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Abdominal compartment syndrome monitoring in neonates with an acute abdomen – A pilot, retrospective, observational study

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ABSTRACT

Background: Abdominal compartment syndrome (ACS) is a pathological increase of the intra-abdominal pressure (IAP) with dysfunction of one or more organs. There is lack of clarity in neonates regarding what intravesical pressure (IVP) value, a surrogate marker for IAP, indicates the need for intervention for ACS.
Methods: The medical records at a Children's Hospital NICU were reviewed to identify all neonates that had IVP/s monitored over a 10-year period (2008–2017). Demographic parameters, IVPs, and important clinical outcomes were obtained. Associations between IVP monitoring and clinical outcomes were explored.
Results: Forty-six neonates had IVP monitoring, with 4 (8%) being diagnosed with ACS requiring further operative intervention. There was no significant correlation between IVP and need for surgery. There was a significant positive correlation between the maximum IVP and the need for total parenteral nutrition ($rs = 0.350$, $p = 0.017$), ventilator support ($rs = 0.321$, $p = 0.034$) and length of stay ($rs = 0.362$, $p = 0.016$) and between a diagnosis of ACS and neonatal mortality ($rs = 0.299$, $p = 0.044$).
Conclusions: IVP monitoring and raised IVP did not correlate with the need for surgical intervention. Raised IVP was associated with neonatal morbidity and maybe neonatal mortality. A large, prospective, observational study is required to evaluate the role of IVP monitoring in ACS and its associated outcomes.
Level of Evidence: III.

Abdominal compartment syndrome (ACS) is a pathological increase of the intra-abdominal pressure (IAP) with associated dysfunction of one or several organs [1]. It can lead to increased intra-abdominal pressure and an acute abdomen with reduced splanchnic, hepatic and portal perfusion causing bowel ischemia and refractory metabolic acidosis [2,3]. It is a well-recognized disease entity in adults, with the most common causes being major abdominal surgeries for trauma and/or aortic aneurysms [2,3].

In neonates on the other hand, ACS is rare and has a significantly lower incidence of 0.6–4.7% demonstrated in previous studies [4–6]. Despite this, it carries a high mortality rate of 60% [2,3]. The pediatric subcommittee of the World Society of Abdominal Compartment Syndrome (WSACS) recently defined pediatric intra-abdominal hypertension (IAH) as >10 mmHg and ACS as a sustained or repeated pathological elevation in IAP >10 mmHg with associated new or worsening organ dysfunction [7]. Interestingly, there remains a lack of a clear definition in the guidelines regarding what constitutes a sustained elevation in IAP. Moreover, compared to the pressures of 20–50 mmHg required to have detrimental effects in adults, this is strikingly low and indicates a need for rigorous monitoring and diagnosis.

There are numerous diagnostic options available, with the gold standard being directly via an intraperitoneal catheter [7,8]. However, its use in clinical practice is limited due to the potential complications of bowel perforation and associated peritoneal contamination [8–10]. Therefore, several indirect methods have been studied, with the current preferred standard for these being the use of intravesical pressure (IVP) monitoring as it provides a good, safe surrogate measure for IAP [8–11]. It has been demonstrated that serial IVP measurements in neonates with a confirmed diagnosis of necrotising enterocolitis (NEC) may guide decisions surrounding surgical intervention and mortality prediction [10].

However, there exists a lack of evidence for the use of IVP monitoring in the earlier stages of an acute abdomen [4]. In these early stages, the initial findings are non-specific and are often very difficult to separate from findings indicating neonatal sepsis from extra-gastrointestinal aetiologies or other gastrointestinal conditions [4,10]. Many of the detrimental effects caused by increased IAP are potentially

Abbreviations: ACS, abdominal compartment syndrome; IAH, intra-abdominal hypertension; IAP, intra-abdominal pressure; IVP, intravesical pressure; NEC, necrotising enterocolitis; WSACS, World Society of Abdominal Compartment Syndrome.

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reversible with early and appropriate intervention [4]. Therefore, there remains an ongoing need for effective diagnostic tests that can facilitate this early detection of the ACS process and potentially earlier diagnosis of NEC [10].

