**Hemodynamic, Airway Pressure, and Capnometric Changes and Perioperative Outcome in Pediatric Laparoscopic Inguinal Herniorrhaphy: A Comparison with Open Inguinal Herniorrhaphy**

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**Abstract**

**Background:** Laparoscopic procedures which are now established in pediatric population as well exposes the child to supplemental cardiorespiratory changes due to increase in intraabdominal pressure (IAP) and hypercarbia. **Aims:** This study aims to analyze the effects of pneumoperitoneum and postural modifications on cardiorespiratory system (primary outcome) during pediatric laparoscopic herniorrhaphy (LH) and its comparison with open herniorrhaphy (OH) and assessment of overall perioperative outcome (secondary outcome). **Settings and Design:** A prospective, observational study conducted in a tertiary care hospital. **Materials and Methods:** Fifty children undergoing either LH (n = 25) or OH (n = 25) were included in the study. Anesthetic procedure was standardized. Parameters monitored were heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressures (MAP), electrocardiogram lead-II, end-tidal CO₂ (ETCO₂), airway pressures P_{Peak}, P_{Plateau}, P_{Mean}, pulse oximetry, IAP, minute ventilation/respiratory rate alterations. **Statistical Analysis Used:** Student’s t-test and Chi-square test were applied to compare different variables between the two groups. Intragroup analysis was done using the analysis of variance test. **Results:** The HR was comparable in both groups. The rise in SBP, DBP, and MAP was 9% (102.88 ± 6.91–121.32 ± 6.63), 19% (60.88 ± 4.94–77.00 ± 9.75), and 14.8% (73.92 ± 4.65–90.40 ± 8.42), respectively, in group LH. The rise in peak, plateau, and mean airway pressures was 19.4% (14.20 ± 2.00–18.00 ± 2.54), 20.1% (13.32 ± 1.89–16.89 ± 2.60), and 16.1% (6.20 ± 1.00–7.47 ± 0.96), respectively, in group LH. ETCO₂ showed a maximum rise of 19.4% (34.52 ± 3.61–41.21 ± 3.99) in group LH. In laparoscopic group, recurrence was seen in 3 patients. **Conclusions:** We found significant hemodynamic, airway pressure, and capnometric changes during pediatric LH with comparable perioperative outcome among the two groups. **Keywords:** Airway pressure, capnometry, hemodynamic, herniorrhaphy, laparoscopic, perioperative outcome

**INTRODUCTION**

Recent advances in anesthetic and surgical technique and refinement in equipment have led to a significant increase in the use of laparoscopic video surgery in pediatric population. The proposed benefits of laparoscopic techniques over traditional open operative techniques are numerous including minor incisions, better cosmetic results, quicker recovery, less pain, earlier postoperative ambulation, fewer wound complications, and an overall shorter hospital stay. The physiological impact of these procedures is not well extensively documented in the literature and cannot be simply extrapolated from the adult data, which may vary among the wide range of pediatric age. The aim of the present study was to evaluate the hemodynamic, airway pressure, and capnometric changes and overall perioperative outcome in patients undergoing laparoscopic herniorrhaphy (LH), to correlate these changes to various factors such as intraabdominal pressure, postural modification, duration of surgery, and total carbon dioxide (CO₂) used, and to compare this with open herniorrhaphy (OH) in the pediatric age group.

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Quick Response Code:  
Website: www.aeronline.org  
DOI: 10.4103/aer.AER_112_17

**How to cite this article:** Garg J, Kale S, Sabharwal N, Bagga D, Gogia AR. Hemodynamic, airway pressure, and capnometric changes and perioperative outcome in pediatric laparoscopic inguinal herniorrhaphy: A comparison with open inguinal herniorrhaphy. Anesth Essays Res 2018;12:165-9.
**Materials and Methods**

This prospective observational study was conducted in our hospital after approval from the Institutional Ethical Committee on 50 children between age group of 3–10 years belonging to American Society of Anesthesiologists (ASA) physical status class I and II of either gender after obtaining a written informed consent from parents or guardians. Twenty-five patients each scheduled to undergo laparoscopic (group LH) and open (group OH) herniorrhaphy were included, while children with coexisting cardiorespiratory, congenital diseases, or on chronic medications were excluded from the study. All patients were premedicated with oral midazolam 0.25 mg/kg given 1 h before surgery and eutectic mixture of local anesthetics cream was applied on the dorsum of the hand. An intravenous line was secured in the preoperative area in the presence of parents just before surgery. In the operating room, standard monitoring including electrocardiogram (ECG), noninvasive blood pressure, and pulse oximetry (SpO₂) was instituted and lactated ringer’s solution was started. General anesthesia (GA) was induced with fentanyl 12 µg/kg and propofol 2.0–2.5 mg/kg and endotracheal intubation was facilitated with vecuronium 0.1 mg/kg with an appropriate size of an endotracheal tube. GA was maintained with an oxygen, nitrous oxide, and isoflurane (0.8%–1.2%), supplemented with fentanyl 0.5–1.0 µg/kg and vecuronium boluses at appropriate intervals. Intraoperative fluid was given using Holliday-Segar formula.

