Management of Incarcerated Indirect Hernia in Pediatric Patients with Intra-abdominal Hypertension: A Retrospective Study

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Research Article

Keywords: inguinal hernia, herniorrhaphy, intra-abdominal hypertension, children, retrospective study, surgery

Posted Date: February 4th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-172176/v1

Management of incarcerated indirect hernia in pediatric patients with intra-abdominal hypertension: a retrospective study

Running title: IIIH in children with IAH

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Abstract

Background: Intra-abdominal hypertension (IAH) is a critical condition that can be induced by incarcerated indirect inguinal hernia (IIIH). There are currently no specific guidelines for laparotomy in children. To determine whether laparotomy should be performed during the management in pediatric patients with IIIH combined with IAH.

Methods: This is a retrospective study of pediatric patients with IIIH and IAH who were admitted and treated at the Department of General Surgery of Jiangxi Provincial Children's Hospital from 01/2010 to 06/2020. The patients were divided into Group A (intra-abdominal pressure (IAP) of 10-20 mmHg) and Group B (IAP ≥ 21 mmHg). Each

group was further subdivided into Group 1 (decompression) and Group 2 (no decompression) depending on whether decompressive laparotomy was performed or not. The last follow-up was three months after discharge.

Results: A total of 49 patients were enrolled, and divided into group A1 (n = 21), A2 (n = 10), B1 (n = 4), B2 (n = 14). Compared with patients in group A1, those who had decompression (group A2) has longer hospital stay (7.5 ± 1.9 vs. 5.2 ± 2.1, $p = 0.01$), higher 24h-postoperative IAP (11.3 ± 2.4 vs 9.5 ± 2.1, $p = 0.03$), longer PICU stay (2.1 ± 0.9 vs. 1.1 ± 0.5, $p = 0.001$), and more perioperative complications. In contrast, among patients with IAP higher than 20mmHg, those who had decompresion via laparotomy (group B2) had comparable hospital stay (7.1 ± 5.1 vs. 8.5 ± 4.1, $p = 0.57$), a shorter PICU stay (3.0 ± 1.4 vs. 4.7 ± 1.3, $p = 0.04$) and lower mortality rate (7.1% vs. 50%, $p = 0.04$) than patients in group B1.

Conclusions: The selection of appropriate surgical methods according to IAP and based on clinical diagnosis can relieve the pain of children, shorten hospital stay, and reduce the mortality rate.

Keywords: inguinal hernia; herniorrhaphy; intra-abdominal hypertension; children; retrospective study; surgery

Background

Hernias are caused by a congenital weakness of the fascia transversalis at the medial inguinal canal. Inguinal hernias (IH) are the most common type of hernias in men and women and are characterized by a protrusion of the abdominal content above the inguinal ligament [1-3]. In children, indirect IH (IIH) occurs through the patent processus vaginalis and constitutes the most common type of IH in children [4, 5]. The

incidence of IH is 0.8%-4.4% [5] and reaches 13% in infants born < 32 weeks of gestation and 30% in children with birth weight < 1000 g [5]. The incidence of IIH among male children is higher than that of female children (ratio of 9:1) [4].

Incarcerated indirect inguinal hernia (IIIH) in children is a common acute abdominal condition characterized by the inability to reduce the IIH without manual assistance or surgery [4]. In addition to the risk of obstruction and perforation, some pediatric patients exhibit a sharp increase in intra-abdominal pressure (IAP), which can induce respiratory and circulatory failure and endanger their lives [6, 7]. Intestinal incarceration causes mechanical intestinal obstruction and over-dilatation of the proximal intestinal canal. Even if the intestinal canal is successfully restored, the loss of intestinal peristalsis might still induce paralytic ileus and cause increased IAP [8]. The comorbidities include enteritis, pneumonia, renal hypoperfusion, ascites, and intra-abdominal hypertension (IAH), and the condition progresses rapidly [9, 10].

The normal IAP in children is 0-4 mmHg, and IAH occurs when the IAP is higher than 10 mmHg. Multiple organ dysfunction or failure will occur once IAH progresses and develops into the abdominal compartment syndrome [11, 12]. IAH leads to decreased mesenteric blood flow, intestinal ischemia, intestinal bacterial translocation, and sepsis. Elevated IAP uplifts the diaphragm, resulting in insufficient pulmonary ventilation and dysfunction. Finally, excessive IAP compresses the abdominal capillary bed and causes a decrease in the returned blood volume, thereby leading to circulatory failure [13-15]. Laparotomic intervention is generally required at this point.

