIS 1. Fewer SSIs occurred in infants fed with an institution-based feeding protocol, undergoing a sutured closure 2. Other outcomes NS 3. Time to full feeds NS
			Time to first feed (days)	NS		
			Time to full feeds (days)	NS		
			LOS (days)	NS		
			SSI incidence (%)	9 vs. 19	**P=0.026**	
Utria et al. [18] **N = 74** SINGLE CENTER RETROSPECTIVE MULTIVARIATE ANALYSIS LOE III	2012–2020 50 vs. 24 Compared in same time period	Advance: 10 ml/kg/day vs. 20 ml/kg/day	TPN (med days)	22 vs. 29	**P=0.001**	20 ml/kg/day feeding advancements 1.Safe 2.Faster attainment of goal feeds **3.Shorter LOS** 4.Trend toward cost savings ADD A ROW BELOW THIS ROW- SEE COMMENTS
			LOS (med days)	30 vs. 36	**P=0.001**	
			Time to full feeds (med days)	14 vs. 20	**P=0.001**	
			Age at goal feeds (med days)	26 vs. 34	**P=0.001**	
Gilliam et al.19 **N =47** SINGLE CENTER RETROSPECTIVE LOE III	2012-2014 2014-2015 22 vs. 25	Protocol: Orogastric tube removed when output <20cc/kg/day Commence 5ml q3h, advance 5ml/day to 30ml/kg/day	LOS (med days)	28 v. 30	P=0.31	1.Significant decrease in time to full feeds for infants with delayed closure. 2.Achieved full feeds about a week earlier than delayed closure patients in the control group 3.Comparable with time to full feeds in primary closure infants
			Time to full feeds (med days)	9.1 v. 12.1	P=0.13	
			Time to full feeds for delayed closure (med days)	9 v. 15	**P=0.04**	
			Time to initiate feeds (med days)	16.1 v.19.9	P=0.14	

A multicenter study of eleven institutions compared infants fed with any institution-specific protocol to infants fed without adherence to a specific protocol. Subgroup analysis of closure technique found a significant decrease in surgical site infections in those fed according to any institutional protocol undergoing a sutured closure ($p = 0.026$). No significant differences in any other specified outcomes were identified (Table 1) [17].

Question 1—section summary and recommendations

Do standardized nutrition protocols facilitate early enteral feeding and improve outcomes?

- For uncomplicated gastroschisis, feeding protocols, and broader clinical care pathways that include a feeding protocol, may standardize intestinal feeding, and reduce the total days of TPN administration.
- Volume increases of 12–30 ml/kg, advanced every 24–48 h, may promote feeding tolerance and reduce necrotizing enterocolitis incidence.
- For infants undergoing delayed closure, implementation of a feeding protocol was associated with significantly more rapid achievement of full enteral feeds.

Grade C Recommendation supported by Levels III and IV evidence.

Question 2

Have any postnatal management strategies demonstrated superior outcomes such as reduced hospital stay, anesthesia and mechanical ventilation use, infection incidence and mortality rates?

Twenty-four manuscripts were reviewed that examined the following postnatal management strategies: i. monitoring during gastroschisis closure, ii. implementation of a dedicated care team and care protocol, iii. hospital volume, and iv. use of anesthesia, opioids, and fluids.

i. Monitoring during closure

The impact on outcomes of two categories of monitoring strategies to guide abdominal wall closure and prevent abdominal compartment syndrome were examined: (i) bladder pressure monitoring and (ii) evaluation of bowel perfusion and/or motility.

(i) Bladder pressure monitoring

One animal study, and one human study, demonstrated visceral and renal blood flow were preserved if intra-abdominal pressure remains below 20 mmHg or 20 cm H20 [20, 23]. Based on these reports, two institutions instituted protocols to measure bladder pressure in the operating room during management of uncomplicated gastroschisis and proceed with closure if the pressure remained below these respective measurements [24, 25].

Olesevich reported outcomes from an uncontrolled, descriptive, prospective study [24]. Thirty-three (79%) neonates with a mean bladder pressure of 16 mm Hg underwent primary closure and were compared to 9 with a mean of 27 mm Hg that underwent delayed closure with a non-spring-loaded silo. Patients treated with primary closure demonstrated a faster return to full feeds and a significantly shorter LOS compared to infants treated by delayed closure ($P = 0.04$). All infants required only one definitive surgical procedure with no subsequent manipulations [24].

An intraoperative bladder pressure below 20 cm H20 was used to determine primary or staged closure in a cohort of 45 newborns with gastroschisis and reviewed retrospectively [25]. In 24(53.3%), delayed primary closure was achieved, while the remaining 21(46.7%) underwent staged reduction and closure. No significant differences in the frequency of complications, time to commence oral feeding, infection rates, total days of TPN or LOS were identified. The average incidence of oliguria or anuria was similar in each group (33%) [25].

Two reports describe that a bladder pressure threshold of 20 mmHg or 20 cm H20 may successfully guide timing, frequency, extent of silo reduction and use of a prosthetic patch for infants undergoing staged closure. Complications such as bowel necrosis and prolonged oliguric renal failure were avoided [24, 25].

(ii) Bowel Perfusion

Visceral perfusion has been evaluated as a method to assist gastroschisis closure. In 1996, Pistor et al. used intraoperative ultrasound to ensure < 50% vena cava lumen compression during closure [26]. This metric guided the use of a biologic patch. Others measured intragastric pressure with the same technique used to measure bladder pressure and found that a splanchnic perfusion pressure (mean arterial blood pressure—intragastric pressure) of > 43 mmHg determined that a primary closure is feasible with > 90% specificity [27].