Patients were mechanically ventilated with Datex Ohmeda Aestiva 5/7100 ventilator using oxygen and nitrous oxide with tidal volume of 12 ml/kg, an inspiration ratio of 1:2 and respiratory rate (RR) was adjusted initially to maintain end-tidal CO₂ (ETCO₂) below 30–35 mmHg with the aim of keeping it below 45 mmHg at all times after creating pneumoperitoneum. Peak airway pressure alarm limit was set at 30 cmH₂O beyond which intervention was done. Pneumoperitoneum was created following insertion of verres insufflations cannula with the patient in supine position and CO₂ was insufflated at the rate of 0.5 L/min using Karl Storz electronic endoflator to maintain an intraabdominal pressure of 10–12 mmHg. After allowing 5 min for intraabdominal pressure to stabilize, the patient was positioned in the final surgical position of 15° Trendelenburg tilt.

After completion of surgery, isoflurane and nitrous oxide were discontinued and patients extubated after neuromuscular reversal with neostigmine 50 µg/kg and glycopyrrolate 10 µg/kg. No blood, blood products, or plasma expanders were required at any stage. Postoperative analgesia was provided with rectal paracetamol suppository 20 mg/kg and local infiltration of port sites with 0.25% bupivacaine in laparoscopic cases and causal bupivacaine in open cases.

The hemodynamic parameters monitored were ECG lead–II, heart rate (HR), noninvasive systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP). The respiratory parameters monitored were peak, plateau, and mean airway pressures (P_{Peak}, P_{Plateau}, P_{Mean}), end-tidal CO₂ (ETCO₂), SpO₂, and RR alterations. These variables were recorded at the following intervals in group LH: 5 min postintubation (baseline), after creation of pneumoperitoneum (B), following Trendelenburg tilt (C), during surgery every 5 min until desufflation (D), postdesufflation (E), postextubation (F) and postoperatively every 15 min for 1 h. In group OH, parameters were recorded 5 min postintubation (baseline), after final position (C), during surgery every 5 min (D), postextubation (F), and postoperative every 15 min till 1 h. Other parameters monitored were intraabdominal pressure, duration of pneumoperitoneum, total CO₂ consumed, postoperative anesthetic, and surgical sequelae.

**Statistical analysis**

Data were analyzed using statistical package for social sciences software (SPSS) for Windows, Version 16.0. Chicago, SPSS Inc. Data variables were expressed as mean ± standard deviation. Student’s t-test and Chi-square test were applied to compare different variables between the two groups. Intragroup analysis was done using analysis of variance test for repeated measurements to test for time effects. P < 0.05 was considered statistically significant.

**Results**

Patients’ demographic profile and duration of surgery are presented in Table 1. The two groups (group LH; n = 25 and group OH; n = 25) were comparable in terms of age, gender distribution, and duration of surgery. HR did not show statistically significant variations in either group from the baseline, P > 0.05 as shown in Figure 1 nor were there any ECG abnormalities. SBP, DBP, and MAP were significantly greater (P < 0.001) after

![Heart rate trend in group LC (blue) versus group OC, (pink).](image)

Heart rate was comparable in both the groups, P > 0.05

| Table 1: Demographic and other parameters |
|------------------------------------------|
| **Group LH** | **Group OH** |
| Age (year) | 5.96±2.42 | 5.96±2.47 |
| Sex (male/female) | 23/2 | 22/3 |
| Weight (kg) | 19.00±4.49 | 17.44±5.51 |
| Duration of surgery (min) | 33.92±5.60 | 31.68±6.53 |

LH=Laparoscopic herniorrhaphy, OH=Open herniorrhaphy
creation of pneumoperitoneum in group LH compared to baseline which was 9% (102.88 ± 6.91–121.32 ± 6.63) [Figure 2], 19% (60.88 ± 4.94–77.00 ± 9.75) [Figure 3], and 14.8% (73.92 ± 4.65–90.40 ± 8.42) [Figure 4], respectively, in group LH and the rise was sustained throughout insufflation, not returning to the baseline even 10 min postextubation. No significant changes were observed in the open group.

