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ORIGINAL ARTICLE

Review of the evidence on the closure of abdominal wall defects

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Abstract Infants with congenital abdominal wall defects pose an interesting and challenging management issue for surgeons. We attempt to review the literature to define the current treatment modalities and their application in practice. In gastroschisis, the overall strategies for repair include immediate closure or delayed operative repair. The best level of data for gastroschisis is grade C and appears to support that there is no major difference in survival between immediate closure or delayed repair. In patients with omphalocele, the management techniques are more varied consisting of immediate closure, staged closure or delayed closure after epithelialization. The literature is less clear on when to use one technique over the other, consisting of mostly grade D and E data. In patients with omphalocele, a registry to collect information on patients with larger defects may help determine which of the management strategies is optimal.

Keywords Abdominal wall defects · Gastroschisis · Omphalocele · Treatment

Introduction

Infants with gastroschisis and omphalocele can pose an interesting and challenging management issue for surgeons. Due the fact that reports of these diseases in literature are sporadic, we performed a review of literature to summarize the current state of the available data to identify management recommendations and illuminate pathways for future clinical research. The data sources used for evaluation included PubMed and other databases limited to English literature including: Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, and International Network of Agencies for Health Technology Assessment Database.

Evidence was separated into three classes where Class I was defined as prospective, randomized controlled trials or meta-analysis. Class II was defined as prospective studies without randomization or other studies in which data were collected prospectively. These included observational studies, cohort studies, prevalence studies and retrospective cause control studies. Class III was defined as uncontrolled studies using retrospective data such as clinical series or case reviews and expert opinion. The rating scale of evidence we used ranged from A to E, defined as: A, greater than or equal to two large Class I studies; B, one large Class I study; C, small randomized trials with uncertain results; D, greater than or equal to one non-randomized trial with controls; and E, expert opinion, case reports or uncontrolled studies.

Embryology

The abdomen develops in the 4th gestational week by the invagination of the embryo in both the craniocaudal and mediolateral directions [1]. The lateral folds meet in the anterior midline, encompassing the yolk sac, where they create the pleuroperitoneal space. Meanwhile, the cranial fold descends bringing the heart from

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its original position distal to the brain down into the midline along with the transversum suptum [2]. The caudal fold rises cranially as well, bringing with it the bladder (or allantois) from its previously distal location [2]. Later, the midline constricts around the sac forming the umbilical cord. From weeks 6–10, there is a transient herniation of the intestines into the umbilical cord due to rapid intestinal growth [1]. The bowel then migrates back into the peritoneal cavity, and the first, second and third portions of the duodenum, as well as the ascending and descending colon, undergo fixation into their retroperitoneal positions as it rotates counterclockwise.

An omphalocele, in which the abdominal wall defect is covered by a sac, [1] is thought to occur by failure of the intestines to retract into the abdominal cavity from the umbilical stalk. The resultant sac comprises the layers of the umbilical cord: amnion, Wharton's jelly and peritoneum [1]. In omphaloceles, the umbilical cord extends directly from the sac. Most omphaloceles are in the midline of the abdomen where the umbilicus is located and can include a combination of small intestines, liver or stomach. Less commonly, omphaoceles can occur from the cranial folds (ectopia cordis; pentalogy of Cantrell) and caudal folds (cloacal exstrophy) in which the location will be epigastric or hypogastric.

Gastroschisis is an abdominal wall defect located to the right of a normal umbilical cord that is not covered by a sac, but instead has evisceration of the intestines, stomach and occasionally other organs. The etiology of gastroschisis is not definitively known, but multiple theories exist. One theory is that thrombosis of the right omphalomesenteric vein causes necrosis of the abdominal wall [3, 4]. This theory also supports the association between gastroschisis and intestinal atresia [5, 6]. There is retrospective data that have shown an increase in gastroschisis/atresia with the use of vasoconstrictive drugs including ephedrine, pseudoephedrine, cocaine and smoking during gestation [7]. Other theories include: failure of the intestines to herniate into the umbilical stalk and rupture of abdominal wall from the rapidly increasing volume; failure of the mesoderm to form in the anterior abdominal wall; and failure of the lateral folds to fuse in the midline [8–11]. There are reports in the literature of left-sided or "mirror image" gastroschisis. The presentation of the abdominal wall defect is variable in location with a higher increase in associated extraintestinal anomalies. There remains controversy over the etiology of left-sided or "mirror image" gastroschisis and if it should be categorized as a unique disease process from gastroschisis given its variable presentation and higher incidence of associated extraintestinal anomalies [12–14].