Williams performed a prospective observational study of 23 infants and employed magnetic resonance imaging (MRI) to assess motility and superior mesenteric artery (SMA) flow [28]. Images were obtained at abdominal wall closure, initiation of feeds, and achievement of full feeds. The study reported that increased SMA flow at the time of closure significantly correlated with earlier establishment of full intestinal feeds. An MRI has limited clinical application. However, the study findings suggest a less cumbersome method such as ultrasound, may confirm perfusion and motility, and, therefore, guide feeding success [28].

Another feasibility study assessed intestinal motility in gastroschisis patients using ultrasound [29]. The authors used daily bedside, real-time ultrasound to document peristalsis. Full intestinal motility was defined as observation of peristalsis in all four abdominal quadrants. The primary care team was blinded to the ultrasound results and determined feeding initiation by traditional clinical criteria. Initiation of feeds based solely on clinical indicators of bowel function, was significantly delayed by three full days when compared to initiation based on ultrasound documented motility [29].

ii. Dedicated care team/standardized clinical care protocol

Seven studies examined the benefit of a specialized care team for simple gastroschisis [20, 21, 30–34]. Wide institutional variability was observed. Each study hypothesized that standardized care should improve outcomes.

Gover et al. defined a multidisciplinary care team as three or more disciplines (e.g., neonatology, surgery, gastroenterology) involved in weekly rounds for uncomplicated gastroschisis infants, before the initiation of feeds [30]. This comparative study of 396 gastroschisis infants documented those managed by the care team had significantly longer duration of parenteral nutrition and LOS. The paradoxical findings were attributed to overall improved survival of a greater number of high-risk infants [30].

Five studies [20, 21, 31, 32, 34] documented improved outcomes when standardized care protocols were implemented for simple gastroschisis (Table 2). The outcomes included significant reduction in anesthesia use, silo days, LOS, use and duration of mechanical ventilation, antibiotics, sepsis/surgical site infection, TPN duration, time to initiate feeds, and mortality. No impact on surgical complications, average per-patient costs, central catheter days, or cholestasis was found.

In one study of combined data from two administrative databases, the proportion of sutureless bedside closures increased significantly after implementation of a clinical care protocol. (32.5% between 2008 and 2011, $N=53$ vs. 71.0% between 2015 and 2019, $N=43$, $P<0.01$). Median time for post procedure mechanical ventilation decreased significantly from 4 to 2 days ($P<0.01$). However, the duration of TPN administration was not significantly reduced [34].

Because comparative studies are limited, Baird proposed the methodology of evidence-based practice improvement in quality (EPIQ) and plan–do–study–act (PDSA) cycles to replace randomized controlled trials (RCTs) [33]. Mansfield adapted the recommendation and utilized quality improvement methodology with statistical process control charts and subgroup analysis to evaluate specific endpoints at one institution [31]. After implementation of a best practice protocol, length of hospital stay was decreased by 5 days in a prospective cohort ($N=94$) as compared to historical controls ($N=25$). These methods may represent realistic approaches to optimize gastroschisis care given the challenges of comparative study design.

iii. Hospital volume

Two studies addressed whether hospital volume impacts uncomplicated gastroschisis outcomes [35, 36]. Definitions of high, medium, and low-volume centers vary, but most define low as < 5, medium as between 5 and 9, and high as > 9 cases annually [33, 35]. Youssef analyzed the CAPSNet database and included only infants with uncomplicated gastroschisis born between 2005 and 2013. Infants with atresia, perforation or necrosis at birth were defined as complicated and were excluded [35]. Data for CAPSNet is collected prospectively and analyzed retrospectively. The report found that hospitals with a moderate volume of cases (3–9) per year had a slight outcome advantage over high volume hospitals (> 9 cases per year) with reduced TPN days of less than the median of 24 days [OR 0.59(0.38–0.92), $P=0.02$], and a shorter hospital stay of less than the median of 34 days [OR 0.61 (0.40–0.93), $P=0.02$]. Overall survival was above 96% [35].

Gonzalez analyzed the Pediatric Health Information System database between 2005 and 2013. After subtracting complicated cases, a subset of 3533 uncomplicated cases were included [36]. Infants who underwent early closure (within 1 day of birth) were compared to delayed closure defined as closure after the first day of life. When controlling for hospital volume, the report found that uncomplicated infants with

Table 2 Comparison of standardized care protocols for uncomplicated gastroschisis

