The value of intra-abdominal pressure monitoring through transvesical route in the choice and outcome of management of congenital abdominal wall defects

Adham Elsaied, Sherif Medhat, Hesham Sheir and Kamal Aly

Introduction **Gastroschisis and omphalocele are most common congenital abdominal wall defects (AWDs). Surgical management aims to reduce the evisceration safely, close the defect with a cosmetically acceptable outcome under guidance of intraoperative monitoring of intra-abdominal pressure (IAP). Intravesical pressure monitoring technique recommended by (WSACS) is the most reliable technique for IAP measurement in neonates.**

Aim **The aim of this study is to assess the value of IAP monitoring via vesical pressure measurement in the choice and outcome of management of congenital AWDs.**

Patients and methods **This is a prospective study of 25 cases that suffered congenital anterior AWDs (gastroschisis and omphalocele) admitted to Mansoura University Children Hospital during the period from October 2013 to October 2015. They were all operated upon guided by IVP monitoring during and after repair.**

Results **In our study, 14 (56%) cases presented with gastroschisis and 11 (44%) presented with exomphalos with a median age of 24 h. Males (56%) were slightly more than females (44%). Congenital anomalies were reported in 16 cases (64%). Primary fascial closure was successful in 15 (60%) cases, whereas Silo repair was done in six (24%) cases and skin closure in only four (16%) cases. During the attempts of closure the mean abdominal perfusion pressure was 40.24 ± 5.59, the mean peak inspiratory pressure was 24 ± 6.11 and the mean IAP was 22.60 ± 6.89. Two cases developed intra-abdominal hypertension after abdominal closure (8%) and only one of them needed decompressive laparotomy (4%). Postoperative complications were reported in 15 (60%) cases and mortality occurred in eight (32%) cases.**

Conclusion **Increased IAP secondary to forceful closure of the abdominal defect is associated with the occurrence of complications. IVP monitoring is feasible during closure of AWDs and a threshold of 20 cm H_2O is appropriate to decide between primary and staged approach. *Ann Pediatr Surg* 13:69–73 © 2017 Annals of Pediatric Surgery.**

Annals of Pediatric Surgery 2017, 13:69–73

Keywords: congenital abdominal wall defect, intravesical pressure, intra-abdominal hypertension

Department of Pediatric Surgery, Mansoura University Children's Hospital, Mansoura, Egypt

Correspondence to Adham Elsaied, Department of Pediatric Surgery, Mansoura University Children's Hospital, 60 Gomhoria Street, Mansoura 35516, Egypt
Tel: +20 122 391 2996; fax: +20 502 238 673;
e-mail: adhamawe@yahoo.com

Received 24 October 2016 **accepted** 29 November 2016

Introduction

Intra-abdominal hypertension (IAH) and abdominal compartmental syndrome (ACS) represent a spectrum of severity of a disorder that affects whole-body systems including cerebral, cardiac, renal and respiratory functions and carries a significant morbidity and mortality [1,2].

Normal intra-abdominal pressure (IAP) is $\sim 7 \pm 3$ mmHg, whereas IAH in children is defined as a sustained or repeated pathological elevation in IAP of at least 10 mmHg [3]. Abdominal perfusion pressure (APP) (mean arterial pressure minus the IAP) is a more accurate predictor of visceral perfusion and a potential endpoint for resuscitation. Its normal value ranges between 40 and 50 mmHg [4].

ACS in pediatric and neonatal age group is defined as a sustained IAP of greater than 10 mmHg associated with new organ dysfunction or failure [5]. It is a known complication of repair of abdominal wall defects (gastroschisis or omphalocele). Omphalocele has been called 'a prototype for ACS'. However, there are only few reports dealing with ACS in newborns [6].

The best treatment of ACS is prevention, by recognition of the patient at risk, that allows early interventions [7]. The WSACS has proposed a graded approach to the management of IAH/ACS. This approach consists of four elements: (a) serial IAP monitoring; (b) prevention of IAH and ACS; (c) medical management; and (d) surgical management [8]. When indicated, decompressive laparotomy (DL) often results in immediate and dramatic improvement in all affected organ functions and in stabilization of the patient's condition [9].

