



Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jped surg



Management of asymptomatic pediatric umbilical hernias: a systematic review[☆]



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ARTICLE INFO

Article history:

Received 18 April 2017

Received in revised form 11 July 2017

Accepted 16 July 2017

Key words:

Pediatric
Umbilical hernia
Herniorraphy
Umbilical hernia repair

ABSTRACT

Introduction: Uncomplicated pediatric umbilical hernias are common and most close spontaneously. No formal practice guidelines exist regarding the optimal timing and indications for repair. The objective of this review is to examine the existing literature on the natural history of pediatric umbilical hernias, known complications of repair and non-operative approaches, and management recommendations.

Study design: A systematic literature search was performed to identify publications relating to pediatric umbilical hernias. Inclusion criteria comprised studies addressing recommendations for optimal timing of repair, evidence examining complications from hernias not operatively repaired, and research exploring the likelihood of pediatric umbilical hernias to close spontaneously. In addition, the websites of all pediatric hospitals in the United States were examined for recommendations on operative timing.

Results: A total of 787 manuscripts were reviewed, and 28 met criteria for inclusion in the analysis. Studies examined the likelihood of spontaneous closure based on child's age and size of hernia defect, complications of unrepaired umbilical hernias including incarceration, strangulation and evisceration based on child's age and size of defect, incidence of postoperative complications and current recommendations for timing of repair. In addition, 63 (27.5%) of the United States pediatric hospital websites published a wide range of management recommendations.

Conclusion: Despite the high prevalence of pediatric umbilical hernias, there is a paucity of high quality data to guide management. The literature does suggest that expectant management of asymptomatic hernias until age 4–5 years, regardless of size of hernia defect, is both safe and the standard practice of many pediatric hospitals.

Type of study: Review Article.

Level of evidence: Level IV.

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Abbreviations: MeSH, Medical Subject Headers; FDA, Food and Drug Administration; AAP, American Academy of Pediatrics.

[☆] Author Disclosure Statement: The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article. This work has not been presented at any national meeting or conference.

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Pediatric umbilical hernias occur as a result of failure of the umbilical ring to close completely after birth. These hernias are extremely common, present in 15–23% of newborns or approximately 800,000 children annually in the United States [1,2]. Despite their prevalence, umbilical hernias are poorly studied, perhaps because surgical repair involves a relatively minor and technically straightforward operation. Unlike umbilical hernias in adults, many pediatric umbilical hernias will close spontaneously. Consequently, observation for a period of time to allow for spontaneous closure is frequently recommended as an appropriate option for children [4,5]. There are no consensus recommendations or practice guidelines regarding the appropriate timing and indications for surgical repair of asymptomatic pediatric umbilical hernias from the major pediatric surgical organizing bodies, including the American Academy of Pediatrics, the American Pediatric Surgical Association or the American College of Surgeons. In order to better understand the existing knowledge about the natural history and optimal management of uncomplicated umbilical hernias, we performed a systematic review of the literature on spontaneous closure of umbilical hernia, complications associated with umbilical hernias, and recommendations for timing of and indications for operative management. We further analyzed the recommendations published to the websites of American pediatric hospitals in order to characterize the current state of practice. By better understanding the current state of practice, and the foundation of evidence upon which it is based, we may begin to better understand the role for consensus guidelines to reduce the number of unnecessary or premature umbilical hernia repairs. Such guidelines could reduce the risks of complications and alleviate a burden on the healthcare system.

1. Methods

1.1. Database sources

A reference librarian and the authors performed a comprehensive literature search of Cochrane Review, EMBASE, PubMed, and Web of Science in order to identify publications addressing complications from pediatric umbilical hernias, spontaneous closure of umbilical hernias and recommendations regarding timing of repair.

1.2. Search terms

Medical subject headers (MeSH) search terms were used for the initial PubMed literature review

including “hernia” and “umbilical,” “surgery” or “surgical,” “herniorrhaphy” or “repair,” “complication,” “time factors” or “time” or “timing” or “wait” or “waiting” or “early” or “delay” or “delayed” or

“predict” or “risk” or “treatment outcome” and “child” not “adult” or “child” or “pediatric” or “neonate.” Similar search terms were used in the Cochrane Review, EMBASE and Web of Science databases in order to conduct a comprehensive search for pertinent literature. Additionally the complete list of references from any included study was reviewed and additional pertinent articles were retrieved for analysis

1.3. Study eligibility and selection

Studies published in English were eligible for review and no publication date limits were placed on the search. Inclusion criteria comprised of studies addressing recommendations for optimal timing of asymptomatic pediatric umbilical hernia repair, studies describing complications from umbilical hernias not operatively repaired, and research exploring the likelihood of a pediatric umbilical hernia to close spontaneously without operative intervention. Exclusion criteria included studies exclusively examining subjects older than 18 years, umbilical hernias in children with congenital syndromes, children with complicating medical comorbidities such as cirrhosis, studies involving abdominal wall defects such as gastroschisis and omphalocele, studies in which umbilical hernias were a complication of another procedure, studies describing multiple procedures, and studies limited to description of surgical techniques.

1.4. Online search

In addition to an analysis of peer-reviewed literature, the authors reviewed the websites of all pediatric hospitals across the United States registered with the Children's Hospital Association [6] as well as the website of the American College of Surgeons [7] for any published patient or health care provider education materials pertaining to recommendations for timing of surgical repair of asymptomatic pediatric umbilical hernias. Educational materials/guidelines were included only if they were published directly on the hospital website, rather than produced by a third party or included as a link to another website. All published online recommendations were evaluated for recommended timing of operative repair and any special considerations noted for decision making about surgical intervention.