There also remains a lack of guidance regarding what IAP values indicate the need for medical and/or surgical intervention in neonates with ACS and/or suspected NEC [4]. Previous research has suggested that intra-abdominal pressures of 10-15 mmHg can have significant detrimental effects in children and could provide the threshold at which ACS occurs [9–12].

Therefore, this study aims to further investigate the benefit of routine monitoring of IVPs in neonates with ACS. In particular, if raised IVP correlates with need for surgical intervention and is associated with important clinical outcomes.

1. Materials and methods

1.1. Study population

The electronic medical records and neonatal database at the Sydney Children's Hospitals Network Westmead neonatal intensive care unit (NICU) were reviewed in order to identify all neonates that had their intravesical pressure/s monitored over a ten-year period from 2008 to 2017. Additionally, hardcopy records were reviewed in order to reduce potential bias. Ethics approval was obtained from the Human Research and Ethics Committee (HREC) at The Children's Hospital at Westmead, reference number LNR/18/SCHN/120.

Once the neonates had been identified, their medical records were reviewed in more detail. Their demographic parameters including gender, gestational age, birth weight, antenatal or postnatal diagnosis and APGAR scores at 1 and 5 min were obtained. Other data collected included the documented IVP, number of times the pressure was measured, and duration of IVP monitoring in days. Maximum, minimum and average IVPs were calculated. The reason for pressure monitoring was also recorded. Additional data points collected in relation to the secondary outcomes included time on ventilation, time on TPN, length of stay and mortality. Finally, the records were reviewed to collect the primary outcome, or if surgery was required and, if so, what operation was performed.

1.2. Bladder pressure monitoring method

As demonstrated in Fig. 1, a revised closed system technique was used to measure IVP. In more detail, a ramp with three stopcocks is inserted in the drainage tubing connected to the indwelling catheter, with each attached to a different component:

- First stopcock: standard infusion set connected to a bag with 1000 mL of normal saline
- Second stopcock: 60 mL syringe
- Third stopcock: connected to a pressure transducer via rigid pressure tubing

The pubic symphysis used as the zero point [10,13]. The transducer is connected to the monitor, reset and the saline solution of 1 mL/kg is injected into the bladder [10]. With the flow into the urinary bag blocked by the triple tap, the IVP can be measured [10]. The pressures were monitored every 4 h as per the WSACS guidelines [7].

1.3. Statistical analysis

The data was de-identified and analyzed using SPPS (V.24) and STATA (STATA, Version 14; StataCorp, College Station, TX, USA). Descriptive statistics were used for the whole cohort and subgroups for demographic variables, primary and secondary outcomes. Between group analysis was completed using Spearman rho correlations. All tests were two tailed and statistical significant differences were considered at the $p < 0.05$ level. Only correlation analysis could be performed in this study due to their being a low number of neonates diagnosed with ACS and a low number of these neonates requiring operative management.

2. Results

2.1. Demographics

Forty-six neonates had their IVP monitored in the NICU over a 10-year period. Twenty-two (48%) were male and 24 (52%) were female. The median gestational age was 37 (IQR = 35.25–38.0) week and median birth weight 2610 (IQR = 2186–3213) grams. Forty neonates (87%) had an antenatal diagnosis of a foetal anomaly (Table 1). The most common anomalies diagnosed were gastroschisis in 21 (48%) neonates and exomphalos in 8 (17%) neonates.

Table 2 outlines the indications for IVP monitoring for the population. Of the 46 neonates who had IVP monitoring, 39 (85%) had it performed following an operative intervention. Of these, 36 (78%) had it monitored following a gastrointestinal operation and 3 (7%) had it monitored following a cardiothoracic procedure. Comparatively, 3 (7%) of the 46 neonates had their IVP monitored and did not undergo surgical management. Finally, 4 (8%) of the 46 neonates had their IVPs monitored due to ACS being suspected prior to any operative intervention.