	Mansfield et al. [31]		Zalles-Vidal et al. [21]		Haddock et al. [32] (contemporaneous)		DeUgarte et al. [20]	
Comparative groups Protocol vs. controls	2010–2016 $N = 94$ vs. 2008–2010 $N = 25$		2014–2016 $N = 46$ vs. 2010–2014 $N = 46$		2012–2016 $N = 24$ vs. $N = 33$		2015–2018 $N = 70$ vs. 2007–2012 $N = 168$	
LOE	III		III		III		II/III	
Comparison of outcomes impacted by protocol implementation								
TPN (median days)	Not evaluated		27 vs. 21	**P = 0.026**	29 vs. 32	$P = 0.86$	Not evaluated	
Antibiotics (median days)	Not significant (data not shown)		Not evaluated		Not evaluated		9–5.5	**P = 0.01**
In hospital mortality (%)	Not reported		22 vs. 2	**P=0.007**	Not reported		Not reported	
Sepsis incidence (%)	NS (data not shown)		70 vs. 37	**P = 0.003**	SSI 21 vs. 8	P = 0.30	Not evaluated	
Ventilator (Median days)	5 vs. 2	**0.01**	14 vs. 3	**P = 0.001**	4 vs. 1	**P < 0.001**	5 vs. 2	**P < 0.01**
Anesthesia use (%)	**Not evaluated**		100 vs. 57	**P = 0.001**	100 vs. 52	**P < 0.001**	Changed fascia to skin closure 78 vs. 22	**P < 0.001**
Opioid use (%)	NS (data not shown)		Not evaluated		Opioid plan was part of PDSA cycle and was reduced		65 vs. 50	P = 0.30
Time to goal feeds (median days)	33 vs. 22	**P = 0.017**	24.5 vs. 20	$P = 0.250$	28 vs. 31	$P = 0.85$	9 vs. 8.5	P = 0.94
LOS (median days)	34 vs. 29	P = 0.160	41 vs. 32	$P = 0.146$	40 vs. 39	$P = 0.73$	29 vs. 28	P = 0.70
LOS (median days) Subgroup analysis by closure type	Bedside silo or primary 42 vs. 38	**P = 0.010**	Silo w or without protocol 15 vs. 4.5	**P = 0.001**	Not evaluated		27 vs. 28	P = 0.63
Comparison of protocols								
Preferred delivery	Vaginal, ≥ 37 weeks, C-section for obstetrical indications only, level III NICU		Outborn protocol*		Not described		Inborn	
IV fluids	20 mL/kg NS bolus followed by D5(0.2)NS at 2X maintenance, 1:1 replacement of OGT losses		Start pre-transport: D10W 100–120 mL/kg/day, additional fluids given only for clinical hypovolemia; only maintenance fluids given thereafter		D10NS 100 mL/kg/h (they must mean per day not per hour)		Not described	
Initial defect coverage	Plastic bowel bag up to the axillae		Plastic bowel bag coverage		Plastic bowel bag up to the axillae		Not described	

Table 2 (continued)

	Mansfield et al. [31]	Zalles-Vidal et al. [21]	Haddock et al. [32] (contemporaneous)	DeUgarte et al. [20]
Routine antibiotics	Signs of sepsis: Amp + Gent started, continued until 48 h post-silo placement or post-closure; Routine delivery: 1st 48 h after delivery + cefoxitin periop × 3 doses (two differing protocols described in the same paper)	At delivery: Amp + Amikacin continued until abdominal closure achieved, then as dictated by infectious disease team	Two pathways: (1) No risk of Early Onset Sepsis (EOS) and low risk bowel injury—cloxacillin + tobramycin/gentamicin while silo in situ (2) risk of EOS and/or high-risk bowel injury—Amp + tobramycin/gentamicin + cloxacillin while silo in situ, Amp continued as dictated by need to cover EOS; routine antibiotics discontinued 48 h post-closure	No signs of sepsis: Amp + Gent, discontinue ≤ 48 h after abdominal closure in absence of sepsis/instability
Orogastric tube	Place immediately, LCWS	Place 10–12 Fr OGT at referring institution	Place immediately	Have in place for bedside silo placement, suction manually during bowel reduction
Initial reduction/procedure	Silo placed in NICU or OR (surgeon choice; practice shifted to bedside silo)	Bedside in NICU, no anesthesia	Bedside in NICU, up to 3 boluses of IV morphine 50 µcg/kg/dose	Bedside in NICU, no anesthesia when feasible
Reduction device	Preformed silo	Preformed silo	Not described (likely preformed silo based on previous publication)	Preformed silo (implied)
Reduction frequency	1–3 times per day	Not described	Not described	Not described
Adjunctive procedures	Not described	Saline enema to decompress colon	Standardized techniques of silo placement, umbilical cord protection, visceral reduction, and cord flap closure (not specifically described in manuscript); "gastroschisis cart" maintained in NICU	If silo used, closure within 3 days when feasible; recommend gastric and rectal decompression strategies to facilitate reduction
Preferred closure technique	Practice shifted to bedside silo placement followed by secondary fascial closure in OR	Sutureless at bedside	Sutureless at bedside	Sutureless at bedside
Use of mechanical ventilation	Only in cases of respiratory distress	Only in cases of respiratory distress	Maintain spontaneous ventilation whenever possible	Routine intubation not recommended
Preferred central access	PICC placed within 24-48 h postop, remove when tolerating 120 mL/kg/d enterally	PICC on arrival to NICU	PICC within 24 h of NICU admission	PICC preferred, remove when tolerating 100 mL/kg/d enterally
OGT management	Off suction when output clear (regardless of volume), then removed 24 h later if no emesis	Progressive orogastric tube clamping if drainage ≤ 40 mL/day regardless of fluid character	Not described	Have in place for bedside silo placement, suctioned manually during reduction of bowel

Table 2 (continued)

	Mansfield et al. [31]	Zalles-Vidal et al. [21]	Haddock et al. [32] (contemporaneous)	DeUgarte et al. [20]
Nutrition management	TPN started on DOL 1 or 2, EBM (preferred) or formula feeds start at 20 mL/kg/d, advanced by 20 mL/kg/d as tolerated	Early TPN (as soon as possible), progressive enteral feeding, starting 3 days after progressive OGT clamping, EBM (preferred) start at 20 mL/kg/d, advanced by 24 mL/kg/d as tolerated, TPN discontinued when tolerating 120 mL/kg/d enterally	Not described	Encourage oral-care protocol with colostrum/EBM at least 4X/d; initiate feeds ≤ 48 h after gastric output becomes nonbilious; EBM preferred; advance by 20 mL/kg/d as tolerated
Analgesia	IV fentanyl + oral sucrose for silo placement and reductions; rectal acetaminophen x 48 h after procedures + morphine intermittent/Infusion depending on degree of tension of fascial closure	Acetaminophen and morphine used for procedures	Up to 3 boluses of IV morphine 50 µcg/kg/dose during silo application, otherwise not described	Recommend no narcotics; discontinue opioids ≤ 48 h after abdominal closure; oral sucrose for silo placement, reduction, and closure; if opioids are used during silo placement or closure, limit to a single dose when feasible to prevent apnea and intubation
Paralysis	Not described	None used	Not described	Not recommended
Other	None	Cisapride used in all patients after ruling out cardiac rhythm anomalies; if OGT output > 40 mL/kg/d x > 2 weeks after closure, water soluble contrast enema performed to rule out atresia	None	For bedside silo placement/closure, recommend placing peripheral IV, pulse oximeter, nasal cannula, and OGT

delayed closure had a significantly longer duration of TPN and hospital stay ($P < 0.05$) [36].