2. Results

2.1. Included studies

Seven hundred seventy-six manuscripts were initially reviewed for inclusion in this study. After screening abstracts and titles, 604 of these manuscripts were excluded. An additional 11 manuscripts were

added by screening reference lists from relevant articles. After reading these 183 manuscripts, 155 articles were excluded based on content. The remaining 28 publications were included in this evaluation. They consisted of six case series, two case reports, eleven retrospective cohort studies, one cross-sectional study, seven prospective cohort studies, and one review of case reports.

2.2. Likelihood of spontaneous closure of umbilical hernias

Our review included ten studies which discussed the likelihood of spontaneous closure of a pediatric umbilical hernia without surgical intervention (summarized in Table 1). The manuscripts included seven prospective cohort studies, one cross-sectional observational study, and two retrospective cohort studies, with publication dates between 1945 and 2016. The overwhelming consensus from these articles was that the majority of umbilical hernias close spontaneously without surgical intervention. In a retrospective case series, Woods et al. in 1953 found that 93% of hernias spontaneously closed in the first year of life [5]. Similarly, Mack et al. in 1945 estimated based on prevalence data in a population of African children that 90% of hernias closed spontaneously and that there was a continual curve of healing from infancy to puberty [4]. A prospective study by Heifetz et al. in 1963 found 92.3% hernias over 0.5 cm in diameter closed spontaneously (40% closed within 1 year, 65% within 2 years, and 85% by 3 years). This study found that

over the first year of life, the diameter of these comparatively large umbilical hernia defects decreased by an average of 18% per month [8].

2.2.1. Spontaneous closure later in childhood

Several studies examined the likelihood of an umbilical hernia to close spontaneously later in childhood or early adulthood. Hall et al. examined a cross-section of 451 African-American children and found that the prevalence of umbilical hernias at age 11 was approximately half that at age 4–5, suggesting spontaneous closure later in childhood [9]. Meier et al. prospectively measured umbilical hernias in 4052 Nigerians and reported spontaneous umbilical hernia closure up to age 14 based on statistical analysis [10].

2.2.2. Spontaneous closure of large defects

Three studies addressed the ability of large umbilical hernias to close spontaneously. In a cross-sectional study of South African children in 1980, Blumberg et al. found that hernia prevalence steadily decreased with age, suggesting that even the majority of large hernias tend to close by in 3–4 years of life without surgery [3]. In addition, the Meier et al. study was conducted in a patient population with large defect sizes (a mean umbilical hernia defect size was 4.2 cm), but this study documented spontaneous closure in children up to 14 years of age [10]. In contrast, a prospective cohort study of African American children in 1967 by Walker et al. found that although 89.1% of hernias closed spontaneously by age 6, larger hernias were less likely to close. This

Table 1
Spontaneous Closure of Umbilical Hernias.

Authors	Publication Year	Study Design	Country	Results	Recommendations regarding asymptomatic umbilical hernia management
Mack et al.	1945	- Prospective cohort study - 720 patients with umbilical hernia	Tanganyika	- 90% of hernias closed spontaneously - Continual curve of healing from infancy to puberty but doubtful if healing takes place after puberty	- None
Woods et al.	1953	- Retrospective cohort study - 283 children <2.5 years old with umbilical hernia	United Kingdom	- Incidence of hernia 1 in every 5.4 children - 93% of hernias spontaneously closed in the first year of life	- None
Haworth et al.	1956	- Prospective cohort study - 100 children <12 months old who received umbilical strapping versus no strapping	United Kingdom	- Hernias with defect <6 mm closed in 100% of cases with strapping and 96% without in by 12 months - Hernias with defect >6 mm closed in 80% of cases with strapping and 43% without in 12 months	- None
Heifetz et al.	1963	- Prospective cohort study - 78 children with umbilical hernias and facial defects >0.5 cm	United States	- 92.3% hernias closed spontaneously; 40% closed within 1 year, 65% within 2 years, and 85% by 3 years - Rate of closure was 18% per month - Of 417 cases treated non-operatively, 98.3% closed by 6–17 years old and 98.8% by 18–31 years old	- Expectant management unless evidence of complicated or symptomatic hernia
Sibley et al.	1964	- Retrospective cohort study - 514 children with umbilical hernia from 1930 to 1954	United States	- 10.9% hernias did not spontaneously close by age 6 - 96% of hernias with defect <0.5 cm closed but no hernias with defect >1.5 cm closed	- Protuberant hernias at age 5 - Non-protuberant hernias at age 10–12 - Facial defects >1.5 cm should undergo surgical closure at age 6
Walker et al.	1967	- Prospective cohort study - 426 infants with umbilical hernias over 6 years	United States	- Regardless of original size, hernias tend to close between age 3 and 4 without surgery	- Persistent hernia at age 3
Blumberg et al.	1980	- Prospective cohort study - 1815 children with umbilical hernias	South Africa	- Half the hernias present at age 4–5 spontaneously closed by age 11 - Aim of study to establish the natural history of spontaneous closure after age 5	- Repair at puberty unless symptomatic or causing psychological disturbance
Hall et al.	1981	- Cross-sectional observational study - 665 African American children 4–11 years with umbilical hernias of at least 1 cm	United States	- In children, mean defect size as 4.7 mm, largest diameter was 6 cm - Umbilical hernias can spontaneously close up to age 14	- Expectant management unless evidence of complicated or symptomatic hernia
Meier et al.	2001	- Prospective cohort study - 4052 patients including 2542 patient <18 years old	Nigeria	- 91% of umbilical hernias with adhesive strapping closed in 13 weeks - Closure speed was faster with adhesive strapping - Adhesive strapping caused skin complications in 5.6% of children	- None
Yanagisawa et al.	2016	- Prospective cohort study - 89 infants who underwent adhesive umbilical strapping versus 8 infants who were observed - Closure monitored by ultrasound	Japan		

Ten studies discussed the likelihood of spontaneous closure of a pediatric umbilical hernia without surgical intervention.