2.2. Intravesical pressures

The median IVP of all 46 neonates was 10 mmHg (IQR = 6–13). As outlined in Table 4, the highest IVP recorded was 40 mmHg in neonate number 33 who had IVP monitoring post primary repair of gastroschisis. Their postoperative course was complicated by suspected ACS secondary to bowel obstruction from a stricture on day 3 post procedure. The second highest IVP was 32 mmHg in neonate number 38 who was

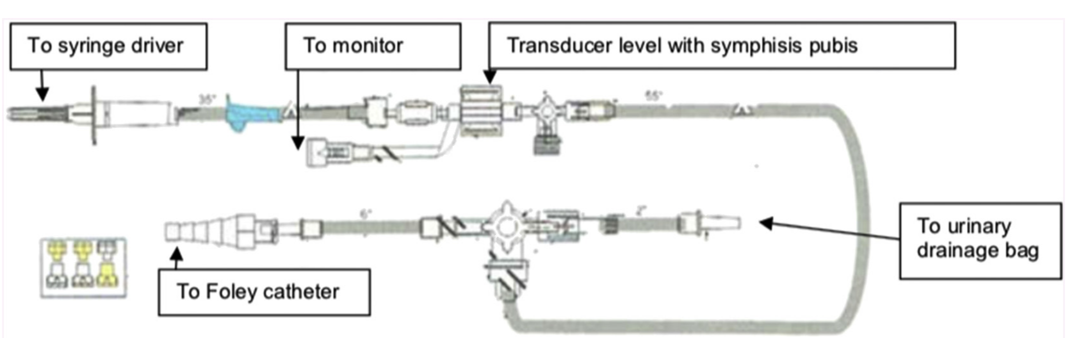

Fig. 1. IVP monitoring setup used in the study.

Table 1
Patient demographics.

General demographics	Total (n = 46)
Male gender	22 (48%)
Female gender	24 (52%)
Foetal anomaly	40 (87%)
Median gestational age	37 weeks (*IQR* = 35.25–38.0)
Median birth weight	2610 g (*IQR* = 2186–3213)
Median head circumference	32.1 cm (*IQR* = 30.0–32.5)
Median APGAR at 1 min	8 (*IQR* = 9–6)
Median APGAR at 5 min	9 (*IQR* = 9–8)
Anomalies	**Total (n = 46)**
Gastroschisis	21 (47%)
Exomphalos	8 (17%)
Congenital diaphragmatic hernia	8 (17%)
Hypoplastic left heart	2 (4%)
Volvulus	2 (4%)
Other congenital cardiac anomaly	2 (4%)
Other congenital gastrointestinal anomaly	3 (7%)

being monitored post patch closure and repair of their congenital diaphragmatic hernia. Neither neonate required further operative intervention and their elevated IVPs resolved.

Additionally, there were neonates whose primary indication for IVP monitoring was post gastrointestinal surgical procedure, who then went on to require further gastrointestinal operations. Neonates 18, 20, 22, 41 and 44 underwent further gastrointestinal operations for management of a small bowel obstruction, bowel stenting, hernia repair, adhesiolysis and enterostomy and correction of ileal atresia respectively. None experienced ACS and only had their IVPs monitored after their initial operation.

In Table 3 the neonates highlighted in bold font are those who had IVPs monitored due to clinical suspicions of ACS. These were neonates numbered 29, 34 and 37 and their maximum IVPs were 17 mmHg, 11 mmHg and 27 mmHg respectively. Neonate 30 had IVP monitoring following primary gastrointestinal surgery and did not require any further operative management. On the other hand, neonate 37 had their pressures monitored during their NICU admission, without requiring any operative management.

Comparatively, in underlined font are the neonates who were diagnosed with ACS. These were numbers 2, 5, 17 and 34 and their maximum IVPs were 22 mmHg, 11 mmHg, 13 mmHg and 15 mmHg respectively. Neonates 2, 5 and 17 initially required IVP monitoring following their primary gastrointestinal surgery. Neonate 34's course is outlined in more detail below. Once the diagnosis of ACS was made, each of these 4 neonates required operative management, and postoperative IVP monitoring. Moreover, they each experienced a complicated postoperative course, which is also outlined in more detail below.