Infants with complicated gastroschisis frequently have a significantly longer hospital stay and higher inpatient mortality [37]. A systematic review by Morche followed PRISMA guidelines and evaluated the outcomes of large database studies that included both complicated and uncomplicated infants [33, 38–44]. When complicated cases are included in outcome analysis, high volume hospitals may have a lower mortality rate. However, the systematic review found no article that examines the impact of surgeon-specific volume [38].

iv. Anesthesia, Opioids, Fluids

Bianchi and Dickson proposed in 1998, and further reported in 2002, their experience with the "minimalist approach" whereby anesthesia and paralysis are avoided for gastroschisis infants [45, 46]. While these initial studies demonstrated that such an approach was feasible, comparison groups were not included. In 2012, van Manen et al. studied 79 infants who received pre-closure paralysis versus 88 who received none [47]. Infants receiving paralysis required an average of three extra days to achieve closure (8 vs. 5 days; $P < 0.001$) and required significantly more days of mechanical ventilation (12 vs. 7 days; $P < 0.001$). The relationship between paralysis and days to closure remained after adjusting for other variables [47]. Subsequent reports, including the studies described in the immediately preceding section, document similar findings that avoidance of anesthesia and paralysis were associated with reduced days of mechanical ventilation [20, 32] and improved resource utilization with no impact on LOS (Table 2) [20, 21].

Opioid minimization is a component of modern gastroschisis care; however, few studies have directly evaluated the long-term impact of opioids on gastroschisis outcomes. Significant variation in opioid administration prior to fascial closure is reported [48].

Opioid administration has been identified as a risk factor for prolonged mechanical ventilation for neonates after intestinal surgeries including gastroschisis closure [49]. Twenty-two GS infants were compared to 191 infants with 5 other conditions undergoing operation. The GS infants had the longest median duration of opioid administration of 9 days which was 2 days longer than infants undergoing operation for NEC (median:7 days) [49]. Gastroschisis infants may receive a longer duration of opioid administration than other neonatal intestinal conditions that require surgery, but it remains unclear whether the practice is beneficial or necessary. An observational study of 48 infants reported 22(45.8%) that received a local anesthetic block had a significant reduction in the need for postoperative ventilation ($P < 0.05$) [50]. The difference was observed in both term and preterm infants.

One evaluation of quality of life with a 6-year follow-up, found that gastroschisis infants who received an overall longer duration of opioids had lower scores in the "communication" and "problem solving" items of a validated developmental assessment tool [51].

Between 2010 and 2014, Bonasso et al. examined the total volume of intravenous fluid administered in a cohort of 24 gastroschisis infants [52]. The study documented that regardless of closure approach (primary versus staged), gastroschisis infants received fluids more than required of typical newborns, with correspondingly excessive urine output. In addition, hyponatremia and hypoalbuminemia significantly correlated with increased days of mechanical ventilation [53]. These studies, while only descriptive, support the concept that infant perfusion requires frequent evaluation. Fluid administration should be goal-directed and correlate to volumes that maintain adequate organ perfusion.

Question 2—section summary and recommendations

Have any postnatal management strategies demonstrated superior outcomes such as shorter hospital stay, reduced use of mechanical ventilation, and fewer infections?

i. Monitoring techniques

- Monitoring techniques such as maintaining bladder pressure below 20 mm Hg or 20 cm H20 during operative closure exist. The measurements may select infants with adequate abdominal domain and, therefore, guide an uncomplicated primary closure. Ultrasound assessment of intestinal motility and perfusion to guide feeding initiation are reported. However, no prospective comparative studies were found for any monitoring technique.

  No recommendation for monitoring can be made from the available literature.

ii. Use of a dedicated care team and protocol

- Superior outcomes such as shorter hospital stay, reduced use of mechanical ventilation, and fewer infections are often achieved when a dedicated care team and protocol are implemented. Use of a standardized gastroschisis management protocol is recommended.

Grade C recommendation supported by Level III Evidence.

iii. Hospital volume

- No recommendation for minimal volume of patients to improve outcomes can be made from available literature.

iv. Use of anesthesia, opioids, and fluids

- Avoid anesthesia and paralysis when feasible.
- Specific goal-directed use of fluids, and reduced opioid administration, may decrease use of anesthesia and mechanical ventilation, and are recommended.

Grade D recommendation supported by Level III–IV evidence.

Discussion

For infants with uncomplicated gastroschisis, prematurity and lower birth weight are known significant independent predictors of a longer hospital stay [54]. In addition, examination of the literature by the APSA OEBPC found the implementation of a standardized feeding protocol significantly reduces the time to introduction of enteral feeds and decreases overall TPN administration. This finding was consistent across studies. However, the length of hospital stay was not consistently reduced. Some hypothesize that the inherent intestinal inflammation of gastroschisis remains a rate-limiting factor in achieving full enteral feeds and is not consistently overcome with implementation of a feeding protocol [29].