Intravesical pressure monitoring technique recommended by (WSACS) represents the most recent and reliable technique for IAP measurement in neonates [10]. It is simple, easy to perform and is considered an intraoperative reference for IAP measurement that is beneficial in determining the type of abdominal closure in repair of congenital anterior abdominal wall defects in neonates [11]. However, it has some pitfalls, such as bladder pressure measurements are not feasible in those with bladder trauma and malpositioning of the pressure transducer with regard to the symphysis pubis after repositioning of the patient may lead to fallacies [12].

Aim

The aim of this study was to assess the value of IAP monitoring through vesical pressure measurement in the choice and outcome of management of congenital abdominal wall defects.

1687-4137 © 2017 Annals of Pediatric Surgery DOI: 10.1097/01.XPS.0000511425.39279.13

Patients and methods

This is a prospective study of 25 cases sufferring from congenital anterior abdominal wall defects (gastroschisis and omphalocele) admitted to Mansoura University Children Hospital during the period from October 2013 to October 2015.

The protocol of this study design was approved by the ethical committee of our institution. An informed detailed written consent was obtained from the parents to conduct IAP monitoring through transvesical route during and after surgery for either exomphalos or gastrochisis.

Inclusion criteria

This study included neonates suffering from congenital anterior abdominal wall defects (gastroschisis and omphalocele).

Exclusion criteria

Parents that refused surgical interference or IVP monitoring, patients that were unfit for surgery due to unstable general conditions, patients with associated bladder anomalies as bladder exstrophy, and patients with associated anorectal malformations were excluded from the study.

After proper initial management after birth, cases were cared for in neonatal surgical ICU. Cases of gastroschisis and ruptured omphalocele were urgently prepared for surgery.

Intraoperative approach

In all cases attempt of primary closure of the abdomen was carried out by interrupted sutures. Then, IVP was measured as follows. The patients were catheterized with a 6F infant feeding tube. The bladder pressure was measured directly after attempt of primary closure of the abdomen as recommended by WSACS. The urinary bladder was emptied. Normal saline was instilled into the bladder with a volume of 3 ml/kg. The feeding tube was held vertically up in the mid-axillary line at the level of iliac crest and the height of the column of saline was measured at the end of expiration. All pressures were noted in centimeters of saline (Fig. 1).

Fig. 1

Measurement of intra-abdominal pressure through transvesical route. The feeding tube was held vertically up in the mid-axillary line at the level of iliac crest and the height of the column of saline was measured at the end of expiration.

After measuring IVP, decision of closure was made according to the recommendations of Santos Schmidt *et al.* [13]. If IVP remained under 20 cm H_2O, the sutures were tied and fascial closure was performed as usual. If IAP was higher than 20 cm H_2O, a surgical silo was placed and staged closure was done or raising of skin flaps and skin closure was performed.

In addition, peak inspiratory pressure (PIP) was measured and APP was calculated during the attempt of closure. Operative time was recorded in minutes. We also documented if the baby needed intraoperative blood transfusion or not.

Postoperative care

IAP, temperature, urine output, arterial blood gas, O_2 saturation ratio, creatinine level and blood pressure were monitored and recorded after 12, 24 and 48 h, respectively. Great care for follow-up of manifestations of ACS and IAH was done. An IVP greater than 20 cm H_2O associated with new onset end-organ compromise including hypotension, respiratory distress, increased ventilatory requirement, uncorrectable acidosis and persistent oliguria or anuria were all indicators for IAH to be dealt with.

Management of IAH if presented was by conservative measures according to the recommendation of Kirkpatrick *et al.* [14] in the form of avoiding excessive fluid resuscitation and diuretics in combination with albumin may be used in hemodynamically stable patients to mobilize third space edema into the intravascular space. In addition, the head position was maintained at less than 20° and muscle relaxant was shown to significantly reduce IAP by improving abdominal compliance [14]. DL was performed if conservative measures failed.