Table 2
Complications from Umbilical Hernias.

Authors	Publication Year	Study Design	Country	Results	Recommendations regarding asymptomatic umbilical hernia management
Woods et al.	1953	- Retrospective cohort study - 283 children <2.5 years old with umbilical hernia	United Kingdom	- No episodes of incarceration and strangulation	- None
Sibley et al.	1964	- Retrospective cohort study - 514 cases of umbilical hernia from 1930 to 1954	United States	- 28 of children underwent operative repair of umbilical hernia. 24 were asymptomatic, 1 incarceration, 1 strangulation	- Protuberant hernias at age 5 - Non-protuberant hernias at age 10–12
Morgan et al.	1970	- Retrospective cohort study - 180 cases of incarcerated umbilical hernia from 1952 to 1966	United States	- 101 adults and only 7 children. 93% of cases were female - No mortality in incarcerated umbilical hernias in children, 7% mortality in adults	- Repair in girls over 2 years and all children over 4 years
Lassaletta et al.	1975	- Retrospective cohort study - 590 children <12 years old from 1964 to 1974	United States	- 5.1% complication rate; rates of incarceration were 3.7% in children <1 year old, 5.7% in children 1–3 years, and 4.7% in children >4 years - Rates of incarceration were 4.3% in defects <0.5 cm, 7.4% in defects 0.5–1.5 cm and 3.7% in defects >1.5 cm - 1 episode of strangulation requiring bowel resection - 9 postoperative complications (1.5%): 5 hematomas, 3 wound infections, 1 recurrent hernia	- Hernias with defect >1.5 cm which persist beyond 4 years of age
Blumberg et al.	1980	- Prospective cohort study - 1815 children with umbilical hernias	South Africa	- No complicated umbilical hernias noted	- Persistent hernia at age 3
Chatterjee et al.	1986	- Retrospective cohort study - 53 children with umbilical hernia from 1975 to 1984	India	- 32.1% of cases presented with acute incarceration - 1 case required bowel resection - 7 cases presented more than 24 h after incarceration - Age range 4 months to 5 years - 37.5% cases were admitted for incarceration - No bowel resections - Average age for girls was younger (2.5 years) than boys (7 years) - No post-operative complications, no morbidity	- Early elective repair of hernias in children <2 years are warranted when poor access to healthcare would cause children to present later than 24 h after incarceration
Mawera et al.	1994	- Retrospective cohort study - 40 patients (including two adults) with umbilical hernia from 1990 to 1993	Zimbabwe	- No post-operative complications, no morbidity	- Repair in girls over 2 years and all children over 4 years
Vrsansky et al.	1997	- Case series, 1990–1995 - 4 incarcerated/strangulated umbilical hernias	France	- None requiring bowel resection - Age 2 months–5 years - 75% had hernia defect <1.5 cm	- None
Papagrigoriadis et al.	1997	- Case series, over 20 years - 3 incarcerated umbilical hernias	United Kingdom	- All children <48 months - None requiring bowel resection - No postop complications	- None
Meier et al.	2001	- Prospective cohort study - 4052 patients including 2542 patients <18 years old	Nigeria	- 2 children underwent emergency surgery, no deaths	- Expectant management unless evidence of incarceration
Keshtgar et al.	2003	- Case series, 1997–2000 - 7 incarcerated umbilical hernias	United Kingdom	- No cases required bowel resection - No postop complications	- Non-operative management of asymptomatic hernias until age 4–5 years
Ameh et al.	2003	- Case series, 1987–2000 - 47 children with umbilical hernia	Nigeria	- 15 cases of acute incarceration, 12 cases of strangulation, 2 requiring bowel resections, 5 cases of intestinal evisceration - 67% complications were in children <4 years old, 33% in children <2 years old. All cases of evisceration occurred at <1 year old - All complications occurred in hernias with defect >1.5 cm - Two postoperative wound infections	- None