In contrast, for uncomplicated gastroschisis infants undergoing primary repair, a nutritional protocol that incorporated 20 ml/kg/day feeding advancements resulted in faster attainment of goal feeds and a shorter hospital stay [18]. For infants undergoing delayed closure, protocolized feeding promoted significantly earlier attainment of full enteral feeds [55]. This recommendation is applicable to daily practice in NICUs that care for uncomplicated gastroschisis infants. Further studies are needed to identify modifiable barriers to feeding that may promote early discharge for gastroschisis infants.

The implementation of a standardized gastroschisis clinical care team and care protocol are recommended because superior outcomes such as shorter hospital stay, reduced use of mechanical ventilation, fewer infections, and reduced mortality rates are achieved. Interventions within the care protocol which may decrease hospital stay include (i) avoidance of anesthesia and paralytics around the time of closure, (ii) goal-directed fluid administration, and (iii) minimal opioid exposure. Reduction in opioid use to improve gastroschisis outcomes is a modifiable practice that warrants further evaluation within care protocols.

No recommendations can be made for use of specific monitoring techniques at closure or minimal patient volume to improve outcomes, as no comparative studies were identified. The benefits of high-volume hospitals, which may be important for some complex pediatric surgery diagnoses, are not yet well-defined for treatment of uncomplicated gastroschisis.

The development of evidence-based guidelines for uncomplicated gastroschisis postnatal management, is complicated by a lack of comparative data [56]. One consistent limitation of studies that evaluate feeding protocols and clinical care strategies is the comparison of prospective data to historical controls. These studies must be interpreted with caution as neonatal critical care, feeding implementation, and parenteral nutrition formulations were refined over time, and likely contribute to outcome differences [57].

Similarly, the examination of the impact of minimal patient volume on outcomes had several limitations. Patient factors such as the severity of the bowel findings may contribute to the results but are difficult to characterize and analyze. Infants with greater abdominal domain, better intestinal condition, higher gestational age, fewer signs of infection and a stable cardiopulmonary status may remain at lower volume hospitals. High-volume centers may accept transfers of more complex patients and change the cohort. Large studies of administrative databases did not consistently demonstrate improved gastroschisis outcomes at high volume hospitals and often include complicated cases in the analysis. For all factors, studies that rely on large databases have the inherent limitations of inaccurate or missing information. Some data points rely on clinician-specific evaluation and its inherent bias.

For both recommendations, the results of guideline implementation through future case control comparison of uncomplicated gastroschisis infants with infants of similar gestational age and weight is warranted. Prospective outcomes data collection from the recommendations should include time of TPN administration, length of hospital stay, cost, mortality, infection incidence, fluid administration, opioid dosing, use of anesthesia and mechanical ventilation, and necrotizing enterocolitis incidence. Others promote a gastroschisis core outcome set that also includes growth, number of operations, liver disease, number of severe gastrointestinal complications and a quality of life evaluation [58]. The use of quality improvement methodology to study gastroschisis outcomes warrants further evaluation to address the barriers to randomization.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00383-024-05819-5.

Acknowledgements The American Pediatric Surgical Association Outcomes and Evidence-based Practice Committee: Division of Pediatric Surgery, Penn. State Children's Hospital, Hershey, PA, USA (Afif N. Kulaylat), Division of Pediatric Surgery, Joe DiMaggio Children's Hospital, Hollywood, FL, USA (Tamar L. Levene), Division of Pediatric Surgery, Naval Medical Center San Diego, CA, USA, Department of Surgery, F. Edward Hebert School of Medicine, Uniformed Services University, Bethesda, MD, USA (Donald J. Lucas), Division of Pediatric Surgery, Nationwide Children's Hospital, Columbus, OH, USA (Sara A. Mansfield), Division of Pediatric Surgery, Children's Mercy Hospital, University of Missouri-Kansas City, Kansas City, MO, USA (Rebecca M. Rentea), Department of Surgery, Mayo Clinic, Rochester, MN, USA (Stephanie F. Polites), Department of Surgery, Texas Children's Hospital, Baylor College of Medicine, Houston, TX, USA (Kristy L. Rialon), Division of Pediatric Surgery, Greenville Memorial Hospital, University of South Carolina, Greenville, USA (Robert L. Ricca), Division of Pediatric Surgery, University of Utah, Salt Lake City, UT, USA (Katie W. Russell), Division of Pediatric Surgery, Children's Hospital of Richmond at Virginia Commonwealth University, Richmond, VA, USA (Jason P. Sulkowski), Division of Pediatric Surgery, Hassenfeld Children's Hospital at NYU Langone Health, New York, NY, USA (Jun Tashiro), Division of Pediatric Surgery, University of Rochester, Rochester, NY, USA (Derek Wakeman), Harvey E. Beardmore Division of Pediatric Surgery, The Montreal Children's Hospital, McGill University Health Centre, Montreal, Canada (Yasmine Yousef), Johns Hopkins All Children's Hospital, 501 6th Avenue South, St. Petersburg, FL, USA (Henry Chang), University of Maryland Medical Center, 22 S. Greene St, Baltimore, MD, USA (Brian Englum), St. Lukes Children's Surgery, 305 E Jefferson St, Boise, ID, USA (Katherine Gonzalez), Section of Pediatric Surgery, C.S. Mott Children's Hospital, 1540 E Hospital Dr, Ann Arbor, MI, USA (Elizabeth Speck), Pediatric Surgery Division, Children's Hospital Colorado, University of Colorado School of Medicine, 13123 East 16th Avenue, Aurora, CO, USA (Sarkis Darderian), Pediatric Surgery Division, Children's Hospital Colorado, University of Colorado School of Medicine, 13123 East 16th Avenue, Aurora, CO, USA (Shannon Acker), Pediatric Surgery Division, Children's Mercy Hospital, 2401 Gillham Road, Kansas City, MO (Shawn St. Peter), Pediatric Surgery Division, Children's Hospital, 4650 W Sunset Blvd, Los Angeles, CA, USA (Lorraine Kelley-Quon), Division of Pediatric General Surgery, Department of Surgery, Faculty of Medicine, University of British Columbia, Vancouver, 2775 Laurel Street, 11th Floor, Vancouver, British Columbia, Canada (Robert Baird), Division of Pediatric Surgery, St. Christopher's Hospital for Children, 160 E Erie Ave, Philadelphia, PA, USA (Alana L. Beres), Yale University School of Medicine, Yale New Haven Children's Hospital, 1 Park Street, New Haven, CT, USA (Emily Christison-Lagay), Division of Pediatric Surgery, University of Texas Southwestern; Children's Health Dallas, Dallas, TX, USA (Diana Diesen), Jacobs School of Medicine, University at Buffalo, John R. Oishei Children's Hospital, 818 Ellicott St, Buffalo, NY, USA (P. Benson Ham III), University of Miami, DeWitt Daughtry Department of Surgery, 1601 NW 12th Ave, Miami, FL, USA (Carlos T. Huerta).