The type of secondary closure (fascial closure or mesh repair) and the time at which it was done for cases with silo was noted.

Results

This study included 25 cases diagnosed as congenital anterior abdominal wall defects, 14 (56%) of them were diagnosed as gastroschisis and 11 (44%) were exomphalos. Their ages at the time of surgery ranged from 4 to 720 h with a median age of 24 h. There were more male cases (56%) than were female cases (44%). Gestational age at birth ranged from 32 to 39 weeks with a mean gestational age of 36.88 ± 1.92. The median size of the defect was 3 cm^2.

Operative data

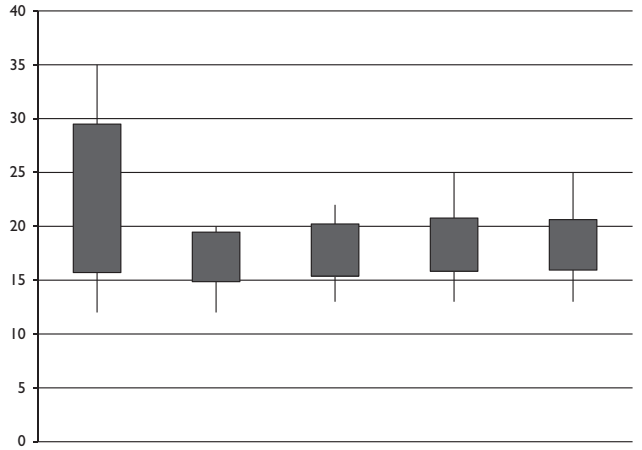
Guided by intraoperative measurement of IAP through transvesical route, primary fascial closure was successful in 60% of cases, whereas silo repair was done in six (24%) cases and skin closure in only four (16%) cases. Regarding

Table 1 Intraoperative and postoperative intra-abdominal pressure and abdominal perfusion pressure measurements

	Minimum	Maximum	Mean	SD
IAP at attempt of primary closure	12	35	22.60	6.89
IAP at end of operation	12	20	17.16	2.30
IAP after 12 h	13	22	17.80	2.42
IAP after 24 h	13	25	18.30	2.47
IAP after 48 h	13	25	18.28	2.34
PIP at attempt of primary closure	14	36	24.00	6.11
APP at attempt of primary closure	31	51	40.24	5.59
Postoperative APP	38	52	43.48	3.55

APP, abdominal perfusion pressure; IAP, intra-abdominal pressure.

Fig. 2



Values of intra-abdominal pressure at different times during and after closure.

Table 2 Relation between intra-abdominal pressure and abdominal perfusion pressure values at attempt of primary closure to their values after 24 h

	At attempt of primary closure	After 24 h	*T*	*P*
IAP	22.60 ± 6.89	18.30 ± 2.47	3.346	0.003*
APP	40.24 ± 5.59	43.48 ± 3.55	− 2.936	0.007*

APP, abdominal perfusion pressure; IAP, intra-abdominal pressure.
*$P < 0.05$, significant.

the cases that underwent silo repair, five were managed later by secondary closure with in-lay mesh in three cases and fascial closure without mesh in two cases and one case died before secondary closure.

Operative time during the attempts of primary closure ranged from 65 to 110 min with a mean operative time of 86.72 ± 12.01. Fourteen (56%) cases needed intraoperative blood transfusion.

Intra-abdominal pressure measurements

Table 1 and Fig. 2 show the ranges and the mean values of the different readings of the IAP, APP, and PIP. The mean IAP during attempts of closure was 22.60 ± 6.89 versus 18.30 ± 2.47 and 18.28 ± 2.34 after 24 and 48 h, respectively. Fig. 2 also shows wider range of IAP during attempts of closure than all other postoperative values and also there is a high possibility of lower values of IAP in all postoperative measurements than during attempts of closure.

Correlative studies of intra-abdominal pressure

The relation between the values of IAP measured at attempts of primary abdominal closure and those measured 24 h after closure was found to be statistically significant ($P = 0.003$). This means that intraoperative IAP monitoring is a good and sensitive predictor for estimation of postoperative IAP, which have eminent role in prevention of postoperative IAH. Similarly, the calculated APP intraoperatively was found to correlate significantly with the calculated APP 24 h postoperatively ($P = 0.007$) (Table 2).