Chirdan et al.	2004	- Retrospective cohort study - 52 children <15 years with umbilical hernia from 1996 to 2004	Nigeria	- 44.2% children presented with acute incarceration, 5.8% with strangulation - Incarceration defects ranged from 0.7 cm to 4 cm - Age of incarceration ranged from 3 weeks to 15 years	- Advisable to observe asymptomatic umbilical hernias unless population has poor follow-up or access to healthcare, then elective repair is recommended - Persistent hernias at age 4–5 - Hernias greater than 1.5 cm in diameter - None
Weik et al.	2005	- Case report - Spontaneous evisceration	United States	- Ex-premature 5-month-old girl on prolonged ventilatory support, who experienced bowel evisceration via uncomplicated umbilical hernia	
Fall et al.	2006	- Case series, 1997–2001 - 41 cases of strangulated umbilical hernia	Senegal	- 5 cases required bowel resection - 83% of strangulations occurred between 8 and 36 months - 2 post-operative infections, 1 recurrence	
Brown et al.	2007	- Retrospective cohort study - 389 children from 1991 to 2005	South Africa	- 7.2% presented with complicated umbilical hernias - 82% of complications occurred in children <4 years old - Defect size ranged from 0.5-5 cm and did not relate to complications - 9 incarcerated hernias, no bowel resections - 1 superficial wound infection, 1 abscess	- Non-operative management until age 5 years if there is a persistent defect >2 cm
Komlatse et al.	2009	- Case report - Strangulated Meckel's diverticulum	Togo	- 18 month old with strangulated small bowel and Meckel's diverticulum, 8 cm of bowel resected, 4 cm facial defect	- None
Zendejas et al.	2011	- Retrospective cohort study - 489 children from 1956 to 2009	United States	- 7% of umbilical hernias were complicated umbilical hernias, included recurrent incarceration (22), enteric fistula (7), strangulation (4), and evisceration (1) - No difference in age at repair for children with and without complicated hernias (mean, 4.5 vs 3.9 years; P = .75) - Mean defect size was 1.0 cm emergent vs 1.5 cm elective repairs, P = .008 - Post-operative complications: 7 wound infection, 3 hematoma, and 1 seroma → overall complication rate of 2% - 2% recurrence.	- If defect persists beyond 4–5 years old - If defect 1–2 cm or enlarging before 4 years
Thomson et al.	2012	- Review of cases reports of spontaneous evisceration from umbilical hernias between 1956 and 2011	South Africa	- 19 cases of spontaneous evisceration usually precipitated by crying, coughing, pneumonia, ascites, positive pressure ventilation or abdominal pathology - Age range 2 weeks-11 years, facial defect 1.3 to >6 cm - Two deaths	- Surgical repair if facial defect >2 cm at age 2–3 years - Persistent hernias at age 4–5
Ezomike et al.	2012	- Retrospective cohort study - 20 cases of umbilical hernia from 2001 to 2011	Nigeria	- 45% presented with acute incarceration, mean age of incarceration was 4.72 years - 1 case required bowel resection - 83% post-operative complication rate: 1 granulation tissue, 2 suture reactions, 2 surgical site infection	- Elective repair of patients older than 5 years with defect greater than 1.5 cm
Ireland et al.	2014	- Retrospective cohort study - 433 umbilical hernias from 1999 to 2012	Australia	- Mean age of repair for complication was 5 years old - 5 cases of acute incarceration, one resection of necrotic omentum, no bowel resections - Rate of acute complications requiring surgery = 1% or 0.41 cases per year - Incidence of complication 1:3000–1:11,000 umbilical hernias	- Patient or guardian directed repair for asymptomatic hernias
Komlatse et al.	2014	- Case series, 2012–2013 - 146 children with umbilical hernia	Togo	- 4 hernias presented with incarceration - No incarcerations in the hernias with >3 cm defect - 1 post-operative hematomas, 3 cosmetic complications	- None

22 studies discussed complications from pediatric umbilical hernias not surgically repaired.

study reported that 95% of hernias (201/211) with a defect <0.5 cm in infancy closed compared to 0% of hernias (0/21) with a defect >1.5 cm in infancy [11].

2.2.3. Closure with non-operative umbilical strapping

Two prospective cohort studies investigated non-operative umbilical strapping as a method of treating umbilical hernias without surgery. In 2016, Yanagisawa et al. examined 89 children who underwent umbilical strapping. They found that 91% of umbilical hernias treated with adhesive strapping closed in 13 weeks regardless of the diameter of the hernia defect, gestational age, or the timing of treatment and only 2.25% of hernias recurred [12]. Similarly, Haworth et al. found a benefit to non-operative strapping in umbilical hernias with diameters of >6 mm given 62% of these cases closed with strapping, compared to only 41% without [13]. Both studies noted complications which included 25.5% of patients in the Haworth et al. study and 25.8% of the patients in the Yanagisawa et al. study experiencing skin irritation or excoriation [12,13]. Two (3.9%) infants in the Haworth et al. study and five (5.6%) infants in the Yanagisawa et al. discontinued treatment related to complications from strapping [12,13].

2.3. Complications of pediatric umbilical hernias not surgically repaired

We identified 22 studies that discussed complications from pediatric umbilical hernias not surgically repaired (summarized in Table 2) [2,3,5,10,14–31]. The complications ranged in severity from symptomatic intermittent incarceration to spontaneous evisceration. These articles, consisting of 6 case series, one review of case reports, 11 retrospective cohort studies, two case reports and two prospective cohort studies, assess the consequences of a watchful waiting approach to umbilical hernias. A recent retrospective study of 433 umbilical hernia repairs over 12 years at a single institution by Ireland et al. found that umbilical hernias repairs were performed due to acute hernia complication in 1% of patients (0.41 cases per year) for a population-wide estimate of complications occurring in 1:3000–1:11,000 umbilical hernias [31]. This is considerably lower than the South African study by Brown et al., and the American studies by Zendejas et al. in 2011 and Lassaletta et al. in 1975 which noted incidences of complications at 7.2%, 7.0% and 5.1% respectively [16,25,28]. All of these studies were retrospective reviews of children undergoing umbilical hernia repairs. In contrast, a 1980 South African study by Blumberg et al. documented no complicated hernias in a prospective observational study of 1815 children [3]. The large discordance in reported complication rate (0%–7.2%) between these five large retrospective reviews likely reflects a selection or sampling bias, with many asymptomatic children not having operations.