Author contributions Joanne Baerg (JB), Jarod McAteer (JM), Doug Miniati (DM), Stig Somme (SS), Mark Slidell MD (MS). Study conception and design: JB, JM, DM, SS, and MS. JB prepared Fig. 1. Acquisition of data: JB, JM, DM, SS, and MS analysis and interpretation of data: JB, JM, DM, SS, and MS drafting of manuscript: JB, JM, DM, SS, MS. JB and MS wrote the main manuscript text. Editing of manuscript: all listed authors of APSA Outcomes and Evidence-based Practice Committee All authors approved the final manuscript. There was no funding support for guideline development.

Funding There was no funding support for guideline development.

Data availability No data sets were generated or analysed during the current study.

Declarations

Competing interests All authors and APSA OEBPC members indicated no conflict of interest that could impact recommendations, and no financial or non-financial competing interests.

References

1. Sydorak RM, Nijagal A, Sbragia L et al (2002) Gastroschisis: small hole, big cost. J Pediatr Surg 37:1669–1672. https://doi.org/10.1053/jpsu.2002.36689
2. Baerg J, Kaban G, Tonita J et al (2003) Gastroschisis: a sixteen-year review. J Pediatr Surg 38:771–774. https://doi.org/10.1016/jpsu.2003.50164
3. Gupta R, Cabacungan ET (2018) Outcome of neonates with gastroschisis at different gestational ages using a national database. J Pediatr Surg 53:661–665. https://doi.org/10.1016/j.jpedsurg.2017.07.015
4. Brebner A, Czuzoj-Shulman N, Abenhaim HA (2020) Prevalence and predictors of mortality in gastroschisis: a population-based study of 4803 cases in the USA. J Matern Fetal Neonatal Med 33:1725–1731. https://doi.org/10.1080/14767058.2018.1529163
5. Puligandla PS, Baird R, Skarsgard ED et al (2017) Outcome prediction in gastroschisis—the gastroschisis prognostic score (GPS) revisited. J Pediatr Surg 52:718–721. https://doi.org/10.1016/j.jpedsurg.2017.01.017
6. Mutanen A, Koivusalo A, Pakarinen M (2018) Complicated gastroschisis is associated with greater intestinal morbidity than gastroschisis or intestinal atresia alone. Eur J Pediatr Surg 28:495–501. https://doi.org/10.1055/s-0037-1607198
7. Molik KA, Gingalewski CA, West KW et al (2001) Gastroschisis: a plea for risk categorization. J Pediatr Surg 36:51–55. https://doi.org/10.1053/jpsu.2001.20004
8. Melov SJ, Tsang I, Cohen R et al (2018) Complexity of gastroschisis predicts outcome: epidemiology and experience in an Australian tertiary centre. BMC Pregnancy Childbirth 18:222. https://doi.org/10.1186/s12884-018-1867-1
9. Kassa AM, Lilja HE (2011) Predictors of postnatal outcome in neonates with gastroschisis. J Pediatr Surg 46:2108–2114. https://doi.org/10.1016/j.jpedsurg.2011.07.012
10. Hobson D, Spence K, Trivedi A, Thomas G (2019) Differences in attitudes to feeding post repair of Gastroschisis and development of a standardized feeding protocol. BMC Pediatr 19:475. https://doi.org/10.1186/s12887-019-1858-z
11. Harrison H, Griffin SJ, Kuhn I, Usher-Smith JA (2020) Software tools to support title and abstract screening for systematic reviews in healthcare: an evaluation. BMC Med Res Methodol 20:7. https://doi.org/10.1186/s12874-020-0897-3
12. Brouwers MC, Kerkvliet K, Spithoff K (2016) The AGREE reporting checklist: a tool to improve reporting of clinical practice guidelines. BMJ. https://doi.org/10.1136/bmj.i1152
13. Slim K, Nini E, Forestier D et al (2003) Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg 73:712–716. https://doi.org/10.1046/j.1445-2197.2003.02748.x
14. Passaro RC, Savoie KB, Huang EY (2018) Use of a gastroschisis feeding guideline to improve standardization of care and patient outcomes at an Urban Children's hospital. Nutr Clin Pract 33:545–552. https://doi.org/10.1002/ncp.10083