Significant increases in airway pressures \( (P < 0.001) \) were seen from baseline in group LH after creating pneumoperitoneum and Trendelenburg position. The increase in peak, plateau, and mean pressures is 19.4\% (14.20 ± 2.00–18.00 ± 2.54), 20.1\% (13.32 ± 1.89–16.89 ± 2.60), and 16.1\% (6.20 ± 1.00–7.47 ± 0.96), respectively, as seen in Table 2. No significant rise in airway pressures was seen in the Group OC. Group LH showed a progressive increase in ETCO\(_2\) after beginning of CO\(_2\) insufflation which attained a plateau 10–15 min after insufflation with a maximum rise of 19.4\% (34.52 ± 3.61–41.21 ± 3.99) as seen in Table 2. After creation of pneumoperitoneum, respiratory frequency was increased by 42\% (15.80 ± 2.04–22.44 ± 3.35) to keep ETCO\(_2\) below 45 mmHg. Group OH patients did not show any significant variation in ETCO\(_2\) throughout the surgery, \( P > 0.05 \) and did not require any RR alterations.

In group LH, mean total CO\(_2\) insufflated was 4.64 L, while mean duration of pneumoperitoneum was 27.60 ± 5.42 min, and mean IAP maintained was 10.3 mmHg. In all patients, peripheral oxygenation remained stable throughout the perioperative period. Postoperative complications are shown in Table 3.

**DISCUSSION**

Hemodynamic and respiratory repercussions seen during laparoscopic surgery are mainly related to an increase in IAP, postural modifications (head up or head down tilt), and hypercarbia.\(^4\) As compared to adults, there is a paucity of literature in pediatric population and simple translation of adult data is not possible because of unique and different physiology of children.\(^4\) We conducted a study on ASA physical status class I and II children and analyzed the effects of pneumoperitoneum and postural changes on hemodynamic and respiratory parameters which was the measure of the

| **Table 2: Respiratory parameters in laparoscopic herniorrhaphy group** |
|-----------------|-----------------|-----------------|-----------------|
| **Parameter**   | **Baseline**    | **Maximum**     | **Percentage increase** | **P**      |
| Peak airway pressure (mmHg) | 14.20±2.00 | 18.00±2.54 | 19.4 | <0.001 |
| Plateau airway pressure (mmHg) | 13.32±1.89 | 16.89±2.60 | 20.1 | <0.001 |
| Mean airway pressure (mmHg) | 6.20±1.00 | 7.47±0.96 | 16.1 | <0.001 |
| End-tidal CO\(_2\) (mmHg) | 34.52±3.61 | 41.21±3.99 | 19.4 | <0.001 |
| Respiratory rate (bpm) | 15.80±2.04 | 22.44±3.35 | 42 | <0.001 |

*Values are mean±SD. CO\(_2\)=Carbon dioxide, SD=Standard deviation

| **Table 3: Perioperative outcome** |
|-----------------|-----------------|
| **Group I** | **Group II** |
| PONV | 6 | 2 |
| Recurrence | 3 | 0 |

PONV=Postoperative nausea and vomiting

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**Figure 2:** Systolic blood pressure trend in group LC (blue) versus group OC, (pink). Systolic blood pressure increased significantly by 9% from baseline in group LC

**Figure 3:** Diastolic blood pressure trend in group LC (blue) versus group OC (pink). Diastolic blood pressure increased significantly by 19% from baseline in group LC

**Figure 4:** Mean arterial pressure trend in group LC, (blue) versus group OC, (pink). Mean arterial pressure increased significantly by 14.8% from baseline in group LC
primary outcome while the secondary outcome studied was
the perioperative outcome.

There were no significant variations seen in HR from baseline
throughout the surgery in either of the groups. No dysrhythmias
or ECG changes were observed. Gentili et al.,[5] Kardos et al.,[8]
Baroncini et al.,[3] Schäfer et al.,[7] and Manner et al.[9] also
observed no significant change in the HR in children during
pneumoperitoneum.

In our study, SBP, DBP, and MAP increased significantly by
9%, 19%, and 14.8%, respectively, after pneumoperitoneum.
The higher increase in DBP and MAP as compared to
SBP correlates with an increase in systemic vascular
resistance (SVR) caused by mechanical compression of
splanchnic vascular bed, a sympathetic reflex from the
splanchnic region, and a release of humoral vasoconstrictive
mediators such as renin or vasopressin.[10] Similarly, Gentili
et al.[3] and Schäfer et al.[7] also documented a significant
increase in DBP during pneumoperitoneum and attributed it to
an increase in SVR. Elevated IAP produces complex changes
in hemodynamics through its effects on SVR, venous return,
and myocardial performance. A study in children revealed that
IAP of 5–8 mmHg produces no significant change in cardiac
output (CO), while IAP of 12 mmHg decreases CO by 13%.[9]
In our study, we kept IAP at or below 10 mmHg to minimize
its consequences on the hemodynamics.