Epidemiology

Prior to 1970, omphalocele was considered to occur more commonly than gastroschisis; however, since the two entities have been more accurately defined, gastroschisis has been found to have a higher incidence [2]. The incidence of gastroschisis is 1 per 4,000 to 4.9 per 10,000 as diagnosed by ultrasound at 20 weeks [1, 2, 15, 16]. The incidence of gastroschisis is higher in mothers less than 21 years old [17], and its overall incidence has been increasing over the past few decades independent of maternal age [18, 19]. Postulations for this phenomenon include environmental teratogens, oral contraceptives, aspirin, illicit drugs, smoking and vasoconstrictive agents [4, 7, 20]. The incidence of omphalocele by ultrasound at 18 weeks is 1 per 1,100 fetuses; however, this decreases to 1 per 4,000 live births, with a male preponderance, due to fetal attrition [1, 21].

Prenatal diagnosis

Imaging

Prenatal ultrasound sensitivity for omphalocele is 75 and 83% for gastroschisis as noted in a study of the US/EU registries. The gestational age for detection by ultrasound is about 18 weeks for omphalocele and 20 weeks for gastroschisis [22]. In evaluating cardiac abnormalities, which are present in up to 48% of babies with omphalocele [23], ultrasound has been found to detect between 18 and 24% [1].

Amniocentesis

Alpha-fetoprotein and acetylcholinesterase elevations in the amniotic fluid in the absence of a myelomeningocele have been correlated with both gastroschisis and omphalocele [2]. In gastroschisis alpha-fetoprotein is invariably elevated, while in omphalocele this is less reliable [1]. A study of 23 gastroschisis and 17 omphalocele patients in the second trimester demonstrated an alpha-fetoprotein level 9.42 times normal for gastroschisis and 4.19 times normal for omphalocele [24]. Acetylcholinesterase was elevated in 80% of gastroschisis and 27% of omphaloceles patients [25].

Associated anomalies

While no specific genes have been identified for congenital abdominal wall defects, there are syndromes associated with these defects. Beckwith–Wiedemann syndrome is the

most common syndrome associated with congenital abdominal wall defects; being associated with both omphalocele and gastroschisis [2, 26]. Gerishoni–Baruch and [27] Donnai-Barrow, which are autosomal recessive [28], and Fryn's syndrome [29] are also associated with omphalocele. Additionally, omphalocele has been associated with chromosomal defects including trisomy 13, 18 and 21 [10, 30, 31]. A complex of associated defects with omphalocele has been termed the OEIS complex (omphalocele–exstrophy–imperforate anus–spinal defects) [10]. It has also been reported that gastroschisis babies have a 6% chance of having a relative with the disease [32].

Management

Gastroschisis

The mode of delivery in patients who are prenatally found to have gastroschisis has grade D evidence supporting cesarean delivery. The reported advantages of cesarean delivery include a decreased exudative fibrinous reaction on the serosal surface of the bowel and improved bowel quality [33, 34]. However, there has not been a demonstrated survival advantage from any of these studies advocating cesarean delivery [35]. For the timing of delivery, there is grade C evidence that induction can be performed such that the timing of birth can occur when sufficient staff and infrastructure to treat the infant are mobilized, resulting in decreased overall mortality and morbidity [36]. However, there are conflicting papers showing no benefit and in some cases an increase in morbidity, namely respiratory compromise [37, 38, 39].

In patients with gastroschisis, the best level of evidence regarding closure technique is grade C, which shows there is no survival difference between immediate closure and delayed closure with employment of a silo. The level of evidence for using intra-abdominal pressure measurements, either vesicular or gastric for guidance in closure of the defect, is grade C, with most papers citing 20 mmHg or less for primary closure [40–43]. The overall survival of neonates with either method of closure ranged from 90 to 95% [44]. There are some data, overall grade D, showing the impact of intestinal atresia, ischemia or short bowel syndrome, which plays a larger role in overall patient survival than timing of abdominal wall defect repair [45, 46]. In a prospective trial, no difference was found in morbidity based on the timing of closure [47]. However, this study was underpowered and patients with complications present at birth were excluded. There are multiple retrospective and single institution studies, grades D and E, which have documented increased intra-abdominal pressure and infections in patients who underwent immediate repair, while other reports have not shown a difference [45, 46, 48–50]. A Cochrane review of staged reduction without anesthesia versus operative reduction and repair stated that they could not find a single study that met their inclusion criteria for review [51].

