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# Does Massive Irrigation Reduce the Risk of Intra-Abdominal Abscess after Laparoscopic Appendectomy for Perforated Appendicitis?

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## Abstract

**Introduction**: This study aimed to determine if massive intra-abdominal irrigation reduced the risk of postoperative intra-abdominal abscess (PO-IAA) after laparoscopic appendectomy (LA) for perforated appendicitis in pediatric patients. **Materials and Methods**: A case-control study was conducted at Saitama Prefectural Children's Medical Center between January 2014 and December 2023. Sixty-nine pediatric patients with perforated appendicitis who underwent LA were included. Patients were divided into PO-IAA and PO-IAA-free groups. We compared the irrigation volume (IV), the ratio of IV to body weight (IV/BW), and the ratio of IV to body surface area (IV/BSA) between the two groups. Statistical analyses were performed to identify significant differences and optimal cutoff values. **Results**: The PO-IAA-free group had a significantly higher IV (median 8000 mL vs. 6000 mL, $p = 0.014$), IV/BW (270.9 mL/kg vs. 159.2 mL/kg, $p = 0.009$), and IV/BSA (7500.6 mL/m$^2$ vs. 4890.6 mL/m$^2$, $p = 0.008$) than the PO-IAA group. Receiver operating characteristic curve analysis identified cutoff values of 6000 mL for IV, 234.6 mL/kg for IV/BW, and 6352.2 mL/m$^2$ for IV/BSA. **Conclusions**: Massive intra-abdominal irrigation during LA for perforated appendicitis in children may be effective in preventing PO-IAA. Additionally, IV/BW and IV/BSA may be indicators that determine the IV.

## Keywords

Irrigation, Postoperative Intra-Abdominal Abscess, Laparoscopic Appendectomy, Perforated Appendicitis

## 1. Introduction

Perforated appendicitis accounts for 15% - 20% of all cases of pediatric appendicitis [1] [2]. Perforated appendicitis is itself a significant risk factor for postoperative intra-abdominal abscess (PO-IAA), which occurs in 5% - 10% of pediatric patients with perforated appendicitis [2]-[5]. PO-IAA prolongs hospitalization due to long-term antibiotic use, drainage, and reoperation [6] [7]. Therefore, many surgeons have attempted to improve the surgical technique and perioperative management of appendectomy to prevent PO-IAA, and intraperitoneal irrigation has been the subject of much discussion [1] [6] [8]-[13].

Intraperitoneal irrigation for peritonitis was first reported in 1906, since it has been performed by many surgeons [1] [9] [14], with only 7% of pediatric surgeons in North America in 2004 not performing intraperitoneal irrigation during appendectomy [15]. We also irrigated the abdominal cavity with a large volume of saline solution during laparoscopic appendectomy (LA) for perforated appendicitis. Several studies have compared irrigation with suction alone, most of which supported the suction-alone approach, indicating that irrigation is ineffective in preventing PO-IAA [8] [10] [16]. However, most studies that supported the suction-alone approach reported irrigation volumes (IV) of 500 - 1000 mL [1] [6] [9] [11]-[13] [17]. We irrigated until the irrigation solution was clear, with an empiric IV of 500 - 1000 mL, which is insufficient. It is important to estimate the abdominal cavity volume since the amount of abdominal cavity irrigation depends on it. Yao et al. measured abdominal cavity volume using 3D CT and reported that the volume correlates with body weight [18]. Additionally, Fischbach et al. stated that the dialysate filling volume should be adjusted according to body surface area in pediatric peritoneal dialysis patients [19]. Therefore, we hypothesized that BW and BSA are factors involved in determining the IV. Contrastingly, few reports have examined the effects of a large IV on PO-IAA. Although several reports have compared irrigation versus suction alone and massive irrigation versus suction alone [1] [6] [8]-[13] [16] [17], no reports have examined the effect of the IV.

This study aimed to compare the IV between patients with and without PO-IAA. As a secondary objective, we also compared the IV to body weight (IV/BW) and IV to body surface area (IV/BSA) ratios between the PO-IAA and PO-IAA-free groups to identify the parameters determining the IV.

## 2. Patients and Methods

### 2.1. Study Design and Setting

This case-control study was conducted at a single institution between January 2014 and December 2023. The study conforms to the STROBE reporting guidelines [20]. Data were collected retrospectively from medical records at the institution.