There were no neonates that experienced ACS secondary to development of ascites after aggressive fluid resuscitation. There were no recorded complications associated with IVP monitoring in this population.

Table 2
Specific indication for intravesical pressure monitoring and mean intravesical pressure for each diagnosis.

Indication	Total (n = 46)	Median intravesical pressure (mmHg)
Postoperative monitoring		
Post gastrointestinal surgical procedure	36 (78%)	10 (*IQR* = 6–13)
Post cardiothoracic surgical procedure	3 (7%)	7 (*IQR* = 7–11)
Other monitoring		
Diagnosed gastroschisis	3 (7%)	8 (*IQR* = 6–9)
Suspected ACS	4 (8%)	11 (*IQR* = 8–15)

2.3. Neonates with abdominal compartment syndrome

As previously mentioned, there were 4 neonates who had a confirmed diagnosis of ACS. Table 4 outlines their primary indication for operative management and the maximum IVPs that guided this, with the highest being 20 mmHg for neonate 2. Additionally, their median IVPs prior to the operative management of their ACS are outlined, with neonate 2 having the highest average pressure of 14 mmHg. In each case, the decision to operate was made in a multidisciplinary setting and was guided by the clinical deterioration of the neonate.

In more detail, neonate 2 initially received postoperative IVP pressure monitoring following a silo, reduction and patch repair of their exomphalmos. Their postoperative course was complicated by ACS that required one further operation, an emergency laparotomy, exploration and closure. Following this operation, they did not undergo any further IVP monitoring.

Neonate 5 also had postoperative IVP monitoring, performed following a silo, reduction and delayed primary closure of their gastroschisis. Their postoperative course was complicated by ACS secondary to adhesions and malrotation that required two further operations: a laparotomy, adhesiolysis, malrotation repair and a re-look laparotomy. Following their laparotomy, adhesiolysis and malrotation repair, no further IVP monitoring was performed.

Neonate 17 initially had a congenital diaphragmatic hernia repair, with postoperative IVP monitoring performed. Their recovery was complicated by ACS secondary to an intestinal malrotation that required a Ladd's procedure. Following this procedure, no further IVP monitoring was performed. Their subsequent returns to theater were for a percutaneous endoscopic jejunostomy tube insertion and an oesophagostomy. Despite these multiple operations, they deteriorated clinically and passed away at 34 days of age secondary to post haemorrhagic hydrocephalus.

Neonate 34 is highlighted in red and green as there was a clinical suspicion of ACS requiring IVP monitoring. This progressed to a confirmed diagnosis of ACS once imaging demonstrated an intra-abdominal hemorrhage. This was managed with a laparotomy, washout and laparostomy, again with no further IVP monitoring performed. Following this, they deteriorated clinically and passed away 26 days of age secondary to overwhelming sepsis.

3. Results – primary and secondary outcomes

3.1. Primary outcome

There were no statistically significant correlations between the need for surgery and minimum IVP ($r_s = -0.184$, $p = 0.220$), maximum IVP ($r_s = 0.202$, $p = 0.177$) or average IVP ($r_s = 0.073$, $p = 0.630$). Additionally, there were no statistically significant correlations between the need for surgery and if the maximum IVP was <10 mmHg ($r_s = -0.147$, $p = 0.329$) or the maximum IVP was >10 mmHg ($r_s = 0.147$, $p = 0.329$).

3.2. Secondary outcome

There was a statistically significant, positive correlation between the maximum IVP and length of time the neonate required TPN ($r_s = 0.350$, $p = 0.017$), ventilator support ($r_s = 0.321$, $p = 0.034$) and their length of stay ($r_s = 0.362$, $p = 0.016$). There was no statistically significant correlation between the maximum IVP and a diagnosis of ACS ($r_s = 0.015$, $p = 0.923$) or neonatal mortality ($r_s = -0.005$, $p = 0.976$). There were no statistically significant correlations regarding the minimum IVP and aforementioned variables.

Finally, there was a statistically significant, weak, positive correlation between a diagnosis of ACS and neonatal mortality ($r_s = 0.299$, $p = 0.044$).

