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Umbilical access in laparoscopic surgery in infants less than 3 months of age: A survey of the American Pediatric Surgical Association☆,☆☆,★

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ABSTRACT

Purpose: Laparoscopy is commonplace in pediatric surgery. Abdominal access via the umbilicus may present a unique challenge in neonates and young infants predisposing them to complications.
We hypothesized that these complications may occur more than described in the literature.
Methods: Members of the American Pediatric Surgical Association (APSA) were anonymously surveyed in February of 2018 via REDCap™ regarding technique of umbilical access in infants less than 3 months of age and complications experienced during umbilical access. Approval was obtained from the IRB and the APSA Outcomes and Evidence-based Practice Committee.
Results: The response rate was 31.3% (329/1050). 62.3% of respondents performed 21 or greater neonatal laparoscopic procedures annually. 34 of 322 respondents reported a direct complication from umbilical access for laparoscopy in this age group (10.6%). Surgeons described 37 specific cases with complications related to umbilical access, with laparoscopic pyloromyotomy making up 47.2% (17/36). CO_2 embolism was the most common complication; 15.4% of surgeons reported not knowing about the possibility of CO_2 embolism. 41% of surgeons confirm intraabdominal placement of the umbilical trocar prior to insufflation. There was no association between any complication and where the umbilical trocar was placed (above/below/through umbilicus) or placement technique in patients with no umbilical cord stump. There may be an association between complication and where the umbilicus is entered in patients with an umbilical cord stump still in place ($p = 0.013$).
Conclusions: Umbilical access for laparoscopy in neonates and infants less than 3 months of age can present a unique challenge and result in significant complications. All techniques and methods had complications. Surgeons should be aware of these risks and be prepared to manage them emergently if they arise.
Level of evidence: V, expert opinion.

While the first laparoscopic interventions occurred in the adults in the early- to mid-20th century, laparoscopy in children gained greatest traction in the late 20th century, mainly secondary to the advent of equipment appropriately-sized for the smallest of patients [1]. The use of laparoscopy in most contemporary pediatric surgical practices is commonplace, even for infants and neonates [2–4].

Early adult laparoscopy was almost universally initiated by umbilical access, although other sites of entry were also explored. Pediatric surgeons have employed similar entry techniques. Particularly at the umbilicus however, the anatomy of the neonate and young infant umbilicus presents an increased potential for complications. While case reports have described significant complications and even mortality related to obtaining umbilical access for laparoscopy in young infants, these seemingly rare events have been discussed anecdotally more frequently [5,6]. There are many likely reasons for lack of reporting of these complications including: 1) rare occurrence, 2) negative clinical outcomes for otherwise relatively safe surgical interventions, and 3) potential medicolegal implications preventing discussion. Regardless, we believe the complications are potentially more common than most would anticipate and feel the literature should present a discussion about these complications in practitioners who operate on infants and neonates.

Therefore, the purpose of this study is to describe complications of umbilical access in newborns and infants less than 3 months via an anonymous survey of pediatric surgeons in order to better inform pediatric surgical practitioners. We specifically sought to assess the number and types of complications of umbilical access in newborns and infants

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less than 3 months of age, evaluate for possible associations between these complications and methods of umbilical access and determine surgeon awareness of potential risk of CO_2 embolus.

1. Materials and methods

1.1. Survey creation

The study authors (MPL and DB) created the survey questions relevant to the specific aims with a focus on minimizing the survey length to prevent survey fatigue. Following the creation of this survey, it was administered to a small group of surgeons within our large, academic pediatric surgery practice, to ensure both comprehension of survey questions and functionality of the REDCap™ survey tool. All feedback from this pilot group was incorporated into the survey. The number of survey questions ranged from 10 (if no history of complications from umbilical access) to 25 questions. The survey generally took less than 3 min to complete. The first question of the survey was a question of consent to participate in the study. Respondents who answered "no" were directed to a page thanking them for their time and ending the survey. No data were collected from these respondents. A statement of anonymity and confidentiality was located in the opening paragraph of the survey. Approval for this study was obtained from the Indiana University institutional review board (exempt study #1708771905) and the American Pediatric Surgical Association (APSA) Outcomes and Evidence-based Practice Committee.