IIH in children is often treated by lysis, reduction, and high ligation of the hernia sac via the inguinal incision [4, 5, 16]. No laparotomy is required if no intestinal necrosis is observed intraoperatively. As a typical surgical approach to the treatment of IIIH in children, this surgical method has many advantages, such as small incision, fast

operation, small surgical trauma, no abdominal disturbance, and no postoperative intestinal adhesion. Pediatric surgeons generally believe that there is no intestinal necrosis in an IIIH, and laparotomy is thus not required. Nevertheless, if IAH is concurrent and only lysis, reduction, and high ligation of the hernia sac via the inguinal incision is performed, the proper management of their condition will be delayed, and their lives might be endangered [17]. In addition, blind laparotomy will not only expand the scope of surgery but also cause a more important surgical trauma, prolong their hospital stay, and increase the medical expenses.

It is, therefore, critical to select an appropriate approach for laparotomy, but there is currently no unified view in the guidelines of laparotomy for children with IAH [18-21]. Therefore, this study aims to determine whether laparotomy should be performed during the management in pediatric patients with IIIH combined with IAH. Our study would provide evidence on chosing appropriate treatment and management methods for IIIH pediatric patients with different IAP levels.

Methods

Study design and patients

This is a retrospective study of pediatric patients with IIIH and IAH who were admitted and treated at the Department of General Surgery of Jiangxi Provincial Children's Hospital from January 2010 to June 2020. This study was approved by the Ethics Committee of Jiangxi Provincial Children's Hospital (No. JXSETYY-YXKY-20200055). Written informed consent was obtained from the patient's parent or guardian.

The diagnostic criteria were according to the Chinese Guidelines for the Diagnosis and Treatment of Celiac Hypertension and Celiac Compartment Syndrome (Version 2013).

The inclusion criteria were 1) clinically diagnosed as IIH with incarceration, 2) the IAP measured via the bladder was ≥ 10 mmHg, and 3) surgical treatment was performed. The exclusion criteria were 1) the IIIH self-reduced or no surgery was performed, or 2) complicated with intestinal necrosis.

Indirect IAP measurement

IAP was measured with the indirect pressure measurement method recommended by the World Society of Abdominal Compartment Syndrome, i.e., the urinary bladder pressure (UBP) method [22, 23]. For this method, the patient kept his/her abdominal muscle relaxed in the supine position; after his/her bladder was emptied, 25 mL of physiological saline (37°C-40°C) was injected through a Foley catheter. The measuring device stayed for 30s to 1 min with the mid-axillary line as the zero value. IAP was measured at the end of expiration, with mmHg as the unit. For pediatric patients, 3 to 25 mL of physiological saline was injected at 1 mL/kg, and the remaining steps were the same as those for adult patients.

Grouping

The patients were divided into Group A (IAP 10-20 mmHg) and Group B (IAP ≥ 21 mmHg) according to the classification of IAH in children [24]. Each of the two groups was subdivided into Group 1 (decompression) and Group 2 (non-decompression), depending on whether decompressive laparotomy was performed. Therefore, the groups were Group A1 (IAP 10-20 mmHg, no decompressive laparotomy), Group A2 (IAP 10-20 mmHg, decompressive laparotomy), Group B1 (IAP ≥ 21 mmHg, no decompressive laparotomy), and Group B2 (IAP ≥ 21 mmHg, decompressive laparotomy).

Treatment

All patients underwent tracheal intubation and intravenous compound anesthesia in the supine position and received regular anti-inflammatory treatment, fluid infusion, hemostasis, and monitoring of vital signs after surgery. There are four specific surgical methods that were used:

(1) Lysis of the incarcerated indirect hernia and high ligation of the hernia sac. After successful anesthesia, the surgeon made an oblique incision from the groin, incised the skin to separate each layer, opened the hernia sac, checked whether or not the intestinal canal was necrotic, cut and open the superficial inguinal ring, repositioned the un-necrotic intestinal canal back to the abdominal cavity, dissociated the hernia sac to the high position and ligated the hernia sac, repaired the superficial inguinal ring, and sutured all layers after hemostasis.