Table 3
Indications for intravesical pressure monitoring and key results for each neonate. Note that the neonates highlighted in bold font are those who had intravesical pressures monitored due to clinical suspicions of ACS. Comparatively, in underlined font are the neonates who were diagnosed with ACS.

Neonate	Indication for intravesical pressure monitoring	Further operative management	Number of intravesical pressures measured	Minimum intravesical pressure (mmHg)	Maximum intravesical pressure (mmHg)	Median Intravesical pressure (mmHg)
1	Post gastrointestinal surgical procedure	No	105	0	25	10 ($IQR = 6–13$)
2	Post gastrointestinal surgical procedure	1 operation	336	5	22	13 ($IQR = 12–15$)
3	Diagnosed gastroschisis	No	59	4	20	8 ($IQR = 5–9$)
4	Post gastrointestinal surgical procedure	No	8	5	10	8 ($IQR = 7–10$)
5	Post gastrointestinal surgical procedure	2 operations	20	1	11	5 ($IQR = 3–6$)
6	Diagnosed gastroschisis	No	6	5	10	8 ($IQR = 6–9$)
7	Post cardiothoracic surgical procedure	No	8	5	6	5 ($IQR = 5–6$)
8	Post gastrointestinal surgical procedure	No	12	5	13	6 ($IQR = 6–7$)
9	Post gastrointestinal surgical procedure	No	6	4	7	5 ($IQR = 5–7$)
10	Post gastrointestinal surgical procedure	No	27	6	17	9 ($IQR = 6–10$)
11	Post gastrointestinal surgical procedure	No	5	5	7	6 ($IQR = 6–6$)
12	Post gastrointestinal surgical procedure	No	12	2	17	9 ($IQR = 6–9$)
13	Post gastrointestinal surgical procedure	No	14	7	13	10 ($IQR = 9–11$)
14	Post gastrointestinal surgical procedure	No	40	1	15	2 ($IQR = 2–3$)
15	Post gastrointestinal surgical procedure	No	5	0	11	2 ($IQR = 2–2$)
16	Post gastrointestinal surgical procedure	No	12	7	16	8.5 ($IQR = 8–10$)
17	Post gastrointestinal surgical procedure	3 operations	4	7	13	8 ($IQR = 9–12$)
18	Post gastrointestinal surgical procedure	4 operations	24	4	15	8 ($IQR = 6–8$)
19	Post gastrointestinal surgical procedure	No	16	3	7	6 ($IQR = 5–6$)
20	Post gastrointestinal surgical procedure	5 operations	5	8	12	10 ($IQR = 8–11$)
21	Post gastrointestinal surgical procedure	No	50	2	11	6 ($IQR = 4–8$)
22	Post gastrointestinal surgical procedure	2 operations	50	2	22	8.5 ($IQR = 6–12$)
23	Post gastrointestinal surgical procedure	No	17	2	13	7 ($IQR = 6–8$)
24	Post gastrointestinal surgical procedure	No	17	6	10	8 ($IQR = 8–9$)
25	Post gastrointestinal surgical procedure	No	76	3	8	5 ($IQR = 4–5$)
26	Post gastrointestinal surgical procedure	No	48	7	18	13 ($IQR = 11–15$)
27	Post gastrointestinal surgical procedure	No	8	2	7	4 ($IQR = 3–5$)
28	Post cardiothoracic surgical procedure	No	13	7	15	11 ($IQR = 8–13$)
29	**Suspected ACS**	**No**	**2**	**4**	**6**	**5 ($IQR = 5–6$)**
30	Post gastrointestinal surgical procedure	No	42	5	17	8 ($IQR = 7–10$)
31	Post gastrointestinal surgical procedure	No	4	10	14	11 ($IQR = 10–13$)
32	Post gastrointestinal surgical procedure	No	11	4	12	10 ($IQR = 8–11$)
33	Post gastrointestinal surgical procedure	No	60	1	40	13 ($IQR = 9–19$)
34	Suspected ACS	**1 operation**	11	**3**	15	**4 ($IQR = 3–6$)**
35	Post gastrointestinal surgical procedure	No	16	7	15	10.5 ($IQR = 9–12$)
36	Post gastrointestinal surgical procedure	No	45	4	9	6 ($IQR = 5–7$)
37	**Suspected ACS**	**No**	**124**	**4**	**27**	**12 ($IQR = 9–17$)**
38	Post gastrointestinal surgical procedure	No	35	5	32	11 ($IQR = 9–15$)
39	Post gastrointestinal surgical	No	11	7	13	10 ($IQR = 9–12$)