The REDCap™-based survey was emailed to the listserv of the American Pediatric Surgical Association in February of 2018. Following the initial invitation to participate in the survey, two additional email reminders were sent in an effort to increase the response rate. No incentives were offered to increase response rates.

1.2. Statistical analysis

As this was primarily a descriptive survey, no a priori sample size was calculated. Ultimately, the final sample size was determined by the survey response rate. All data from this survey were categorical. Fisher's exact tests were used to evaluate for differences between groups. P-values <0.05 were considered statistically significant.

2. Results

The response rate was 31.3% (329/1050). Table 1 includes the demographics of respondents. 62.3% of respondents performed 21 or greater neonatal laparoscopic procedures annually and only 10% performed 10 or less procedures annually. A majority of respondents performed laparoscopic pyloromyotomy (84.2%), gastrostomy (90.6%), Nissen fundoplication (83.3%), and diagnostic laparoscopy (88.8%). Both laparoscopic inguinal hernia (46.2%) and a catch-all category of "other" (40.1%) were less frequent. Thirty-four of 322 respondents (10.6%) reported experiencing a direct complication from umbilical access for laparoscopy in this age group. These complications are reported in Table 2. Notably, respondents could report more than one complication. There was no association between how many laparoscopic cases respondents performed and reported complications of umbilical access ($p = 0.703$).

Table 3 includes responses to how the abdomen is entered in this age group, both with and without the presence of the umbilical cord stump. Most surgeons responding to the survey performed an open, direct trocar placement with 63.2% using this technique with the umbilical cord stump in place and 59.2% when no umbilical cord stump was present. In respondents answering the question related to both with and without the umbilical cord stump presence, 90.6% ($n = 288$) performed the same entry technique regardless of the umbilical cord stump status. There was no association with entry technique and report of any complication related to umbilical access by respondents whether the umbilical cord stump was still in place ($p = 0.51$) or absent ($p = 0.66$).

Table 4 includes responses to where the abdomen is entered in this age group, both with and without the presence of the umbilical cord stump. In patients with no remaining umbilical cord stump, the majority of respondents enter directly through the umbilicus (73.3%). When the stump remained, the most common entry sites include directly through the umbilicus (40.6%) and below the umbilicus (41.5%). Overall, 65.2% ($n = 210$) of respondents utilized the same location of entry regardless of whether or not the umbilical stump remains. There was no association between respondents who reported switching sites based on the presence of the umbilical cord stump and experiencing any complication ($p = 0.08$). There was no association between any complication and where the umbilical trocar was placed (above/below/through umbilicus) in patients without an umbilical cord stump ($p = 0.305$). There was an association between a reported complication and where the umbilicus was entered in patients with an umbilical cord stump still in place ($p = 0.013$). This association appeared to be driven by responding surgeons who entered the abdomen above or below the umbilicus depending on the operation being performed. Of these 36 surgeons, 12 (33%) reported experiencing any complication.

15.4% of respondents reported not knowing about the possibility of CO_2 embolism. There was no association between knowledge of CO_2 embolism and reporting the complication of a CO_2 embolism ($p = 0.201$). 41% of respondents confirmed intraabdominal placement of the umbilical trocar prior to insufflation. There was no association between respondents who inserted the laparoscope prior to insufflation to confirm intraabdominal placement and experiencing any complication ($p = 0.181$) or, more specifically, CO_2 embolism ($p = 0.309$). There was no association between respondents who inserted the laparoscope prior to insufflation to confirm intraabdominal placement and awareness of the possibility for CO_2 embolism.