One prospective randomized study, grade C, powered to find differences in the number of ventilator days showed that the silo patients had 3.17 ventilator days versus 5.29 ventilator days for primary repair ($p = 0.07$) [44]. This study also found no difference in the length of stay or TPN days. Additionally in the CAPSnet study of 99 patients, there was no difference in ventilation days, length of stay or TPN days [48], which was similar to a few other grade E reports, except for the King's College group that demonstrated higher ventilator settings in the immediate repair group [46, 50, 52, 53].

In the evaluation of the effect of closure method employed on patient infection, the CAPSnet study showed a decrease in sepsis in patients who received enteral feeding with 10 days of surgery (8.2%) compared to patients who did not initiate enteric feeding until after postoperative day 10 (17.7%) [48]. This increase in infection rate was thought to be due to central line infection, as the patients with delayed enteric feedings had their central line for 1.5 times the duration of patients with earlier feedings [48]. In contrast, a retrospective review of 91 patients with gastroschisis found no difference in the incidence of infection, but a trend toward a decreased incidence with the usage of a silo [50].

Evaluation of long-term outcome is currently limited in literature as most studies report only the initial hospital course. One grade E case-matched series had a median follow-up of almost 3.5 years. In this study, they noted a higher number of umbilical hernias in the group of patients who had non-sutured closure of the defect [54]. Studies evaluating cosmetic outcomes are currently lacking in literature.

Omphalocele

The closure method employed for omphalocele is currently driven by size. In patients with small defects, the defect is closed primarily and the outcome is totally dependent upon the associated anomalies. Closure of the larger defects will therefore be the focus of our management discussion. We currently lack an evidence-based set of definitions or functional working nomenclature. A "giant" omphalocele is loosely defined, >5 cm in size, containing liver or a large portion of intestines [55]. This definition is flawed by the fact that infant size or the size of the remaining abdominal wall are not considered. The literature for large defects is very sparse and comprises either case reports or small case

series. Although there are a large number of methods used for closure, they can broadly be broken down by the time frame of execution: immediate closure, staged closure or delayed closure.

The majority of large defects are not amenable to immediate closure due to their size relative to the abdominal domain. In a report from King's College, London, 12 of 24 large defects were immediately repaired primarily without mortality, had less time on the ventilator and an earlier return to full feedings with a shorter length of stay compared to the 11 that were staged or delayed [56]. However, in this study, patients with lower birth weights and gestational age were more likely to be staged and the reported size of the omphalocele was inconsistent [56]. Therefore, the witnessed difference may be due to the patients' condition and not the method of closure.

When primary closure is not feasible or not attempted, there are multiple reported techniques of staging the repair in the neonatal period: treating the amnion like a silo to gently reduce the contents with a pressure dressing until ready for closure ('amnio inversion'); prosthetic silo placement with gradual reduction and closure; alloderm to patch the defect [57]; vacuum-assisted closure [58]; tissue expanders [59] and other types of mesh materials to assist closure. Most of these techniques are derived from case reports where we can expect a natural publication bias wherein only successful cases are reported [60, 61]. In these reports, complications encountered from staged procedures appear to be related to the high-level medical intervention and prolonged hospital stay, including line infections, sepsis and delayed wound healing [58, 59, 62]. These studies are very heterogeneous and are not possible to be compared directly, so they are summarized in Table 1.

