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Reduction in surgical fog with a warm humidified gas management protocol significantly shortens procedure time in pediatric robot-assisted laparoscopic procedures

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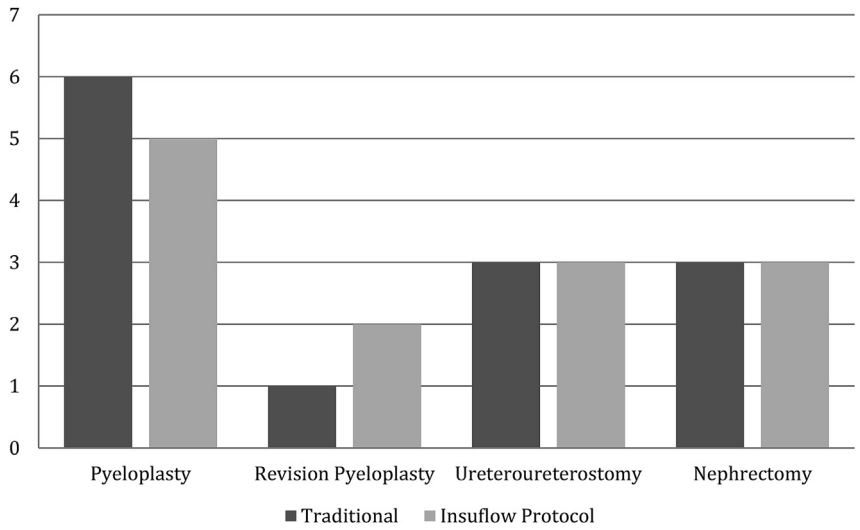
Summary

Introduction
The adoption of robot-assisted laparoscopic (RAL) procedures in the field of urology has occurred rapidly, but is, to date, without pediatric-specific instrumentation. Surgical fog is a significant barrier to safe and efficient laparoscopy. This appears to be a significant challenge when adapting three-dimensional 8.5-mm scopes to use in pediatric RAL surgery. The objective of the present study was to compare matched controls from a prospectively collected database to procedures that were performed utilizing special equipment and a protocol to minimize surgical fog in pediatric RAL procedures.

Methods
A prospectively collected database of all patients who underwent RAL pediatric urology procedures was used to compare: procedure, age, sex, American Society of Anesthesiologists score, weight, console time, number of times the camera was removed to clean the lens during a procedure, length of hospital stay, and morphine equivalents required in the postoperative period. A uniquely developed protocol was used, it consisted of humidified (95% relative humidity) and warmed CO_2 gas (95 °F) insufflation via Insuflow® on a working trocar, with active smoke evacuation via PneuVIEW®XE on the opposite working trocar with a gas pass through of 3.5–5 l/min. The outcomes were compared with matched controls (Summary Fig).

Results
The novel gas protocol was utilized in 13 procedures (five pyeloplasties, two revision pyeloplasties, three ureteroureterostomies (UU), three nephrectomies) and compared with 13 procedures (six pyeloplasties, one revision pyeloplasty, three UU, three nephrectomies) prior to the protocol development. There was no statistical difference in age ($P = 0.78$), sex ($P = 0.11$), ASA score ($P = 1.00$) or weight ($P = 0.69$). There were no open conversions, ≥Grade 2 Clavien complications, or readmissions within 30 days in either group.

Conclusions
This novel gas protocol yielded a statistically significant reduction in procedure time, by decreasing the number of times the camera was required to be pulled during the case by more than five occurrences, and saved approximately 35 min on average per case.



Summary Fig. Matched traditional versus Insuflow protocol stratified by procedure type.

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Introduction

Robot-assisted laparoscopic (RAL) surgical procedures were rapidly adopted in adult urology and then gynecology; this was due to three-dimensional (3D) visualization, improved dexterity, and increased degrees of freedom compared with traditional laparoscopic surgery [1]. However, the process has been slower in pediatric urology and surgery secondary, due to differences in availability of robots at children's hospitals [2], different procedure types, and lack of pediatric-specific instruments. Until pediatric-specific instrumentation becomes available, the pediatric urologist/surgeon will need to adapt techniques to overcome these barriers [3–5] in order to provide patients with the benefits of robotic surgery, including: improved post-surgical recovery, reduced postoperative pain, and smaller scars [6]. Some authors have cited longer operative times and increased costs for these benefits associated with minimally invasive surgery [7,8]. However, recent data have shown that the learning curve associated with robotic surgery may be as short as 15–20 cases for certain pediatric urologic procedures [9]. Additionally, for pyeloplasty, a reduction in operative time has been noted with RAL procedures when compared to traditional laparoscopy [8].