Statistical analysis revealed that several factors like body weight and the size of the defect have no direct effect on the incidence of IAH. On the other hand, PIP measured at attempt of primary closure was found to correlate significantly with the IAP measured at the same time ($P = 0.041$). Accordingly, PIP also can be used as a good predictor of IAH.

Postoperative data

On postoperative follow-up, only two cases developed IAH after abdominal closure (8%) and only one of them needed DL (4%). The IAP at end of operation of this case was 20 cm H_2O and thus primary abdominal closure was done. The baby suffered anuria for 2 days. The pressure requirement on the mechanical ventilator was increased to achieve suitable tidal volume. Oxygen saturation ratio was decreasing and severe respiratory acidosis was noticed in arterial blood gases. Measurements of IAP showed a great rise up to 25 cm H_2O with failure of conservative methods for management of IAH. Therefore, DL was done and exposed intestinal loops were covered by silo.

On evaluation of cases 24 h after closure, one (4%) case developed anuria, which persisted after 48 h. Furthermore, oliguria was reported in eight (32%) cases after 24 h; however, urine output became normal in five of them within the next 24 h.

Mortality occurred in eight (32%) cases, six of them among gastroschisis cases (75%) and only two (25%) among the cases of exomphalos. Table 3 demonstrates the relation between several factors and mortality. Only the measured IAP was found to be related significantly with mortality ($P = 0.028$). By comparing mortality occurred after different methods of closure, it was found that the highest mortality rate occurred among the cases that were covered by silo (66.6%). On the other hand, cases managed by skin closure showed the least ratio among dead cases (12.5%).

Discussion

Surgical management of abdominal wall defects follows five key considerations: reduce the evisceration safely, close the defect with a cosmetically acceptable outcome, and with guidance of intraoperative monitoring of IAP, identify and treat the associated anomalies then support nutrition until full independent enteral feeding is

Table 3 Effect of age, gestational age, BW, size of defect, and value of intra-abdominal pressure at attempt of closure on mortality

	No mortality ($n=17$)	Mortality ($n=8$)	*T*	*P*
Age	85.47 ± 169.05	104.25 ± 205.46	0.242	0.811
Gestational age	37.06 ± 1.64	36.50 ± 2.51	0.670	0.509
BW	2.66 ± 0.49	2.33 ± 0.68	1.398	0.176
Size of defect	8.46 ± 8.82	9.17 ± 13.35	0.159	0.875
IAP at attempt of primary abdominal closure	20.56 ± 6.49	26.94 ± 5.91	2.353	0.028*

BW, body weight; IAP, intra-abdominal pressure.
*$P<0.05$, significant.

established and recognize and treat abdominal, wound, or bowel complications [15].

Nakayama *et al.* [16] and Chin and Wei [17] confirmed that IVP correlated well with inferior vena cava pressure, which reflects IAP, and advocated the use of IVP monitoring as a simple and reliable means of indirectly determining IAP during operations for closure of abdominal wall defects in newborn infants with omphalocele or gastroschisis. Olesevich *et al.* [18] noted faster return to full feeding and shorter hospital stay in newborns in which primary closure was accomplished with an IVP below 20 mmHg. Santos Schmidt *et al.* [13] and Rizzo *et al.* [19] used a lower IVP threshold (20 cm H_2O, equivalent to 15 mmHg) to decide between delayed primary closure and the staged approach. They also reported more prompt diuresis and a trend toward less ventilator support, shorter total parenteral nutrition time, and shorter hospital stay [13,19].

In our study, we used IVP threshold of 20 cm H_2O as Santos Schmidt and colleagues and Rizzo and colleagues and our results concur with theirs as well as with Shimotake *et al.* [20] who reported that IVC pressure should be kept under 20 cm H_2O and found a significant relationship between IVC pressure and visceral blood perfusion guided with Doppler ultrasound.