In the laparoscopic group, a progressive rise in the ETCO₂ was
seen after creation of pneumoperitoneum, reaching a plateau
after 10–15 min. The maximum rise of 19.4% was seen in spite
of increasing respiratory rate by 42%. In 5 patients, ETCO₂
increased beyond 45 mmHg in spite of all ventilatory adjustments.
Gentili et al.[5] observed a significant increase in ETCO₂ after
CO₂ insufflation with a maximum rise of 16.7% from baseline,
while plateau was reached 10–15 min after insufflation in
children undergoing diagnostic/operative laparoscopy. Similarly,
Baroncini et al. found a significant increase (P < 0.05) in ETCO₂
by 23.4% from baseline after CO₂ insufflation.[2] In children,
CO₂ absorption may be more efficient due to the physiological
properties of peritoneum such as reduced thickness of tissues
between the gas containing cavity and the capillaries and larger
absorption area in comparison to weight.[8]

Postdesufflation, although ETCO₂ started falling, it reached
the baseline only after a time lag of 10 min. This has been
explained to be due to large amounts of CO₂ being buffered
in muscle and fat, resulting in an additional load of CO₂ which
must be eliminated through the lungs postoperatively.[10] Hsing
et al.[11] and Tobias et al.[1] also observed a time lag of 8–10 min
for ETCO₂ to reach the baseline value postdesufflation.

Also further, ETCO₂ is shown to correlate well to partial
pressure of arterial CO₂ in children excepting those with
respiratory pathology, neonates, and infants or during prolonged
surgery.[12] We followed the above assumption considering that
we had ASA class I/II patients undergoing short procedure and
therefore avoided doing an arterial blood gas.

Both pneumoperitoneum and Trendelenburg position
contribute to the rise in airway pressures during pediatric LH.
In our study, the peak, plateau, and mean airway pressures
increased significantly from baseline after pneumoperitoneum,
the increase being 13.8%, 13.5%, and 12.3% with a further rise
to 19.4%, 20.1%, and 16.1%, respectively, after Trendelenburg
position. Bergesio et al.[13] and Tobias et al.[1] also found
a significant increase in peak airway pressure. Manner
et al.[9] found that the rise in peak inspiratory pressure (PIP)
correlated well with the fall in lung compliance. The rise in
IAP during pneumoperitoneum causes a decrease in lung
compliance with proportionate increase of both peak and
plateau pressures. This may be complicated further during LH
by a rise in airway resistance due to causes such as kinking
of an endotracheal tube, endobronchial intubation, tracheal
tube abutting on carina, or bronchospasm which will lead to
a selective rise in peak airway pressure without affecting the
plateau airway pressure. Thus, comparing and analyzing peak
and plateau airway pressures were used as a simple guide
to detect and treat any additive cause of increased airway
resistance, especially when facilities of directly measuring
lung compliance and resistance, are not available. Mean
airway pressure signifies overall oxygenation and increased by
16% in our study but did not caused any fall in oxygenation,
lowest oxygen saturation during laparoscopy being 97%.

One of the claimed benefits of laparoscopy is reduced
postoperative pain and in our experience, early postoperative
pain was comparable in two groups probably because
of inclusion of caudal epidural block in open cases, but
subsequently pain and discomfort decreased dramatically
over next 12 – 48 h in laparoscopic group and these children
returned to normal activity much earlier and were discharged
by 2nd postoperative day. Incidence of postoperative nausea and
vomiting (PONV) was higher in laparoscopic group, probably
due to peritoneal irritation by insufflated CO₂.[3,14] Surgical
sequelae such as scrotal edema, hematoma, urinary retention,
and infection were comparable in both groups. Recurrence had
occurred among three patients in laparoscopic group while
none in the open one. Endoscopic surgical procedures are
associated with specific complications that are generally not
encountered with open procedures, for example, air embolism,
subcutaneous emphysema, and capnothorax,[15] which were
not seen in our study.

Strength of the study includes totality of the comparison by
including intraoperative cardiorespiratory and perioperative
outcomes. Limitation of this study may include the relatively
smaller size of the study population and inability to extrapolate
these results on children belonging to ASA physical status
class III and IV.

Conclusions

Significant hemodynamic, airway pressure, and capnometric
changes were seen following pneumoperitoneum with
trendelenburg position during laparoscopic herniorrhaphy in
ASA physical status class I and II children aged 3–10 years at an intraabdominal pressure of 10 mmHg. These changes were well tolerated by our group of patients, but whether they would be tolerated by high-risk children is still a matter of further research. Although the advantages of decreased postoperative pain and early return to activity were seen in the laparoscopic herniorrhaphy group, a higher incidence of PONV and more significantly recurrence in three cases mandating a repeat surgery can turn the balance against the laparoscopic herniorrhaphy group. Combining the above factors with significant cardiorespiratory effects of pneumoperitoneum along with recurrence, our study did not reveal an overall improved perioperative outcome in laparoscopic group as compared to the open group.

Acknowledgments
Dr. Vipul Garg has helped in technical aspects of submitting this manuscript.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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