15. Lemoine JB, Smith RR, White D (2015) Got milk? Effects of early enteral feedings in patients with gastroschisis. Adv Neonatal Care 15:166–175. https://doi.org/10.1097/ANC.0000000000000171
16. Walter-Nicolet E, Rousseau V, Kieffer F et al (2009) Neonatal outcome of gastroschisis is mainly influenced by nutritional management. J Pediatr Gastroenterol Nutr 48:612–617. https://doi.org/10.1097/MPG.0b013e31818c5281
17. Dekonenko C, Fraser JD, Deans K et al (2022) Does use of a feeding protocol change outcomes in gastroschisis? A report from the midwest pediatric surgery consortium. Eur J Pediatr Surg 32:153–159. https://doi.org/10.1055/s-0040-1721074
18. Utria AF, Wong M, Faino A et al (2022) The role of feeding advancement strategy on length of stay and hospital costs in newborns with gastroschisis. J Pediatr Surg 57:356–359. https://doi.org/10.1016/j.jpedsurg.2021.04.011
19. Gilliam EA, Vu K, Rao P et al (2021) Minimizing variance in gastroschisis management leads to earlier full feeds in delayed closure. J Surg Res 257:537–544. https://doi.org/10.1016/j.jss.2020.07.072
20. DeUgarte DA, Calkins KL, Guner Y et al (2020) Adherence to and outcomes of a University-Consortium gastroschisis pathway. J Pediatr Surg 55:45–48. https://doi.org/10.1016/j.jpedsurg.2019.09.048
21. Zalles-Vidal C, Peñarrieta-Daher A, Bracho-Blanchet E et al (2018) A Gastroschisis bundle: effects of a quality improvement protocol on morbidity and mortality. J Pediatr Surg 53:2117–2122. https://doi.org/10.1016/j.jpedsurg.2018.06.014
22. Masey SA, Koehler RC, Ruck JR et al (1985) Effect of abdominal distension on central and regional hemodynamics in neonatal lambs. Pediatr Res 19:1244–1249. https://doi.org/10.1203/00006450-198512000-00004
23. Lacey SR, Carris LA, Beyer AJ, Azizkhan RG (1993) Bladder pressure monitoring significantly enhances care of infants with abdominal wall defects: a prospective clinical study. J Pediatr Surg 28:1370–1374. https://doi.org/10.1016/s0022-3468(05)80329-x
24. Olesevich M, Alexander F, Khan M, Cotman K (2005) Gastroschisis revisited: role of intraoperative measurement of abdominal pressure. J Pediatr Surg 40:789–792. https://doi.org/10.1016/j.jpedsurg.2005.01.043
25. Santos Schmidt AF, Goncalves A, Bustorff-Silva JM et al (2012) Monitoring intravesical pressure during gastroschisis closure. Does it help to decide between delayed primary or staged closure? J Matern Fetal Neonatal Med 25:1438–1441. https://doi.org/10.3109/14767058.2011.640366
26. Pistor G, Märzheuser-Brands S, Weber G, Streich R (1996) Intraoperative vascular assessment for estimation of risk in primary closure of omphalocele and gastroschisis. Pediatr Surg Int 11:86–90. https://doi.org/10.1007/BF00183732
27. McGuigan RM, Azarow KS (2004) Is splanchnic perfusion pressure more predictive of outcome than intragastric pressure in neonates with gastroschisis? Am J Surg 187:609–611. https://doi.org/10.1016/j.amjsurg.2004.01.008
28. Williams SL, Tkach JA, Rattan MS et al (2020) Feeding tolerance, intestinal motility, and superior mesenteric artery blood flow in infants with gastroschisis. Neonatology 117:95–101. https://doi.org/10.1159/000504226
29. Gurien LA, Wyrick DL, Dassinger MS et al (2017) Use of bedside abdominal ultrasound to confirm intestinal motility in neonates with gastroschisis: a feasibility study. J Pediatr Surg 52:715–717. https://doi.org/10.1016/j.jpedsurg.2017.01.018
30. Gover A, Albersheim S, Sherlock R et al (2014) Outcome of patients with gastroschisis managed with and without multidisciplinary teams in Canada. Paediatr Child Health 19:128–132
31. Mansfield SA, Ryshen G, Dail J et al (2018) Use of quality improvement (QI) methodology to decrease length of stay (LOS) for newborns with uncomplicated gastroschisis. J Pediatr Surg 53:1578–1583. https://doi.org/10.1016/j.jpedsurg.2017.11.061
32. Haddock C, Al Maawali AG, Ting J et al (2018) Impact of multidisciplinary standardization of care for gastroschisis: treatment, outcomes, and cost. J Pediatr Surg 53:892–897. https://doi.org/10.1016/j.jpedsurg.2018.02.013
33. Baird R, Eeson G, Safavi A et al (2011) Institutional practice and outcome variation in the management of congenital diaphragmatic hernia and gastroschisis in Canada: a report from the Canadian Pediatric Surgery Network. J Pediatr Surg 46:801–807. https://doi.org/10.1016/j.jpedsurg.2011.02.008
34. Joharifard S, Trudeau MO, Miyata S et al (2022) Implementing a standardized gastroschisis protocol significantly increases the rate of primary sutureless closure without compromising closure success or early clinical outcomes. J Pediatr Surg 57:12–17. https://doi.org/10.1016/j.jpedsurg.2021.09.022
35. Youssef F, Laberge J-M, Puligandla P et al (2017) Determinants of outcomes in patients with simple gastroschisis. J Pediatr Surg 52:710–714. https://doi.org/10.1016/j.jpedsurg.2017.01.019
36. Gonzalez DO, Cooper JN, St Peter SD et al (2018) Variability in outcomes after gastroschisis closure across U.S. children's hospitals. J Pediatr Surg 53:513–520. https://doi.org/10.1016/j.jpedsurg.2017.04.012
37. Abdullah F, Arnold MA, Nabaweesi R et al (2007) Gastroschisis in the United States 1988–2003: analysis and risk categorization of 4344 patients. J Perinatol 27:50–55. https://doi.org/10.1038/sj.jp.7211616
38. Morche J, Mathes T, Jacobs A et al (2022) Relationship between volume and outcome for gastroschisis: a systematic review. J Pediatr Surg 57:763–785. https://doi.org/10.1016/j.jpedsurg.2022.03.022
39. Hong CR, Fullerton BS, Han SM et al (2019) Impact of disease-specific volume and hospital transfer on outcomes in gastroschisis. J Pediatr Surg 54:65–69. https://doi.org/10.1016/j.jpedsurg.2018.10.034
40. Dubrovsky G, Sacks GD, Friedlander S, Lee S (2017) Understanding the relationship between hospital volume and patient outcomes for infants with gastroschisis. J Pediatr Surg 52:1977–1980. https://doi.org/10.1016/j.jpedsurg.2017.08.065
41. Sacks GD, Ulloa JG, Shew SB (2016) Is there a relationship between hospital volume and patient outcomes in gastroschisis repair? J Pediatr Surg 51:1650–1654. https://doi.org/10.1016/j.jpedsurg.2016.04.009
42. Apfeld JC, Kastenberg ZJ, Sylvester KG, Lee HC (2017) The effect of level of care on gastroschisis outcomes. J Pediatr 190:79-84.e1. https://doi.org/10.1016/j.jpeds.2017.07.008
43. Stanger J, Mohajerani N, Skarsgard ED (2014) Practice variation in gastroschisis: factors influencing closure technique. J Pediatr Surg 49:720–723. https://doi.org/10.1016/j.jpedsurg.2014.02.066
44. Sømme S, Shahi N, McLeod L et al (2019) Neonatal surgery in low- vs. high-volume institutions: a KID inpatient database outcomes and cost study after repair of congenital diaphragmatic hernia, esophageal atresia, and gastroschisis. Pediatr Surg Int 35:1293–1300. https://doi.org/10.1007/s00383-019-04525-x
45. Bianchi A, Dickson AP (1998) Elective delayed reduction and no anesthesia: "minimal intervention management" for gastrochisis. J Pediatr Surg 33:1338–1340. https://doi.org/10.1016/s0022-3468(98)90002-1
46. Bianchi A, Dickson AP, Alizai NK (2002) Elective delayed midgut reduction-No anesthesia for gastroschisis: selection and conversion criteria. J Pediatr Surg 37:1334–1336. https://doi.org/10.1053/jpsu.2002.35003