### 2.2. Inclusion and Exclusion Criteria

The study population consisted of pediatric patients diagnosed with perforated appendicitis who underwent LA. Perforation was defined as an intraoperative finding of a hole in the appendix. Irrigation was performed using a saline solution ([Na]: 154 mEq/L and [Cl]: 154 mEq/L) in the right lower abdomen, pelvic cavity, right subdiaphragmatic space, and left subdiaphragmatic space using an irrigation pump at a water pressure of 100 - 200 mmHg. Patients with simple appendicitis, without perforation, interval appendectomy, or those who underwent percutaneous drainage were excluded, because extensive irrigation was not typically performed in such cases.

Not all patients underwent postoperative imaging studies. Patients with postoperative fever, abdominal pain, and elevated inflammatory response who underwent computed tomography or abdominal echocardiography and had intra-abdominal abscesses were classified as the PO-IAA group. PO-IAA was defined as an extra-luminal fluid collection documented on computed tomography or abdominal echocardiography. Additionally, the size of the fluid was not specified.

## 2.3. Variables and Measurements

Preoperative patient characteristics (age, sex, height, BW, body mass index (BMI), and BSA), days until surgery after symptom onset, highest perioperative serum leukocyte count, highest perioperative serum C-reactive protein (CRP) level, duration of antibiotic use, presence of PO-IAA, and IV were collected. The primary outcome was the difference in IV between patients with and without PO-IAA. The secondary outcomes were differences in IV/BW, IV/BSA, operation time, intraoperative blood loss, the incidence of surgical site infection (SSI), and length of hospital stay between the PO-IAA- and PO-IAA-free groups.

Patients with perforated appendicitis were treated with antibiotics that primarily target Gram-negative rods and anaerobic bacteria, and antibiotics were administered until the inflammatory response became negative.

## 2.4. Sample Size

Our sample size calculation was based on the study by Melanie *et al.* [16], who examined the relationship between the amount of intraperitoneal lavage during appendectomy and residual abscess. In this study, the incidence of residual abscess was 0% (0/140) in the high intraperitoneal washout group and 6.2% (18/292) in the other groups. A correlation coefficient of 0.5, alpha of 0.05, and power of 0.9 determined the required sample size as 68.

## 2.5. Statistical Analysis

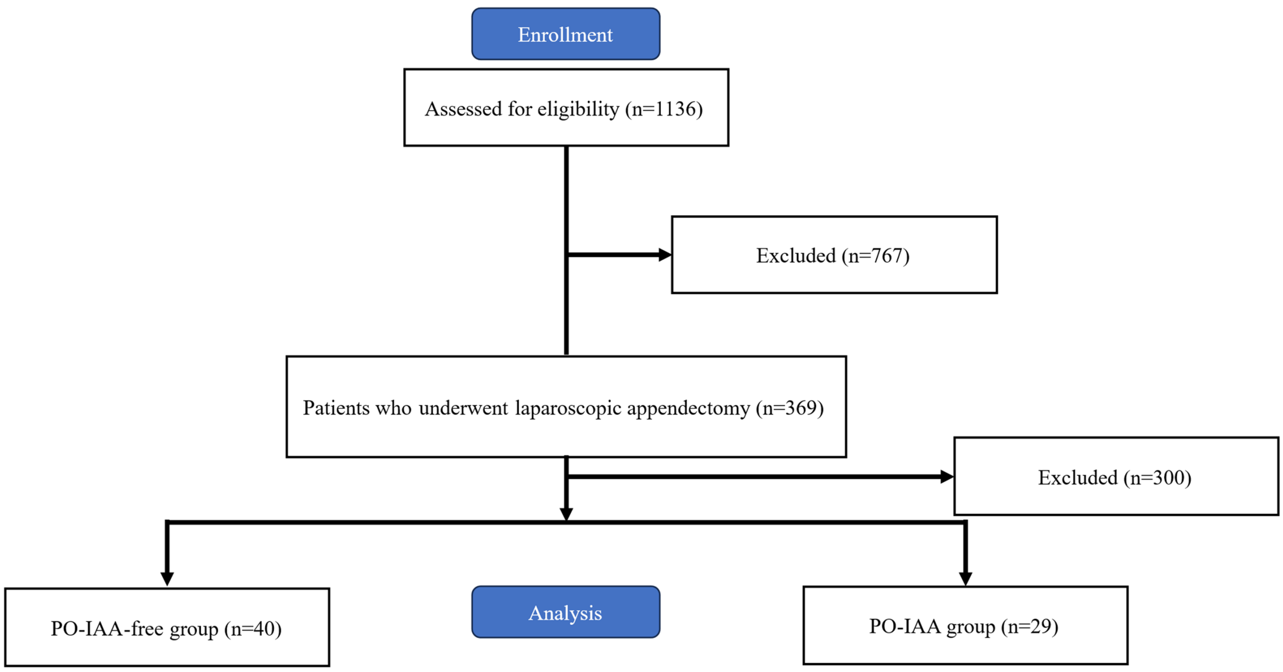
Statistical analyses were performed using appropriate software (EZR version 1.67) [21]. Descriptive statistics were calculated for all variables. Categorical variables were compared with Fisher's exact tests, continuous variables with a normal distribution with *t*-tests, and continuous variables with a non-normal distribution with Mann-Whitney U tests. Statistical significance was set at $p < 0.05$. Receiver operating characteristic (ROC) curves were applied to obtain the area under the curve (AUC) and to determine ideal cutoffs.