2.3.1. Incarceration, strangulation and evisceration

Fifteen of 22 studies described the incidence of umbilical hernia incarceration [2,5,14,15,17–22,25,27,28,30,31]. Five were case series describing complicated umbilical hernias [2,19–21,24]. Ten manuscripts were retrospective cohort studies, where incarceration rates differed based on geographic location. Five studies conducted in the United States, South Africa, and Australia found the incidence of incarcerated umbilical hernia to be between 0.19% and 4.5% [14,15,25,28,31]. One British study found no episodes of incarceration in 283 children followed [5]. In contrast, four similar studies in Nigeria, Zimbabwe, and India noted incarceration incidence between 32.1% and 45%, although the sample size was less than 53 children in all of these investigations [17,18,22,30]. In these manuscripts, authors acknowledged a bias in this data as children in African countries and India rarely present to the hospital unless there is an acute complication related to their hernia [21].

Seven of the twenty-two studies described a total of 63 incidences of strangulated umbilical hernias [14,16,21,22,24,26,28]. Three of the studies were case series describing complicated umbilical hernias and four

were retrospective cohort studies. Strangulation incidence in three of the four retrospective cohort studies ranged from 0.16% to 0.81% [14,16,28]. The one remaining retrospective cohort study was conducted in Nigeria on 52 children and found a higher strangulation incidence (5.7%) [22].

Strangulation of a pediatric umbilical hernia requiring bowel resection is rare and reportable [16,17,21,24,26,30]. A single child requiring bowel resection has been reported in the United States and the remaining 10 cases were in Senegal, Nigeria, Togo, and India. Similarly, there have been only 20 cases documented in the literature of spontaneous evisceration from an umbilical hernia [21,23,28,29]. Precipitating events for these cases included crying, coughing, pneumonia, ascites, positive pressure ventilation or abdominal pathology. The only two deaths reported in the literature as a result of a complication from an umbilical hernia were both secondary to spontaneous evisceration and occurred in England in 1956 and India in 1972 [29].

2.3.2. Timing of complications

Fifteen manuscripts commented on the timing at which children develop complications from umbilical hernias in an effort to aid in recommendations for operative repair. These included five case series, one case report, one review of case reports and eight retrospective cohort studies. The following studies have documented the mean or median age of complication in their series: Ezomike et al. (mean age = 4.72 years), Chirdan et al. (median age for acute incarceration = 4 years, recurrent incarceration = 8.5 years), Mawera et al. (mean age for girls = 2.5 years, boys = 7 years), Ireland et al. (mean age = 5 years) [18,22,30,31]. After examining 47 cases of complicated umbilical hernia, Ameh et al. (Nigeria) found 67% of patients with complicated umbilical hernias were younger than 4 years old and 33% were younger than 2 years old [21]. In contrast, a study of 590 children by Lassaletta et al. (United States) found the incidence of incarceration was 3.7% in children less than 1 year old, 5.7% in children 1–3 years, 4.7% in children 4–7 years, and 4.7% in children 7–12 years [16]. All cases of evisceration described in the Ameh et al. study occurred in children under 1-year-old and all three cases of incarceration in the Papagrigoriadis et al. case series occurred in children under 4 years old [20,21]. The Zendejas et al. study of 489 children concluded there was no difference in age for children undergoing hernia repair for complicated versus asymptomatic hernia (mean = 4.5 years vs. 3.9 years; *p* value = 0.75) [28].

2.3.3. Relationship between defect size and rates of complications

There is conflicting data on the relationship between hernia defect size and complication rates. Two studies suggest that larger defects are more prone to acute complication. A Nigerian 47-patient case series by Ameh et al. documented all complications occurred in hernias with defect >1.5 cm [21]. Similarly, a Nigerian cohort study of 52 children by Chirdan et al. found a median hernia defect size of 2 cm in acute incarceration and 2.5 cm in recurrent incarceration [22]. In contrast, an American study of 489 children by Zendejas et al. found the mean defect size for a hernia requiring emergent repair was 1.0 compared to 1.5 cm in hernias repaired electively (*p* value = 0.008) [28]. Lassaletta et al. determined in his study of 590 children that defects of 0.5 cm to 1.5 cm were the most prone to complication with an incidence of 7.4%. The complication incidence for defects <0.5 cm was 4.3% and defects >1.5 cm was 3.7% in this study [16]. Similarly, Vrsansky et al. from France documented 75% of incarceration or strangulation occurred in defects <1.5 cm and Komlatse et al. from the Togo found no incarcerations in the hernias with >3 cm defect [19,27]. Brown et al. retrospectively studied 389 children from South Africa and did not demonstrate a correlation between defect size and complications [25].

2.4. Complications from operative repair of umbilical hernias

Authors from nine of the twenty-two manuscripts discussed postoperative complications of umbilical hernia repair [2,16,19,20,24,25,27,28,30].

Table 3
Recommendations for Pediatric Umbilical Hernia Repair.