Delayed closure is defined as allowing epithelialization of the intact amnion sac or excision of the sac with closure of the overlying skin with late or even post-infancy closure of the fascial defect. These patients often have severe congenital anomalies that limit the possibility for other strategies of closure. Several different methods have been employed for epithelialization: mercurochrome, povidone-iodine, silver sulfadiazine and neomycin–bacitracin ointments [63]. Mercurochrome is no longer used due to associated mercury poisoning. Povidone-iodine and silver sulfadiazine have become the sclerosing agents of choice, each offering advantages. Silver sulfadiazine has been shown to be safe and without side effects; however, its application and removal can cause bleeding from the underlying granulation tissue and is reportedly more difficult for parents at home. Povidone-iodine is easier for parents to manage; however, there are case reports of the absorption of iodine associated with clinical hypothyroidism [64–66]. However, in a prospective evaluation of the effect of povidone-iodine painting on thyroid function, povidone-iodine did not cause clinically significant hypothyroidism [67]. The subsequent delayed ventral hernia repair was reported as either primary repair, separation of components or patch closure [63, 68, 69]. These techniques were associated with prolonged hospital stays and late morbidity due to infections or wound-related complications. Patient outcomes organized by method of epithelialization are displayed in Table 2.

There is grade D data on the short- and long-term outcomes and quality of life in patients with minor and giant omphaloceles. In a retprospective review of patients diagnosed with omphaloceles prenatally, the overall survival to discharge was 28% with 63% dying in utero. In those that survived to surgery, an additional three died from multi-organ failure [70]. There are three studies that have indicated a good to very good quality of life, which was comparable to the peer group polls in patients surviving to 18 years and older [71–73]. This study reported no difference in outcome between giant and minor omphaloceles, where giant was >5 cm and minor was >4 cm in diameter [73]. This report identifies 57 patients of 111, who had additional congenital anomalies, and reports that 12 patients died within 1 year due to their anomalies, but provides no further analysis [73].

Summary

Based on the few prospective studies and single randomized clinical trial, there appear to be few differences

Table 1 Reports on techniques for staged repair in large omphaloceles

Method	Reference, year	No. of patients	Survival	Complications
Alloderm	Kapfer 2006, JPS 41:216 [62] Alaish 2006, JPS 41:e37 [57]	4	4 short term, 2 long term	Deaths from cardiopulmonary issues
VAC	Kilbride 2006, JPS 41:214 [58]	3	3	None
Tissue expanders	Martin 2009, JPS 44:178 [59] Foglia 2006, JPS 41:704 [74] De Ugarte 2004, JPS 39:613 [75] Bax 1993, JPS 28:1181 [76]	6	6	Infection, extrusion in one

Table 2 Reports on techniques for delayed repair in large omphaloceles

Method of epithelialization	Reference, year	Number of patients	Number of patients who survived	Complications
Mercurochrome	Used in 1960–1980s primarily [2]	n/a	n/a	Mercury poisoning, not used currently
Povidone-iodine	Whitehouse 2010, JPS [67]	6	5 (CHD)	Transient increase TSH, not clinically significant
Silver sulfadiazine/ neomycin/bacitracin	Lee 2006, JPS 41:1846 [63]	22	19	Two ruptured sacs, one bleeding sac
	Pereira 2004, JPS 39:1111 [69]	11	11	

between delayed closure with a silo compared to immediate operative repair for gastroschisis. There is evidence to suggest that immediate closure may have increased abdominal pressures and more ventilation days; however, these associations did not impact on the overall morbidity and mortality, and associated anomalies with gastroschisis may play a larger role in overall survival. The existence of a subset of patients, possibly defined by size or associated anomalies, having benefit with immediate repair or delayed closure, is yet to be determined. Most reports showed no statistical difference in time to enteral feeds or hospital stay; however, none of these studies were specifically powered to examine for differences in these variables. Most of these papers examined short-term outcomes associated with abdominal wall closure. Longer-term data examining differences in abdominal wall hernia formation, surgical interventions for bowel dysmotility or adhesive disease is currently unknown.

The literature on omphalocele is inconclusive. In small defects, primary closure is advocated, with most of the morbidity and mortality related to associated abnormalities. However, in large omphaloceles (>5 cm), there are too little data to make any definitive recommendations. Traditionally, the overall management strategy has been defined by the suspected feasibility of defect closure. However, the techniques employed vary considerably and there are no evidence-based guidelines to indicate on which of the populations certain techniques should be applied. The timing for intervention based on the size of the defect is also subject to great variability in the current literature. Staged and delayed closures remain ill defined on the optimal timing. Overall, patients with large omphaloceles and giant omphaloceles are a rare occurrence, making systematic clinical research for this disease process challenging. The creation of a registry would be useful in data collection for better evaluation of the effectiveness of the treatments they receive.

Conflict of interest None.

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