We did routine postoperative measurement of IAP, which was not done by Olesevich *et al.* [18], who did not believe that routine postoperative measurements of IAP are required. In our study, there was a statistically significant relationship between the values of IAP measured at attempts of primary abdominal closure and those measured 24 h after closure. This means that intraoperative IAP monitoring is a good and sensitive predictor for the postoperative course and, consequently, it has an eminent role in prevention of postoperative IAH and ACS. Accordingly, in agreement with Nakayama and colleagues and Chin and Wei, we concluded that IVP monitoring as a simple and reliable means of determining IAP. However, we believe that further studies in larger number of cases are required to decide whether or not to omit postoperative measurement of IAP depending on the intraoperative values as recommended by Olesevich *et al.* [18].

In the current study, the IAP values measured intraoperatively correlate significantly with the calculated APP and the PIP measured at the same time. Thus, they also can be used as predictors of postoperative IAH/ACS.

In the present study, primary fascial closure was performed in 60% of cases, whereas silo repair in 24% and skin closure in 16%. This is similar to the results obtained by Santos Schmidt and colleagues and Ionescu *et al.* [21], who reported primary closure in 54 and 58.5% of cases, respectively, with intraoperative IVP threshold of 15 mmHg. Nevertheless, Olesevich *et al.* [18] performed primary closure in a much higher percentage of cases (79%). This may be attributed to their higher IVP threshold for closure (20 mmHg) giving better chance for primary abdominal closure. Furthermore, the larger number of cases included in their study should be considered [18].

In the present study, two (8%) cases developed postoperative IAH. This agrees with Clausner *et al.* [22], who have shown that six out of 55 neonates suffering exomphalos (10%) showed signs of inferior venacaval compression after primary omphalocele closure. However, DL was indicated in only one case in our study (4%) after failure of conservation for 2 days. Santos Schmidt *et al.* [13] reported that there were no recorded cases of postoperative IAH among 22 cases underwent primary abdominal closure. Yet, they noticed temporary oligoanuria in about one-third (33.5%) of patients, which may indicate a mild degree of IAH [13].

This low incidence of postoperative IAH clarifies the great value of intraoperative monitoring of IAP and its direct effect in guiding the type of repair.

In our study, mortality ratio among cases underwent primary abdominal closure (20%), which is low in comparison with mortality ratio recorded in cases repaired with silo (66.6%).This was also confirmed in the results of Santos Schmidt and colleagues and Olesevich and colleagues and the cause might be that silo repair increased the liability for infection and intestinal injuries, which increased mortality ratio rather than primary abdominal closure. We also reported lower mortality ratio among cases underwent skin closure compared with those underwent silo repair, which makes it an appropriate way for repair if feasible.

Conclusion

Measurement of bladder pressure by measuring the height of the saline column is simple and easy to perform. It is an intraoperative indicator for IAP that is beneficial in determining the type of repair of congenital anterior abdominal wall defects in neonates. IAP measured during attempt of closure is a good predictor for the postoperative course, and thus it is a dependent guide regarding the decision about the method of abdominal closure.

Conflicts of interest

There are no conflicts of interest.

References

1 Cheatham ML. Abdominal compartment syndrome: pathophysiology and definitions. *Scand J Trauma Resusc Emerg Med* 2009; **17**:10.

2 Hunt L, Frost SA, Hillman K, Newton PJ, Davidson PM. Management of intra-abdominal hypertension and abdominal compartment syndrome: a review. *J Trauma Manag Outcomes* 2014; **8**:2.

3 Ejike JC, Bahjri K, Mathur M. What is the normal intra-abdominal pressure in critically ill children and how should we measure it? *Crit Care Med* 2008; **36**:2157–2162.

4 Blaser AR, Malbrain ML, Starkopf J, Fruhwald S, Jakob SM, de Waele J, *et al.* Gastrointestinal function in intensive care patients: terminology, definitions and management. Recommendations of the ESICM Working Group on Abdominal Problems. *Intensive Care Med* 2012; **38**:384–394.