### 2.6. Ethical Considerations

The study protocol was reviewed and approved by the Institutional Review Board of Saitama Prefectural Children's Medical Center. Informed consent was obtained from the parents or guardians of all participants. Data confidentiality was maintained in accordance with the institutional guidelines and regulations.

## 3. Results

A total of 1136 patients were hospitalized and treated for appendicitis between January 2014 and December 2023, and 369 patients underwent LA. Of these, 69 patients were enrolled based on the operative findings (Figure 1). Forty-nine patients were assigned to the PO-IAA-free group and 20 to the PO-IAA group.




PO-IAA, postoperative intra-abdominal abscess.

Figure 1. Flowchart of patient selection for this study.

### 3.1. Patients

The patient characteristics are shown in Table 1. There were no significant differences in demographics (age, sex, height, BW, BMI, and BSA), highest perioperative serum CRP, days until surgery after symptom onset, and duration of antibiotic use between the groups. However, the highest perioperative serum leukocyte level was significantly higher in the PO-IAA group.

### 3.2. Outcomes

The results are presented in Table 2. The media IV in the PO-IAA-free group

**Table 1.** Patient characteristics.

| | PO-IAA-free (n = 49) | PO-IAA (n = 20) | *p*-value |
|---|---|---|---|
| Age, years, median (IQR) | 10 (0 - 15) | 9 (4 - 13) | 0.477* |
| Sex, n (%) | | | |
| Female | 21 (42.9) | 8 (40.0) | 0.551† |
| Male | 28 (57.1) | 12 (60.0) | |
| Height, cm, median (IQR) | 142.2 (64 - 167) | 133.0 (104 - 163) | 0.771* |
| Body weight, kg, mean ± SD | 31.94 ± 12.89 | 33.52 ± 12.22 | 0.640‡ |
| Body mass index, kg/m$^2$, median (IQR) | 16.40 (12.35 - 22.95) | 17.15 (13.18 - 25.6) | 0.061* |
| Body surface area, m$^2$, mean ± SD | 1.09 ± 0.31 | 1.11 ± 0.28 | 0.826‡ |
| Days until surgery after symptoms, median (IQR) | 2 (0 - 12) | 2 (1 - 10) | 0.285* |
| Highest perioperative serum leukocyte count, /μL, mean ± SD | 16530.8 ± 4583.3 | 18896.5 ± 4076.6 | 0.049‡ |
| Highest perioperative serum C-reactive protein, mg/dL, mean ± SD | 17.1 ± 6.9 | 18.6 ± 7.5 | 0.417‡ |
| Duration of antibiotic use, days, median (IQR) | 11 (3 - 33) | 17.5 (5 - 38) | 0.771* |

PO-IAA, postoperative intra-abdominal abscess; IQR, interquartile range; N, number; SD, standard deviation. *Mann-Whitney U test; †Fisher's exact test; ‡*t*-test.

**Table 2.** Outcome data.

| | PO-IAA-free (n = 49) | PO-IAA (n = 20) | *p*-value |
|---|---|---|---|
| IV, mL, median (IQR) | 8000 (6000 - 10,000) | 6000 (4000 - 7250) | 0.014* |
| IV/BW, mL/kg, median (IQR) | 270.9 (176.0 - 409.4) | 159.2 (128.0 - 223.0) | 0.009* |
| IV/BSA, mL/m$^2$, median (IQR) | 7500.6 (5048.4 - 9656.6) | 4890.6 (3742.8 - 6446.9) | 0.008* |
| Operation time, min, median (IQR) | 107 (53 - 242) | 138 (60 - 261) | 0.146* |
| Intraoperative blood loss, mL, median (IQR) | 1.0 (1.0 - 200.0) | 1.0 (1.0 - 200.0) | 0.915* |
| Surgical site infection, n (%) | 3 (6.1) | 0 (0.0) | 0.551† |
| Length of hospital stay, days, median (IQR) | 12 (3 - 48) | 19.5 (8 - 44) | 0.027* |