Recommendation for Asymptomatic Umbilical Hernia Repair	Literature Review (N = 28)	Website Review (N = 229)
Minimal Age:		
2 years	2 (7.1%)	4 (1.7%)
3 years	1 (3.6%)	28 (12.2%)
4 years	3 (10.7%)	18 (7.9%)
5 years	3 (10.7%)	13 (5.7%)
6 years	1 (3.6%)	0 (0%)
10 years or older	2 (7.1%)	0 (0%)
Only repair if symptomatic or complicated	3 (10.7%)	0 (0%)
No recommendation	7 (25.0%)	166 (72.5%)
Indications for early repair:		
Any indication	13 (46.4%)	55 (24.0%)
Cosmetic/parental preference	2 (7.1%)	7 (3.1%)
Enlarging	1 (3.6%)	20 (8.7%)
Large defect	7 (25.0%)	26 (11.3%)
Not decreasing in size over time	0 (0%)	1 (0.4%)
Initial hernia develops after 6 months old	0 (0%)	1 (0.4%)
Female gender	2 (7.1%)	0 (0%)
Poor access to healthcare	1 (3.6%)	0 (0%)

There is significant variability in author recommendations surrounding surgical repair of asymptomatic pediatric umbilical hernias. This table summarizes recommendations for timing of repair and considerations for early repair in both the current literature and a after a review of children's hospital website recommendations.

The most common complications described were infection (superficial wound infection and subcutaneous abscess), wound granulation or scar formation, hematoma and seroma. Six studies noted infectious complications with incidences ranging from 0.8% in the American study of 590 children by *Lassaletta et al.* to 33.3% in the Nigerian study of 20 children by *Ezomike et al.* [16,24,25,27,28,30]. In the *Ezomike et al.* series, 45% of the hernias operatively repaired presented as strangulated or incarcerated [30]. Cosmetic complications (granulation tissue and scarring) were documented two studies with an incidence of 2% and 5%, respectively [27,30]. Four studies documented postoperative hematomas or seromas with an incidence of between 0.08% and 2% [16,27,28,32]. Three studies described no postoperative complications following umbilical hernia repair [2,19,20].

Three studies commented on incidence of recurrence, which ranged from 0.27%–2.44% [16,24,28]. Only the study by *Zendejas et al.* commented on predictors of hernia recurrence. They found no relationship between recurrence and age, gender, ethnicity, prematurity, defect size, or surgical technique but did find hernias repaired with *non-absorbable* suture were nearly 6 times more likely to recur (HR 5.93, CI 1.48–23.70) [28].

2.5. Author recommendations for timing of repair

Recommendations for operative timing vary widely and are summarized in Table 3. Of twenty-eight manuscripts reviewed, ten studies gave no recommendations regarding the timing of surgery [4,5,12,13,19–21,24,26,27]. Three studies recommend surgical repair only in the instance of complications or symptoms [8,10,22]. Three studies recommend a cutoff of two years of age for operative repair. *Thomson et al.* recommends age 2–3 for defects > 2 cm [29]. *Morgan et al.* and *Mawera et al.* recommend repair in girls over 2 years and all children over 4 years [15,18]. One study (*Blumberg et al.*) recommends repair at age three [3]. Seven studies recommend repair at age four [2,15,16,18,23,28,29]. Three studies advocate for waiting until age five [14,25,30] and one manuscript recommend operative repair after age six [11]. Finally, two studies suggest waiting until children are young adults for operative intervention (*Sibley et al.* recommends repair at age 10–12 and *Yanagisawa et al.* recommends repair at puberty) [12,14].

In addition to age, authors noted several other factors to consider as possible indications for early operative repair. *Chirdan et al.* and *Chatterjee et al.*, from Nigeria and India respectively, emphasize the importance of access to healthcare in the decision-making process regarding timing

for operative repair [17,22]. Numerous authors commented on hernia defect size as a possible indication for early surgical intervention. *Zendejas et al.* recommends repair of defects 1–2 cm, *Weik et al.*, *Lassaletta et al.*, *Ezomike et al.*, and *Walker et al.* recommend repair of defects > 1.5 cm and *Brown et al.* and *Thomson et al.* recommend repair of defects > 2 cm [11,16,23,25,28–30]. *Zendejas et al.* state an enlarging umbilical hernia defect constitutes an indication for operative repair and *Sibley et al.* comment the size of protuberance should be considered [14,28]. Finally, two studies (*Ireland et al.*, and *Hall et al.*) encourage providers to take into account parental preference and psychological distress of the child when determining timing for operative repair [9,31].

2.6. Review of online recommendations for timing of repair

The 228 websites from United States children's hospitals listed as members of the Children's Hospital Association [6] and the website from the American College of Surgeons were reviewed for published patient/family or healthcare provider educational materials regarding pediatric umbilical hernias and timing of asymptomatic umbilical hernia repair. The American College of Surgeons recommended in their online patient education brochure that pediatric umbilical hernias be repaired after age five and had no documented indications for early repair of an asymptomatic hernia. Of the 228 children's hospital websites reviewed, 166 (72.5%) had no published recommendations for the timing of pediatric umbilical hernia repair. The remaining 63 websites posted the following recommendations: 4 (6.3%) advised repair after two years old, 28 (44.4%) after three years old, 18 (28.6%) after four years old and 13 (20.6%) after five years old. Similar to the reviewed literature, many websites offered additional circumstances in which early repair would be recommended. A total of 55 special indications for early repair were identified with some websites citing more than one. The most common indication cited by 26 (47.2%) websites was a large defect. Only three websites defined the exact measurement that constituted a "large" defect size (two stated > 2 cm and one stated > 1 cm). Other special considerations included enlarging hernia (36.4%), cosmetic repair or parental preference (12.7%), umbilical hernia not decreasing in size (1.8%), and initial presentation of hernia after 6 months of age (1.8%).

3. Discussion

Expert consensus among both manuscript and website recommendations is that symptomatic or complicated umbilical hernias should receive prompt operative intervention. However, our review of the research pertaining to the proper timing for asymptomatic pediatric umbilical hernia repairs demonstrates great variability in practice recommendations and no high-level evidence for a particular management strategy.