(2) Manual reduction of the intestinal canal + intestinal decompressive laparotomy + transabdominal ring repair under the direct view of laparotomy. After successful anesthesia, the surgeon made an incision from the right rectus abdominis as the exploratory incision or made a transverse incision from the lower abdomen, separated each layer, opened the abdominal cavity, repositioned the incarcerated intestinal canal, performed the intestinal decompressive laparotomy after no necrosis was observed in the intestinal canal, used 0.5% procaine to close the mesenteric root, sutured and ligated the deep inguinal ring under direct-view laparotomy, placed an abdominal drainage tube into the pelvic cavity, closed the abdomen, and sutured all layers.

(3) Lysis of the incarcerated indirect hernia and high ligation of the hernia sac and intestinal decompressive laparotomy. After successful anesthesia, the surgeon performed lysis of the incarcerated indirect hernia and high ligation of the hernia sac

(as in #1), and then performed intestinal decompressive laparotomy (as in #2).

(4) Lysis of the incarcerated indirect hernia and high ligation of the hernia sac + intestinal decompressive laparotomy through a second surgery. After successful anesthesia, the surgeon performed lysis of the incarcerated indirect hernia and high ligation of the hernia sac (as in #1) in one patient, but upon return to the ward, the patient developed aggravated abdominal distension, limb psychro-esthesia, spotted skin, and continuously elevated IAP. The ventilator exhibited high parameters and could not go offline, so a second intestinal decompressive laparotomy was performed.

Because all cases were operated on in the context of regular clinical practice, all patients were operated on by different surgeons. All surgeons had the qualifications as attending physicians or above, with an experience of no less than 10 years.

Follow-up

After discharge, all children were followed on an outpatient basis, with regular inquiry and physical examination. Follow-ups were conducted once every two weeks in the first month after surgery. The frequency was once per month in the second and third months after surgery. The last follow-up was three months after discharge.

Statistical analysis

SPSS 22.0 (IBM, Corp., Armonk, NY, USA) was used for statistical analysis. Continuous variables were analyzed by the Kolmogorov-Smirnov test and met the normal contribution. They are presented as means ± standard deviations (SD) and analyzed using Student's t-test. Categorical data were expressed as frequencies and percentages (%) and were analyzed using the chi-square test. p-values < 0.05 were considered as statistically significant.

Results

Characteristics of the patients

A total of 49 patients were included in this study, including 47 males and two females, aged 4 months to 1 year and 10 months (8.0 ± 4.0 months). The duration of incarceration was 0.5 to 5 days (2.2 ± 2.1 days). Sixteen cases (32.7%) occurred on the left side and 33 cases (67.3%) on the right side. There were 31 children in group A (IAP of 10-20 mmHg) and 18 in group B (IAP ≥ 21 mmHg). In group A, 10 children underwent decompressive surgery (group A2), and 21 children did not (group A1). In group B, 14 children underwent decompressive surgery (group B2), and four children did not (group B1). There were no significant differences in age, sex, duration/location of incarceration, and IAP between the two subgroups of Groups A and B (all $p > 0.05$), as shown in Table 1.

Clinical outcomes

The hospital stays of the 49 patients ranged from 4 to 13 days. A primary suture was performed on all abdominal incisions, and the wound healed well without incisional hernia happening. In total, 46 patients were cured and discharged (cure rate of 93.9%), and cerebral palsy occurred in one patient. Of the three deaths (mortality rate of 6.1%), two patients were complicated with enteritis and died of septic shock and multiple organ failure, and one patient was complicated with bronchopneumonia and died of respiratory and circulatory failure.

Prognostic comparisons between groups A1 and A2

As presented in Table 2, compared with group A1 (no decompression), the patients in

group A2 (decompression) have a longer hospital stay (7.5 ± 1.9 vs. 5.2 ± 2.1 days, p = 0.01), higher 24h postoperative IAP (11.3 ± 2.4 vs. 9.5 ± 2.1 mmHg, p = 0.03), more perioperative complications (one case, 10% of adhesive ileus and one case, 10% of incisional hernia), and longer PICU stay (2.1 ± 0.9 vs. 1.1 ± 0.5 days, p = 0.001). All patients in group A were cured and discharged, but 2 months after surgery, adhesive intestinal obstruction occurred in one child from Group A2, who was cured and discharged after surgery.