PO–IAA, postoperative intra-abdominal abscess; IQR, interquartile range; IV, irrigation volume; BW, body weight; BSA, body surface area, *Mann-Whitney U test; †Fisher's exact test.

was 8000 mL compared with 6000 mL in the PO-IAA group ($p = 0.014$). We created a ROC curve showing the relationship between sensitivity and 1-specificity for different thresholds of IV, to determine the IV required for PO-IAA prevention (**Figure 2**). The curves help to determine the optimal cutoff values for the assessed parameters in predicting the prevention of PO-IAA. The Youden index was used as the cutoff value [22]. The cutoff value for IV was 6000 mL and the AUC was 0.688. The median IV/BW was significantly higher in the PO-IAA-free group (270.9 mL/kg) compared with the PO-IAA group (159.2 mL/kg) ($p = 0.009$). The cutoff value for IV/BW was 234.6 mL/kg, with an AUC of 0.702 (**Figure 2**). The median IV/BSA was significantly higher in the PO-IAA-free group (7500.6 mL/m$^2$) compared with the PO-IAA group (4890.6 mL/m$^2$) ($p = 0.008$).

The ROC curve for IV/BSA indicated a cutoff value of 6352.2 mL/m², with an AUC of 0.702 (**Figure 2**). There were no significant differences in operative time, intraoperative blood loss, incidence of SSI, or length of hospital stay between the two groups. The outcomes were compared using the Mann-Whitney U test, because both datasets were non-normally distributed according to the Shapiro-Wilk normality test.

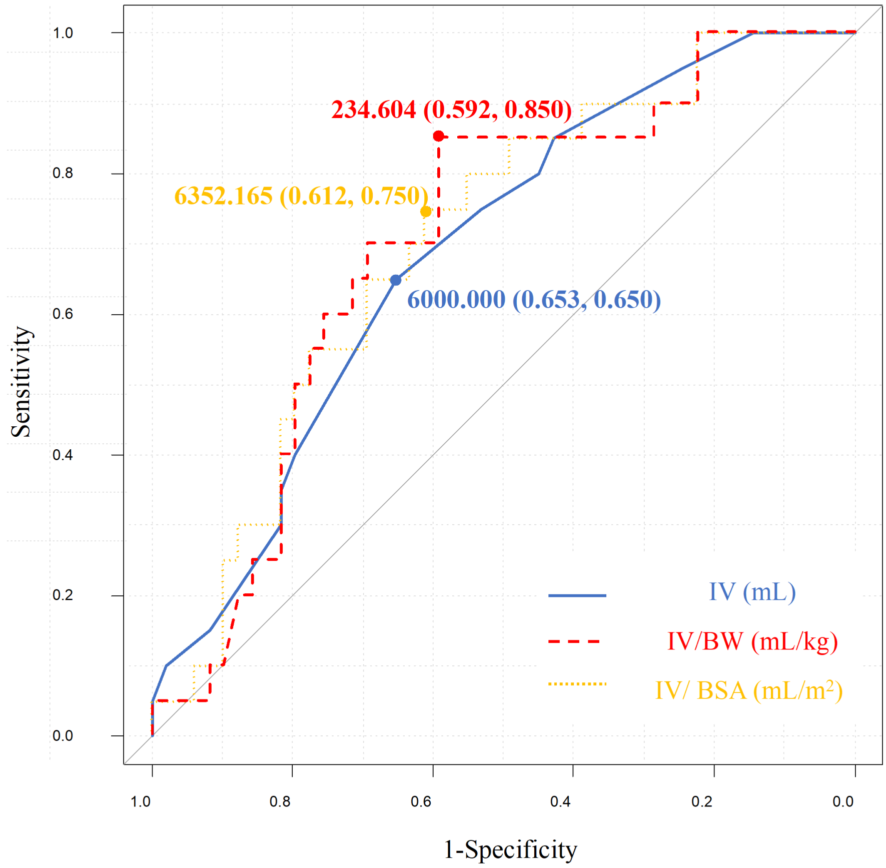



**Figure 2.** Receiver operating characteristic curves for postoperative intra-abdominal abscess (PO-IAA). IV, irrigation volume; BW, body weight; BSA, body surface area. Dots in each graph represent the Youden index, which is the cutoff value for PO-IAA prevention.