47. van Manen M, Bratu I, Narvey M et al (2012) Use of paralysis in silo-assisted closure of gastroschisis. J Pediatr 161:125–8.e1. https://doi.org/10.1016/j.jpeds.2011.12.043
48. Li LT, Hebballi NB, Reynolds EW et al (2021) Variation in opioid utilization among neonates with gastroschisis. J Pediatr Surg 56:1113–1116. https://doi.org/10.1016/j.jpedsurg.2021.03.030
49. Wang H, Gauda EB, Chiu PPL, Moore AM (2022) Risk factors for prolonged mechanical ventilation in neonates following gastrointestinal surgery. Transl Pediatr 11:617–624. https://doi.org/10.21037/tp-22-14
50. Raghavan M, Montgomerie J (2008) Anaesthetic management of gastroschisis—a review of our practice over the past 5 years. Paediatr Anaesth 18:731–735. https://doi.org/10.1111/j.1460-9592.2008.02666.x
51. Tosello B, Zahed M, Guimond F et al (2017) Neurodevelopment and health-related quality of life in infants born with gastroschisis: a 6-year retrospective French study. Eur J Pediatr Surg 27:352–360. https://doi.org/10.1055/s-0036-1597268
52. Bonasso PC, Lucke-Wold B, Hobbs GR et al (2016) Excessive postoperative fluid administration in infants with gastroschisis. Am Surg 82:704–706
53. Tannuri ACA, Sbragia L, Tannuri U et al (2011) Evolution of critically ill patients with gastroschisis from three tertiary centers. Clinics (Sao Paulo) 66:17–20. https://doi.org/10.1590/s1807-59322011000100004
54. Bajinting A, Sutthatarn P, Osei H et al (2022) Predictors of length of stay for simple gastroschisis: analysis of ACS NSQIP-P database. Pediatr Surg Int 38:1371–1376. https://doi.org/10.1007/s00383-022-05189-w
55. Tawil KA, Gillam GL (1995) Gastroschisis: 13 years' experience at RCH Melbourne. J Paediatr Child Health 31:553–556. https://doi.org/10.1111/j.1440-1754.1995.tb00883.x
56. Dama M, Rao U, Gollow I et al (2017) Early commencement of enteral feeds in gastroschisis: a systematic review of literature. Eur J Pediatr Surg 27:503–515. https://doi.org/10.1055/s-0037-1598086
57. Snyder CL (1999) Outcome analysis for gastroschisis. J Pediatr Surg 34:1253–1256. https://doi.org/10.1016/s0022-3468(99)90162-8
58. Allin BSR, Hall NJ, Ross AR et al (2019) Development of a gastroschisis core outcome set. Arch Dis Child Fetal Neonatal Ed 104:F76–F82. https://doi.org/10.1136/archdischild-2017-314560