There are considerable differences in perceptions of umbilical hernia care around the world. *Ameh et al.* illustrates this point when he stated that "in our environment [Nigeria] only patients with complications present for repair" [21]. This difference in practice patterns may reflect a combination of cultural differences and differences in access to healthcare. With regards to cultural differences, two manuscripts (from Australia and the United States) and seven children's hospitals recommend that cosmetic appearance should be considered when determining timing of operative repair. According to *Zendejas et al.*, the reason for operative intervention in 10% of all umbilical hernias repairs was parental concern [28]. To that end, *Cilley* noted that it can be a difficult task for pediatric surgeons to educate families that observation and watchful waiting is often a reasonable treatment strategy in young children with asymptomatic umbilical hernias [33]. For those families who are requesting an intervention to address their child's umbilical hernia, umbilical strapping discussed in the *Yanagisawa et al.* and *Haworth et al.* studies may be a non-invasive option, but has a significant local complication rate.

3.1. Likelihood of spontaneous closure of umbilical defect

There is a strong consensus in the literature that pediatric umbilical hernias have the potential to close spontaneously with watchful waiting. It is important to note that 60% of the studies on this topic were conducted prior to 1970 and 80% prior to 1985. Although the natural history of umbilical hernias has presumably not changed over the last several decades, older studies are limited by the medical record keeping of the time and the level of scientific scrutiny placed on their findings. Additionally, most of the prospective cohort trials have a follow-up time not extending into late childhood and may not be able to fully assess the natural history of umbilical hernias. Although the quality of the literature is poor, it does demonstrate that pediatric umbilical hernias have the ability to continue to close throughout early childhood, with larger hernias apparently less likely to completely close than smaller ones.

3.2. Complications from pediatric umbilical hernias not surgically repaired

The consensus from the literature is that the potential for complication from an unrepaired umbilical hernia is low. There is presumably a large selection bias in published studies of complication rates, as the studies of complications drew only from patients undergoing surgical repair. In the twenty-two studies that examined complications from umbilical hernias, there was a low incidence of complication carrying significant morbidity or mortality.

Overall, the data on timing of complications supports the recommendations for watchful waiting. With the exception of one study performed in Zimbabwe describing only 38 children, the mean age of complication from umbilical hernias was between 4 and 7 years old [18]. The *Zendejas* et al. study of 489 children concluded there was no difference in age for children undergoing hernia repair for complicated versus asymptomatic hernia [28]. Only two small studies support a benefit for early operative repair as a means to prevent complications in early childhood, a case series of 47 patients by *Ameh* et al. and a case series of only 3 children by *Papagrigoriadis* et al. [20,21].

Published data supports no significant increase risk of complication based solely on hernia size. Two studies in our review (*Ameh* et al. and *Chirdan* et al.) documented complications in hernias of larger diameter. However, these Nigerian studies included only 47 and 52 children, respectively, and may reflect a sampling bias, since African children may often have larger mean hernia sizes [10]. In contrast, the *Meier* et al. study of over 4000 Nigerian patients demonstrated an average hernia diameter of 4.2 cm but described only 11 complications (2 occurring in children and 9 in adults) [10]. Two large retrospective cohort studies by *Zendejas* et al. and *Lassaletta* et al. including over 970 children found smaller hernias <1.5 cm in diameter were more prone to complications. Additionally, *Brown* et al. examined 389 children from South Africa and determined that defect size did not relate to complications [25]. Despite these findings, eight manuscripts and forty-five children's hospitals recommended that a large or enlarging defects could be a consideration for early operative repair without clear rationale for these recommendations. According to *Zendejas* et al., the most common operative indication for repair was size of the hernia defect or persistence of hernia defect (46%) [28]. Only three children's hospitals and seven manuscripts define the size specifications of a "large" hernia with the definitions ranging from 1 to 2 cm. Based on the evidence available, early operative repair of a large defect hernia in order to prevent complication does not appear to be an appropriate indication for surgery.

3.3. Impact of early surgical intervention

Early closure of umbilical hernias may result in unnecessary operations, as some defects would have closed naturally with time. This exposes young patients to both the risk of surgical complications and anesthetic complications from a potentially avoidable operation. As a result, the healthcare system is burdened by unnecessary and expensive

operative repair of umbilical hernias. These factors must be considered when advising patients and families regarding operative repair of pediatric umbilical hernias.

The literature consistently demonstrates that pediatric umbilical hernia repair has a low risk of minor surgical complications and recurrence. Over all studies reviewed, very few minor postoperative complications were reported, including superficial surgical site infection, hematoma, seroma, keloid formation or granulation, and abscess. No study has described postoperative complications in only asymptomatic, uncomplicated umbilical hernias. As a result, the incidence of postoperative complications may be lower than reported in the literature given the presence of necrotic tissue from incarceration or strangulation would change the wound class from "clean," increasing the statistical likelihood of complications [34]. Three studies commented on incidence of recurrence, which ranged from 0.27%–2.44%; [16,24,28] however, the ability to accurately predict recurrence is limited by the short follow-up period of these studies.