Prognostic comparisons between the group B1 and B2

As shown in Table 3, the patients in groups B1 and B2 had comparable hospital stay (7.1 ± 5.1 vs. 8.5 ± 4.1 days, p = 0.57). The patients in group B2 had a shorter PICU stay (3.0 ± 1.4 vs. 4.7 ± 1.3 days, p = 0.04) and lower mortality (7.1% vs. 50%, p = 0.04). The two dead patients in group B1 both underwent lysis of the incarcerated indirect hernia and high ligation of the hernia sac. The two patients exhibited multiple organ dysfunction at 31h and 50h after surgery, respectively, and died after rescue failed. The possible cause of death is concurrent abdominal compartment syndrome. For the dead patient in group B2, lysis of the incarcerated indirect hernia and high ligation of the hernia sac was first performed; upon return to the PICU, the child developed aggravated abdominal distension, a peripheral circulation disorder, and spotted skin all over the body. Exploratory laparotomy and intestinal decompression were performed 10h after the first surgery, but the child developed multiple organ dysfunction 10 h after the second surgery and died after the rescue failed.

Discussion

IAH is a critical condition that can be induced by IIIH. There are no guidelines for

laparotomy in children [18-21]. Therefore, this study determined whether laparotomy should be performed during the management in pediatric patients with IIIH combined with IAH. The results suggested that the selection of appropriate surgical methods according to IAP and based on clinical diagnosis can relieve the pain of children, shorten hospital stay, and reduce the mortality rate.

In patients with IAP of 10-20 mmHg, the patients who underwent decompression laparotomy had a longer hospital stay, higher 24-h postoperative IAP, more perioperative complications, and longer PICU stay. Of course, the surgery itself is a reason for longer PICU and hospital stay, and the surgical trauma was conducive to inflammation that might lead to an increase in IAP. Whether the complications were due to the surgery itself or the increased IAP after surgery cannot be delineated effectively. There is a theoretical risk of inducing an abdominal compartment syndrome due to the surgical trauma [25, 26], but this was not observed here, probably because of the small sample size and because the patients had an IAP of 10-20 mmHg. Nevertheless, all patients were cured and discharged. One patient had a surgical complication (adhesive intestinal obstruction), which was successfully managed.

In the more severe group (IAP > 20 mmHg), the patients who did not undergo compressive surgery or underwent decompressive surgery had a comparable hospital stay, highlighting a more severe condition. This was further highlighted by the fact that the patients who underwent decompression surgery had a shorter PICU stay and lower mortality rate than those who did not undergo decompression, probably because of more effective management of severe IAH. The impact of the surgical trauma in patients with IAP > 20 mmHg was not observed, probably because of the high baseline IAP. Some surgical complications were observed, but they were not more severe or important than the complications observed in the no-decompression group.

Available data suggested that no laparotomy was required if there was no sign of intestinal necrosis [18-21], but laparotomy could still be necessary for decompression, even if there were no specific guidelines for decompressive laparotomy in children with IIIH and IAH [18-21]. The present study suggested that avoiding decompressive laparotomy treatments were appropriate for children with IAP 10-20 mmHg, but that for children with IAP > 20 mmHg, decompressive surgery might be indicated and might result in better outcomes. Nevertheless, additional studies are necessary to refine those results. Indeed, Burch et al. [27] indicated that organ failure could occur at IAP of 10-15 mmHg. In addition, the present study only included patients with IIIH, but the treatment algorithms for patients with IAH from various causes are complex [28].

Nevertheless, this study has limitations. The patients were from a single center, and the sample size was small. Even though all surgeons had at least 10 years of experience, the children were operated on by different surgeons with different training, and different surgeries were used. Therefore, the present study cannot be used as a formal reference to guide the treatment of children with IIIH and IAH, but the results could serve as a basis for future studies.