In the final section of the survey, surgeons were invited to provide more information on specific cases in which a complication occurred. Table 5 includes a list of these complications. Responding surgeons described 36 specific cases (4 surgeons described two cases) with complications related to umbilical access. Laparoscopic pyloromyotomy made

Table 1
Demographics. Responses from 329 surgeons.

Annual laparoscopic cases	*n*	%
None	5	1.5
1–10	33	10
11–20	86	26.1
21 or greater	205	62.3
Which cases do you perform laparoscopically?		
Pyloromyotomy	277	84.2
Gastrostomy	298	90.6
Nissen fundoplication	274	83.3
Diagnostic laparoscopy	292	88.8
Inguinal hernia	152	46.2
Other	132	40.1

Table 2
General complications of umbilical access.

	Surgeons reporting complication ($n = 34$)[a]
Bowel injury	3 (0.9%)
Bleeding umbilical vessels	5 (1.5%)
Umbilical vein cannulation	4 (1.2%)
CO_2 embolism	18 (5.5%)
Hypotension	8 (2.4%)
Injury requiring blood transfusion	2 (0.6%)
Neurologic sequelae	6 (1.8%)
Death	3 (0.9%)
Other	7 (2.1%)

[a] Surgeons could report more than one complication.

Table 3
Results of how the abdomen was entered based on presence or absence of umbilical cord stump.

How do you enter the abdomen?				
	Umbilical cord stump in place		No umbilical cord stump	
Skin incision followed by opening in the fascia and peritoneum with trocar placement under direct visualization	203	63.2%	190	59.2%
Skin incision with Veress needle insertion followed by trocar placement	48	15.0%	57	17.8%
Skin incision with Step™ trocar placement	70	21.8%	74	23.1%

up 47.2% (17/36) of these cases. Other cases in which a complication occurred included: laparoscopic gastrostomy ($n = 2$), diagnostic laparoscopy ($n = 4$), laparoscopic inguinal hernia repair ($n = 2$), laparoscopic Nissen fundoplication ($n = 2$) and other ($n = 10$). The umbilical cord stump was present in 19.4% (7/36). 89.2% of these patients were term gestation neonates/infants. CO_2 embolism was the most common complication ($n = 17$). Other reported injuries/outcomes included: hypotension ($n = 7$), bleeding from umbilical vessels ($n = 6$), umbilical vein cannulation ($n = 5$), permanent neurologic sequelae ($n = 3$), death ($n = 2$), need for blood transfusion ($n = 1$), bowel injury ($n = 1$), other ($n = 5$) and unknown ($n = 1$). After the complication, 55.6% (20/36) of respondents changed their umbilical access technique.

3. Discussion

Umbilical access for laparoscopy in neonates and infants less than 3 months of age can present a unique challenge given the anatomy in the neonatal umbilicus after birth. We present the results of a survey of pediatric surgeons which demonstrates that 10% have experienced a complication of umbilical access for laparoscopy in this age group.

The advent of laparoscopy has revolutionized the practice of general surgery. Application of laparoscopic techniques first popularized in adults was subsequently applied to adolescent and younger patients [3,7,8]. Reports of successful use in neonatal and infant patients soon followed [9]. As the application of laparoscopic techniques increased, several authors evaluated outcomes in the laparoscopic versus the open technique, with most noting similar outcomes [10–12]. Several studies in the adult population have evaluated the specific complications related to umbilical access [13]. Hashizume and colleagues, in a large adult Japanese study, noted an overall complication rate of 1.0% related to needle or trocar entry and 0.48% related to pneumoperitoneum [14]. Few reports have been dedicated to understanding these potential complications of umbilical access into the abdomen for children. There are reports scattered in the literature, mainly in the form of case reports [6,15]. As with adult series, this survey demonstrates that all possible complications related to umbilical access can also occur in neonates and infants. Importantly, these survey results should not be interpreted as a 10% complication rate in laparoscopic cases as it is likely that thousands of laparoscopic cases are performed by the more than 300 respondents to this survey. Rather, it is our desire that these results raise the awareness of these potential complications of umbilical access, however rare, so that surgeons can have mitigation strategies prepared should they arise.