## 4. Discussion

The results of this study showed that patients without PO-IAA had a significantly larger IV than those who developed PO-IAA. In terms of the secondary outcomes, IV/BW and IV/BSA were also significantly higher in the PO-IAA-free group. The lack of any significant difference in operative time or intraoperative blood loss between the PO-IAA and PO-IAA-free groups indicated that massive intraoperative rinsing could be performed safely. We generated ROC curves to determine if IV was effective for preventing PO-IAA, and the AUC values suggested that cutoff values of IV/BW 234.6 mL/kg and IV/BSA 6352.2 mL/m² may be more effective than IV 6000 mL.

Several previous studies have reviewed the use of intraoperative irrigation in patients undergoing surgery for perforated appendicitis. Shawn *et al.* reported no significant differences between pediatric patients treated with intraoperative irrigation and suction alone for perforated appendicitis in terms of the incidence of PO-IAA (19.1% and 18.3%, respectively, $p = 1.0$) and length of hospital stay (5.5 ± 3.0 and 5.4 ± 2.7 days, respectively, $p = 0.93$) [9]. Zhou *et al.* reviewed a randomized controlled study that examined the amounts of intraperitoneal washings for intraperitoneal infections. They found no advantages between intraperitoneal lavage compared with suction alone in terms of mortality (0% and 1.1%, respectively; relative risk [RR] 0.31, 95% confidence interval [CI] 0.02 - 6.39], intra-abdominal abscess (12.3% vs. 11.8%, respectively; RR 1.02, 95% CI 0.70 - 1.48; $I^2$ = 24%), incisional surgical site infections (3.3% vs. 3.8%, respectively; RR 0.72, 95% CI 0.18 - 2.86; $I^2$ = 50%), postoperative complications (11.0% vs. 13.2%, respectively; RR 0.74, 95% CI 0.39 - 1.41; $I^2$ = 64%), reoperation (2.9% vs. 1.7%, respectively; RR1.71, 95% CI 0.74 - 3.93; $I^2$ = 0%), and readmission (5.2% vs. 6.6%, respectively; RR 0.95, 95% CI 0.48 - 1.87; $I^2$ = 7%) [13]. Several other studies found that irrigation did not produce superior results in terms of PO-IAA prophylaxis compared with suction alone [1] [3] [6] [12] [17]. Similar to the current results. However, Fengbo *et al.* and Melanie *et al.* studied intraoperative massive irrigation in patients with perforated appendicitis (>2 L and 3 - 12 L, respectively) and found that both were effective in preventing PO-IAA [10] [16].

Intraperitoneal lavage has been considered to be ineffective for several possible reasons: 1) bacteria may adhere to the peritoneal mesothelial cells, such that irrigation cannot decrease the microorganism load on the peritoneum; 2) irrigation may cause bacterial dislocation and diffuse or remote inoculation, leading to contamination by spreading microorganisms; and 3) irrigation may dilute mediators of phagocytosis, such as opsonic proteins and immunoglobulins [13]. However, IV in previous studies that recommended suction alone, rather than irrigation, was 500 - 1000 mL in each case, which was insufficient compared with the current IV, and we therefore assumed that irrigation was ineffective because of insufficient IV [1] [6] [9] [11]-[13] [17]. However, the results of this study suggest that massive irrigation is effective. We speculate that massive irrigation may reduce the number of bacteria in the abdominal cavity and dilute inflammatory mediators. The strength of this study lies in its finding that massive irrigation may effectively help to prevent PO-IAA, as a major complication of perforated appendicitis. Additionally, the generated ROC curve can estimate the amount of IV required; because pediatric appendicitis can occur at various ages, from infancy to adolescence, the definition of massive irrigation may vary depending on the patient's size. Additionally, massive irrigation was also shown to be a safe procedure, as intraoperative blood loss and the incidence of SSI did not significantly differ between the two groups.

One limitation of this study was its retrospective case-control design. Therefore, due to the nature of data collection, potential biases may arise. Furthermore, since this study is based solely on univariate analysis, we believe that various biases can be eliminated by adding more cases and performing multivariate analysis. Additionally, the study did not compare the results with the outcomes of suction alone, which has been the standard procedure in many studies. Further studies are therefore required to compare suction alone with massive irrigation.

## 5. Conclusion

Massive intra-abdominal irrigation may help to prevent PO-IAA in children undergoing LA for perforated appendicitis. Additionally, IV/BW and IV/BSA may be indicators that determine the IV.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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