(continued on next page)

Table 3 *(continued)*

Neonate	Indication for intravesical pressure monitoring	Further operative management	Number of intravesical pressures measured	Minimum intravesical pressure (mmHg)	Maximum intravesical pressure (mmHg)	Median Intravesical pressure (mmHg)
	procedure					
40	Post cardiothoracic surgical procedure	No	1	6	6	6 (*IQR* = 6–6)
41	Post gastrointestinal surgical procedure	3 operations	18	5	14	9.5 (*IQR* = 8–11)
42	Post gastrointestinal surgical procedure	No	11	3	12	6 (*IQR* = 5–8)
43	Post gastrointestinal surgical procedure	No	1	5	5	5 (*IQR* = 5–5)
44	Post gastrointestinal surgical procedure	1 operation	15	8	13	10 (*IQR* = 9–11)
45	Post gastrointestinal surgical procedure	No	35	7	14	10 (*IQR* = 9–11)
46	Diagnosed gastroschisis	No	5	11	13	12 (*IQR* = 11–13)

4. Results – post hoc analysis

There was a statistically significant, positive correlation between the number of IVPs taken and the length of time the neonate required TPN ($r_s = 0.381$, $p = 0.009$), ventilator support ($r_s = 0.324$, $p = 0.032$) and their length of stay in the NICU ($r_s = 0.434$, $p = 0.003$). There was no statistically significant correlation between a diagnosis of ACS ($r_s = 0.017$, $p = 0.908$) or neonatal mortality ($r_s = -0.219$, $p = 0.144$) with an increased number of IVPs taken.

There was a statistically significant, positive correlation between the number of days the neonates' IVPs were monitored for and length of time the neonate required TPN ($r_s = 0.463$, $p = 0.001$), ventilation ($r_s = 0.545$, $p = <0.001$) and their length of stay ($r_s = 0.444$, $p = 0.003$). There no correlation regarding the number of days the pressure was monitored for and a diagnosis of ACS ($r_s = 0.056$, $p = 0.710$) or neonatal mortality ($r_s = -0.056$, $p = 0.713$).

5. Discussion

In the identified population of neonates that underwent IVP monitoring over the 10-year time period, the majority were monitored post-operatively. More specifically, there were only 4 (8.70%) that were monitored due to a suspected acute abdomen and only 4 (8.70%) neonates who were diagnosed with ACS. This incidence is in keeping with the literature, with the occurrence of ACS in pediatric intensive care settings reported as ranging from 0.6–9.8% [7]. More importantly, all 4 of the neonates required operative intervention to relieve their ACS after elevated IVPs >15 mmHg were observed and combined with their clinical status. This highlights the fact that, in all of the patients with ACS, IVP monitoring was important and guided clinical management, namely when operative intervention was required.

Additionally, there were no statistically significant correlations between the need for surgery and minimum IVP, maximum IVP, average IVP or if the maximum IVP was <10 mmHg or >10 mmHg. Whilst there lacked clear statistical significance for these outcomes, there again exists clinical significance. In the small subgroup identified, where IVP monitoring was instituted to investigate potential ACS, their clinical progress supports recent findings in the literature. Several authors have previously suggested that pressures of 10–15 mmHg [9–12] and even as low as 5.25 mmHg [10] can have significant detrimental effects in children and could provide the threshold at which ACS occurs. Moreover, the recent definitions by WSACS define pediatric IAH as an IAP >10 mmHg and ACS as a sustained elevation in IAP >10 mmHg with new or worsening organ dysfunction that can be attributed to elevated IAP [7]. These values were observed in the neonates that required operative intervention, providing further support for these findings, the benefits of routine IVP monitoring and the potential to guide the need for surgical intervention.