5 Ejike JC, Mathur M. Abdominal decompression in children. *Crit Care Res Pract* 2012; **2012**:180797.

6 Gerstmann DR, Null J, Donald M. Bladder pressure and intra-abdominal hypertension in sick neonates. *J Neonatal Perinatal Med* 2010; **3**:301–305.

7 Khadaroo RG, Marshall JC. Gastrointestinal dysfunction in the critically ill: can we measure it? *Crit Care* 2008; **12**:180.

8 Liu Y, Wang L, Cai Z, Zhao P, Peng C, Zhao L, Wan C. The decrease of peripheral blood CD4 + T cells indicates abdominal compartment syndrome in severe acute pancreatitis. *PLoS One* 2015; **10**:e0135768.

9 Ejike JC, Newcombe J, Baerg J, Bahjri K, Mathur M. Understanding of abdominal compartment syndrome among pediatric healthcare providers. *Crit Care Res Pract* 2010; **2010**:876013.

10 Cheatham ML, Malbrain ML, Kirkpatrick A, Sugrue M, Parr M, De Waele J, *et al.* Results from the International Conference of Experts on Intra-abdominal Hypertension and Abdominal Compartment Syndrome. II. Recommendations. *Intensive Care Med* 2007; **33**:951–962.

11 Abraham MK, Viswanath N, Ramakrishnan P, Bindu S, Kedari P, Naaz A, *et al.* Intravesical pressure: a new prognostic indicator in congenital diaphragmatic hernia. *J Indian Assoc Pediatr Surg* 2011; **16**:129–131.

12 Malbrain ML. *Different techniques to measure intra-abdominal pressure (IAP): time for a critical re-appraisal, in applied physiology in intensive care medicine*. Springe: Verlag Berlin Heidelberg; 2009. pp. 143–157.

13 Santos Schmidt AF, Goncalves A, Bustrorff-Silva JM, Oliveira-Filho AG, Miranda ML, Oliveira ER, *et al.* Monitoring intravesical pressure during gastroschisis closure. Does it help to decide between delayed primary or staged closure? *J Matern Fetal Neonatal Med* 2012; **25**: 1438–1441.

14 Kirkpatrick AW, Roberts DJ, De Waele J, Jaeschke R, Malbrain ML De Keulenaer B, *et al.* Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome. *Intensive Care Med* 2013; **39**:1190–1206.

15 Marven S, Owen A. Contemporary postnatal surgical management strategies for congenital abdominal wall defects. *Semin Pediatr Surg* 2008; **17**:222–235.

16 Nakayama M, Horikawa D, Nagai H, Tamiya K, Fujita S, Namiki A. Utility of intra-bladder pressure monitoring during closure of abdominal wall defects in newborn infants. *Masui* 1992; **41**:1647–1650.

17 Chin T, Wei C. Prediction of outcome in omphalocele and gastroschisis by intraoperative measurement of intravesical pressure. *J Formos Med Assoc* 1994; **93**:691–693.

18 Olesevich M, Alexander F, Khan M, Cotman K. Gastroschisis revisited: role of intraoperative measurement of abdominal pressure. *J Pediatr Surg* 2005; **40**:789–792.

19 Rizzo A, Davis PC, Hamm CR, Powell RW. Tntraoperative vesical pressure measurements as a guide in the closure of abdominal wall defects. *Am Surg* 1996; **62**:192–196.

20 Shimotake T, Iwai N, Yanagihara J, Inoue K. Ultrasonic Doppler measurements of visceral blood flow in the repair of giant omphalocele. *Eur J Pediatr Surg* 1993; **3**:366–369.

21 Ionescu S, Andrei B, Tirlea S, Bunea B, Licsandru E, Cirstoveanu C, *et al.* Considerations on gastroschisis repair. *Chirurgia (Bucur)* 2013; **108**: 509–515.

22 Clausner A, Lukowitz A, Rump K, Berger S, Würfel A. Treatment of congenital abdominal wall defects – a 25-year review of 132 patients. *Pediatr Surg Int* 1996; **11**:76–81.