No robust data definitely support one abdominal entry technique over another in pediatric or adult patients. A Cochrane systematic review by Ahmad and colleagues evaluated laparoscopic entry techniques in 57 randomized control trials covering nearly 10,000 patients (mainly adult studies) [16]. The techniques specifically evaluated were open (Hasson technique) entry versus closed entry (includes direct optical trocar and Veress needle), direct optical trocar versus Veress needle entry, direct optical entry versus open entry, and radially-expanding (i.e. STEP™) trocars versus nonexpanding trocars. The authors noted insufficient evidence to support one entry technique over another except for a possible advantage of direct trocar entry over Veress needle entry for failed abdominal entry. A systematic review and meta-analysis by Cornette and Berrevoet evaluated abdominal entry technique and trocar complications in adult laparoscopic surgery [17]. Their analysis demonstrated fewer minor complications (minor vascular injury including trocar site bleeding, wound infection, omental injury, extraperitoneal insufflation) and failed attempts at abdominal entry with the direct trocar technique or the Hasson technique when compared to the Veress needle entry. Evidence was limited for significant differences in major complications. The results from this survey of the APSA membership reveal both major and minor complications in the 36 cases described in more detail by respondents. Unfortunately, the specific method of abdominal entry was not evaluated in these cases. However, in general, there did not appear to be an association between the abdominal entry technique utilized by respondents and the report of complications related to umbilical access.

The best/safest location of abdominal entry at the umbilicus has not been systematically and robustly studied in neonates and infants. In our study, complications were experienced with surgeons utilizing every entry location, except for a minority of surgeons ($n = 10$) who used entry above the umbilicus. As only 2 of these surgeons utilized this same entry location when entering the abdomen with and without the umbilical cord stump present, it is difficult to make broad statements about the benefit of this location over others. Additionally, one of the 36 specific cases reported had abdominal entry above the umbilicus. The presence of the umbilical cord stump clearly dictated the location of entry with 73.3% of surgeons entering directly through the umbilicus when the cord stump was not present and only 40.6% entering directly through with the cord stump still in place. Of the 36 specific cases with complications reported by surgeons in this survey, 77.8% occurred with entry directly through the umbilicus and in most cases the umbilical cord stump was no longer present (80.6%). Further investigations of large case series will need to be performed to understand the outcomes of entry in each of these locations. As is the case in many aspects of surgery, ultimately, the best option may be the option for which the surgeon has the most experience and comfort in obtaining abdominal access at the umbilicus.

The most common complication reported by surgeons responding to this survey was gas/CO_2 embolism (5.5%). This should not be interpreted as 5.5% of laparoscopic cases experiencing this complication; rather, 5.5%

Table 4
Results of where the abdomen was entered based on presence or absence of umbilical cord stump.

Where do you enter the abdomen?				
	Umbilical cord stump in place		No umbilical cord stump	
Above the umbilicus	10	3.1%	2	0.6%
Below the umbilicus	134	41.5%	60	18.6%
Above/below the umbilicus depending on the operation being performed	48	14.9%	24	7.5%
Directly through the umbilicus (i.e., through the congenital fascial defect)	131	40.6%	236	73.3%

Table 5
Thirty-three surgeons described 36 specific cases during which they experienced a complication of umbilical access. These cases, and associated complications, are listed by location of abdominal entry (more than one complication could be reported per case).