Conclusions

In conclusion, the selection of appropriate surgical methods according to IAP and based on clinical diagnosis can relieve the pain of children, shorten hospital stay, and reduce the mortality rate. Laparotomy could benefit IIIH pediatric patients with IAP more than 20 mmHg rather than those with IAP ranging from 10-20 mmHg.

List of abbreviations

IAH: intra-abdominal hypertension

IIIH: incarcerated indirect inguinal hernia

IAP: intra-abdominal pressure

IH: inguinal hernias

IIH: indirect IH

SD: standard deviations

Declarations

Ethics approval and consent to participate

All methods in this research were carried out in accordance with relevant guidelines and regulations. The study was approved by the Ethics Committee of Jiangxi Provincial Children's Hospital (No. JXSETYY-YXKY-20200055). Written informed consent was obtained from the patients' parents or guardians. A copy of the written consent is available for review by the Editor of this journal.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was supported by the Science and Technology Program of the Health

Commission of Jiangxi Province [grant number 20203690].

Authors' contributions

BL and MZ carried out the studies, participated in collecting data, and drafted the manuscript. WQ and BC performed the statistical analysis and participated in its design. BL and WQ helped to draft the manuscript. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

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Tables

Table 1 Baseline characteristics of the patients

Characteristics							
mean ± SD/ n (%)	**Total (n = 49)**	**Group A1 (n = 21)**	**Group A2 (n = 10)**	***p***	**Group B1 (n = 4)**	**Group B2 (n = 14)**	***p***
Age, months	7.9 ± 4.6	9.1 ± 3.5	8.6 ± 4.2	0.75	6.9 ± 4.2	5.9 ± 3.9	0.68
Sex (male)	47 (95.9%)	19 (90.5%)	10 (100%)	0.31	4 (100%)	14 (100%)	
BMI, kg/m^2	18.6 ± 2.7	19.0 ± 2.5	18.0 ± 3.0	0.34	20.3 ± 3.1	18.0 ± 2.9	0.17
Duration of incarceration, h	40.0 ± 17.4	36.4 ± 12.3	33.0 ± 14.1	0.49	46.7 ± 25.8	48.3 ± 19.4	0.89
Location of incarceration (left/right)	16 (32.7%)/33 (67.3%)	7 (33.3%)/14 (66.7%)	3 (30.0%)/7 (70.0%)	0.85	1 (25.0%)/3 (75.0)	5 (35.7%)/9 (64.3%)	0.69
IAP, mmHg	21.9 ± 5.2	14.4 ± 3.1	15.8 ± 4.0	0.29	29.2 ± 6.7	35.5 ± 8.6	0.19

IAP, intra-abdominal pressure

Table 2 Comparison of the clinical outcomes between groups A1 and A2

Variables mean ± SD/ n (%)	**Group A1 (n = 21)**	**Group A2 (n = 10)**	***p***
Hospital stay (days)	5.2 ± 2.1	7.5 ± 1.9	0.01
24-hours postoperative IAP (mmHg)	9.5 ± 2.1	11.3 ± 2.4	0.03
Complications (adhesive ileus/incisional hernia/cerebral palsy)	0/0/0	1 (10%)/1 (10%)/0	-
PICU stay (days)	1.1 ± 0.5	2.1 ± 0.9	0.001
Discharged (healed), n (%)	21 (100%)	10 (100%)	-
Death	0	0	-

IAP, intra-abdominal pressure; PICU, pediatric intensive care unit

Table 3 Comparison of clinical outcome between groups B1 and B2

VARIABLES mean ± SD/ n (%)	**Group B1 (n = 4)**	**Group B2 (n = 14)**	***p***
Hospital stay (days)	7.1 ± 5.1	8.5 ± 4.1	0.57

24-hours postoperative IAP (mmHg)	30.7 ± 8.1	22.3 ± 6.5	0.04
Complications (adhesive ileus/incisional hernia/cerebral palsy)	0/0/1 (25%)	0/1 (7.1%)/0	-
PICU stay	4.7 ± 1.3	3.0 ± 1.4	0.04
Discharged (healed), n (%)	2 (50%)	13 (92.9%)	0.04
Death, n (%)	2 (50%)	1 (7.1%)	0.04

403 IAP, intra-abdominal pressure; PICU, pediatric intensive care unit