Although the operative repair of an umbilical hernia is a relatively straightforward, comparatively low-risk procedure, it is important to also consider the risks associated with anesthesia in very young children. Several studies have demonstrated the potential harm of general anesthesia in the pediatric population. It is known that peak brain synaptogenesis occurs from birth up to 2–3 years of age and that anesthetic exposure can lead to neural damage and apoptosis [35]. A study by *Chemaly* et al. demonstrated that in children under 4 years old, those who were exposed to anesthesia were more likely to have behavioral abnormalities than those who had not received anesthesia (28.4% compared to 5.7%, $p < 0.001$) and the risk increased with younger age, longer duration of anesthesia and multiple anesthetics [35]. A recent meta-analysis by *Wang* et al. in 2014 examined seven studies, and found a pooled hazard ratio of 1.25 (CI 1.13–1.38) for the association between anesthesia and adverse behavioral or developmental outcome in children undergoing the first anesthesia before 4 years of age [36]. Additionally, this study showed multiple anesthetics was a risk factor for neurodevelopmental impairment (HR = 1.75, CI 1.31–2.33) [36]. In December 2016, the US Food and Drug Administration (FDA) issued a report responding to this data suggesting neurologic sequelae from pediatric anesthetics. The FDA advised providers to consider delaying surgery when medically appropriate in children under three necessitating prolonged general anesthesia or multiple anesthetics. In response to this report, the American Academy of Pediatrics (AAP) released their own guidance, saying "the potential risk of negative cognitive or behavioral effects of anesthetic agents remains uncertain and must be placed in the context of the known risks and benefits of both the anesthetic and the related surgical or diagnostic procedure for which the anesthetic is required... Until additional information is available from ongoing studies, parents and providers should carefully weigh the risk and benefit of each contemplated procedure before proceeding" [37]. Although umbilical hernia repair rarely requires prolonged anesthesia, surgery may expose the child to multiple anesthetics if an additional, emergent, procedure is needed within the first few years of life. Using the criteria outlined in the AAP statement, pediatric umbilical hernia repair could reasonably be delayed past age three in order to minimize the possibility of neurocognitive anesthetic risks.

In addition to the negative neurologic consequences of anesthesia, there is also the possibility for respiratory complications. A study by *Mamie* et al. of 800 children undergoing elective procedures without an acute respiratory infection found a 21% incidence of intraoperative respiratory adverse events and 13% incidence of adverse respiratory events in the post-anesthetic care unit [38]. Furthermore, this study found the risk of an adverse respiratory event decreased by 8% with each increasing year of life, indicating a likely significant benefit to delaying elective procedures, like umbilical hernia repairs, until the child is older [38].

3.4. Management recommendations

There is significant variability in author recommendations surrounding surgical repair of asymptomatic pediatric umbilical hernias. The

majority of studies in this review concluded no increased risk of complication in children less than 4 years old, and the anesthesia literature suggests an increased risk of neurologic and respiratory complications in children less than 4 years of age. In total, 60% of manuscript recommendations and 49% of published children's hospital recommendations support waiting to repair asymptomatic umbilical hernias in children until after 4 years old, suggesting that this could be a consensus target. The most common special consideration for early operative intervention of umbilical hernias was a large or enlarging defect; however, the evidence does not conclusively support this approach. The majority of studies show no link between size of hernia defect and likelihood of a child developing a complication. Although larger defects may be less likely to close and eventually require surgery, several small studies have demonstrated the possibility of spontaneous closure later in childhood. In the absence of potential increased harm, there appears to be no indication for early repair of large defects. Two other common special considerations for early repair were parental/patient concern and access to healthcare. Although these are legitimate concerns, they are probably best addressed on a case by case basis between a family and their provider.

3.5. Limitations of the current literature

The existing literature, consisting primarily of case series and case reports with a few longitudinal cohort trials, does not provide high quality evidence to guide clinical practice. With the exception of the Walker et al. study, which follows patients to 6 years, there is a lack of long-term longitudinal follow-up. When attempting to characterize the natural history of a disease process like a pediatric umbilical hernia, long-term follow-up is essential. Existing manuscripts also lack power and are difficult to generalize. Of the 28 manuscripts reviewed, 25% had 20 or fewer patients, 26% had 50 or fewer patients, 54% had 100 or fewer patients, and 79% had less than 500 patients. Another major limitation of the literature is the timeliness of the studies. In fact, 80% of the studies examining spontaneous closure and 31% of the studies examining complications were published more than 2 decades ago. Modern comorbidities, such as increasing rates of childhood obesity, may impact the likelihood of spontaneous closure in the current era. Finally, all data about the management of asymptomatic umbilical hernia (the most common form) must be inferred from the existing reports. There are no studies which exclusively discuss asymptomatic umbilical hernia repairs with regards to current practices in timing of repair and complications.

4. Conclusion

There is a paucity of high quality data from well-powered studies to determine the optimal timing for surgical repair of an asymptomatic pediatric umbilical hernia, which is among the most common surgical conditions of childhood. Ultimately, the large variability in recommendations demonstrates a need for formal practice guidelines to aid both primary care providers and surgeons. Consensus best practice guidelines that balance the risks of complication from an unrepaired asymptomatic umbilical hernia with the likelihood of spontaneous closure and complications from operative intervention would be an important start in the absence of high quality, population level prospective data. Based on our systematic review of the literature, we believe appropriate clinical practice guidelines would include the following: 1) prompt repair of symptomatic or complicated pediatric umbilical hernias, 2) surgical consultation by primary care providers for evaluation of asymptomatic pediatric umbilical hernias at age 4, 3) surgical repair of asymptomatic umbilical hernias after the child is 4 years old but before they reach adulthood, 4) early surgical repair of asymptomatic pediatric umbilical hernias before age 4 may not be indicated regardless of hernia defect size or protuberance.

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