Case Type	Number of cases	Complications Reported with Access Below the Umbilicus	Complications Reported with Access Through the Umbilicus	Complications Reported with Access Above the Umbilicus
Laparoscopic Pyloromyotomy	17	CO_2 embolism (1); Other (1)	CO_2 embolism (4); Umbilical vein cannulation (3); Hypotension (3); Other (3); Bleeding (1); Bowel Injury (1)	
Other	10		CO_2 embolism (8); Bleeding (2); Death (2); Permanent Neurologic Sequelae (1); Hypotension (1); Umbilical Vein cannulation (1)	
Diagnostic Laparoscopy	4	Hypotension (3); Bleeding (2); CO_2 Embolism (1); Permanent Neurologic Sequelae (1)	Unknown (1)	
Laparoscopic Gastrostomy	2		CO_2 Embolus (1); Bleeding (1)	
Laparoscopic Inguinal Hernia Repair	2		Other (1)	Need for Blood Transfusion (1)
Laparoscopic Nissen Fundoplication	2	CO_2 Embolism (1)	CO_2 Embolism (1); Umbilical Vein Cannulation (1); Permanent Neurologic Sequelae (1)	

of responding surgeons, likely representing thousands of laparoscopic cases performed, reported this complication. In adult patients undergoing laparoscopy, CO_2 embolism was described as early as the mid-1970s [18,19]. The mortality rate was 28% in one study of adult patients with gas emboli [20]. Clinically significant gas emboli have been noted to be rare in large adult series with one estimate at 0.001% of nearly 500,000 cases analyzed. [21] However, clinically insignificant emboli may be more common. In a study of adult patients undergoing laparoscopic cholecystectomy with continuous transesophageal echocardiography monitoring, CO_2 emboli could be seen in the right atrium in 11 of 16 patients (68.8%) [22]. In 5 of these 11 patients, the emboli occurred at the time of insufflation. The clinical significance of these emboli in adults is generally minimal; however, in the neonatal population, particularly those with patent foramen ovale or other right-to-left shunts, small emboli could be significant. Graff and colleagues, in the 1950s, studied the effects of air and CO_2 emboli in dogs. They noted an LD_{50} (dose at which half of the study animals died) was 25 mL/kg [23]. As anticipated, given air's decreased solubility in the bloodstream, it had notably higher toxicity (LD_{50} of 5 ml/kg). Standard treatment for presumed air/CO_2 embolus is immediate cessation of insufflation and release of the pneumoperitoneum. The patient should be placed in steep Trendelenburg position with left lateral decubitus position (Durant's position) to encourage obstructing emboli to the apex of the right ventricle [6,24]. Additionally, 100% inspired oxygen and volume expansion should also be employed. Other options also include aspiration of emboli via a central venous catheter, percussion of the chest to break up emboli and hyperbaric oxygen. In patients with hemodynamic collapse, standardized cardiopulmonary resuscitation algorithms should also be employed [20].

The focus on complications of umbilical access in this patient population should not overshadow the fact that, overall, laparoscopy in this age group is safe. Several authors have reported minimal to no significant complications in large series [9,25,26]. In our survey, 15.4% of surgeons did not know about the complication of air embolism as a complication of umbilical access. While this complication was not associated with experiencing an air embolism in this survey, it is important to highlight this knowledge gap. Education and preparation, starting with highlighting this as a possible complication in pediatric patients, will ultimately help surgeons make laparoscopy even safer for future patients.

There are several limitations of this study. First, our response rate was 31%. While this represents a comparable or even higher rate to other recent surveys to the APSA membership, there is certainly the possibility of nonresponse/participation bias. Despite a focus on anonymity, surgeons may have still felt reluctant to describe cases in which a complication and/or death occurred (resulting in response bias). Over surveying fatigue is also a possible etiology for the low response rate. Second, the survey questions were written in a way which generalized several abdominal entry techniques. This limits our ability to make more granular statements about subtle technique differences that may be utilized by surgeons within these broad categories.

4. Conclusions

Laparoscopy is commonly used in neonates and infants less than 3 months of age for a variety of procedures including pyloromyotomy, gastrostomy and Nissen fundoplication. Umbilical access for laparoscopy in this population can present a unique challenge and result in significant complications. The most common complication reported was CO_2 embolism and 15% of the pediatric surgeons surveyed did not know about this potential complication. Surgeons should be aware of these risks and be prepared to manage them emergently if they arise.

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