As may be expected, elevated intra-abdominal pressure has previously been demonstrated to be an independent risk factor for mortality in pediatric intensive care settings [7,14,15], with one study by Kutessa et al. demonstrating that patients with IAH at 6 h postoperatively were 24 times more likely to die than those without elevated IAH [7]. In this study a weak correlation between a diagnosis of ACS and neonatal mortality was observed. The weak nature of the correlation could have been due to the small sample size, however it continues to indicate the critical importance of early diagnosis ACS and early implementation of intervention to prevent this outcome.

Regarding the secondary outcomes, previous research has shown that neonates with ACS are critically unwell and had increased ventilator requirements and length of stay [14]. Here, statistically significant, positive correlations were observed between the maximum IVP with the length of time the neonate required ventilator support, TPN and NICU admission. This provides ongoing support as well as novel correlations regarding the morbidity of ACS and associated need for parenteral nutrition, and endorses the importance of earlier recognition of ACS to facilitate intervention and potentially reduce late diagnosis, deterioration, and associated morbidities.

This highlights a requirement for future prospective research surrounding regular IVP monitoring during the perioperative period in neonates with an acute abdomen. More specifically to provide further support for clear clinical definitions and assist in the formation of guidelines surrounding when operative intervention may be required to prevent morbidity and mortality.

5.1. Strengths and limitations

The main strengths of this study was the use of IVP monitoring, which is the current gold standard for monitoring for ACS [8–12] and that a substantial time period was reviewed at a major tertiary pediatric

Table 4
Specific indication for intravesical pressure monitoring for the neonates with confirmed ACS and mean intravesical pressure for each diagnosis.

Neonate	Primary indication for operative management	Median intravesical pressure (mmHg)	Maximum intravesical pressure that prompted operative management (mmHg)
2	Post silo, reduction and patch repair of exomphalmos	13 (*IQR* = 12–15)	20
5	Post silo, reduction and delayed primary closure of gastroschisis	5 (*IQR* = 3–6)	11
17	Post congenital diaphragmatic hernia repair	8 (*IQR* = 9–12)	13
34	Suspected ACS	4 (*IQR* = 3–6)	15

hospital. Additionally, the perioperative management of these neonates provides another strength. The neonates were commenced on maintenance fluids and losses more than 20 mL/kg/day were replaced with normal saline. There is a strong focus on avoiding excessive fluid replacement to avoid third space losses and further increases in IAP. Moreover, it is routine practice for IVPs to be monitored during the intra-operative closure, with the anesthetist providing feedback regarding ventilator pressures, to avoid aggressive closure of the abdominal wall. These combine to decrease the risk of ACS.

The key limitation to this study was the sample size and its associated decreased ability to draw strong conclusions. This is because it was conducted at a single centre, which limited the sample size. Additionally, it was a retrospective analysis that only included select patients with IVP monitoring, as it was not standard practice to monitor all patients with an acute abdomen. The retrospective nature of the study also limited the information that could be obtained, of particular importance was the lack of documentation indicating clear criteria or clinical information used to guide the decision to operate for each neonate with ACS or whether routine chemical prophylaxis was used to ensure accurate measurements of IVP.

The main statistical limitation of this study was that regression techniques were unable to be used to investigate the relationship between ACS and the variables and account for gestational age. The small sample size was the main cause for assumptions not being met for regression.

5.2. Conclusion/recommendations

Although abdominal compartment syndrome has a relatively low incidence in neonates, it is a condition that requires timely recognition, diagnosis and intervention by all members of the healthcare profession. Intravesical pressure monitoring has the potential to address this critical problem. This report demonstrates the benefit of its routine use in neonates with acute abdomens and its potential to facilitate decreased morbidity and mortality in these neonates. Moreover, this review reinforces the need for future prospective research regarding regular intravesical pressure monitoring preoperatively and postoperatively in neonates with suspected abdominal compartment syndrome.

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