The standard laparoscopic insufflation gas is carbon dioxide (CO_2) at 21 °C and 0% relative humidity. Recent studies in adult literature have demonstrated that increasing the temperature of the gas to 35 °C and the relative humidity to 95% is beneficial, by improving intraoperative thermoregulation, reducing camera lens fogging, reducing postoperative narcotic requirement, and shortening hospital stays. A reduction in cost has also been suggested as another potential benefit. With these goals in mind, the present team developed a method with which to decrease the common problem of surgical fogging during RAL procedures in small children. Over time, the protocol reduced these occurrences, and dramatically and consistently improved visualization during RAL procedures.

The present study described the protocol and prospectively compared patients using the novel protocol with a paired matched cohort of patients who underwent RAL procedures prior to its development. It was hypothesized that the gas protocol would reduce the amount of fogging experienced during a case compared with procedures in which no gas protocol was utilized.

Materials and methods

Prospective data were collected on all pediatric patients undergoing robot-assisted laparoscopic procedures. Insuflow® (Lexicon Medical, St. Paul, MN, USA) is a device that allows heated and humidified CO_2 to be used for pneumoperitoneum, in place of standard CO_2, in laparoscopic procedures and was utilized in the present study. A novel robotic protocol was developed and consisted of heated (95 °F) and humidified (95% relative humidity) CO_2 gas delivered through a working trocar, with active smoke evacuation on the opposite working trocar providing a gas pass through rate of 3.5–5 l/min.

Table 1 Patient characteristics compared between protocols.

	No gas protocol ($n = 13$)	Gas protocol ($n = 13$)	*P*-value
Mean age (years)	5.75	6.19	0.60
Mean weight (kg)	24.4	22.7	0.33
Mean ASA	1.75	1.75	
Male/female ratio	10/3	5/8	0.11
Right/left ratio	6/7	5/8	1.00
Procedure type			
Pyeloplasty	6	5	
Revision pyeloplasty	1	2	
Ureteroureterostomy	3	3	
Nephrectomy	3	3	

ASA, American Society of Anesthesiologists.

Patient characteristics such as age, sex, American Society of Anesthesiologists (ASA) score, and weight were collected from the prospective database. Surgical console time, camera removals for fogging, length of hospital stay, and morphine equivalents required in the postoperative period were collected from hospital charts. In an effort to provide a control group with which to compare outcomes of this novel protocol, data were retrospectively collected from a comprehensive database maintained on all pediatric robotic procedures. Operative videos were reviewed to obtain data on surgery console time and camera removals for fogging. Only removals for which the camera was removed for fogging were included.

Procedure and patient characteristics were used to match retrospective controls to the procedures and patients in the new humidified gas protocol 1:1 (Table 1). The control and experimental groups had no significant differences in age, weight, procedure type, and ASA score. Robotic procedures performed consisted of pyeloplasty, revision pyeloplasty, nephrectomy, and ureteroureterostomy. In both the control and protocol groups, an external warming blanket was used per institutional policy. The primary endpoint was length of console time for the procedure and number of times the camera was required to be removed for cleaning due to fogging. Secondary endpoints were length of stay and analgesic requirement. Descriptive statistics, Chi-squared, and *t*-test analysis were performed with JMP 11.2.0 (SAS Institute, USA). Significance was determined using an alpha of 0.05. Institutional Review Board approval was obtained prior to analysis (see Table 2).

Results

A total of 26 patients were evaluated. The demographic characteristics, including age, sex, ASA score, and weight, were comparable between the two groups (Table 1). Thirteen patients underwent procedures utilizing heated and humidified CO_2 (five pyeloplasties, two revision pyeloplasties, three ureteroureterostomies, and three

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