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ORIGINAL RESEARCH PERIOPERATIVE MEDICINE

Lung ultrasonography for detection of atelectasis in adults undergoing robot assisted laparoscopic pelvic surgeries

Sameer Sethi[1], Rahul Kathuria[2], Tanvir Samra[3], Vikas Saini[4], Dheemta Toshkhani[5], Pankaj Kushal[6]

Author affiliation:

1. Sameer Sethi, Postgraduate Institute of Medical Education and Research (PGIMER), Sector 12, Chandigarh-160012, India; E-mail: sameersethi29@gmail.com
2. Rahul Kathuria, Postgraduate Institute of Medical Education and Research (PGIMER), Sector 12, Chandigarh-160012, India; E-mail: rahulkathuria18@gmail.com
3. Tanvir Samra, Postgraduate Institute of Medical Education and Research (PGIMER), Sector 12, Chandigarh-160012, India; E-mail: drtanvirsamra@yahoo.co.in
4. Vikas Saini, Postgraduate Institute of Medical Education and Research (PGIMER), Sector 12, Chandigarh-160012, India; E-mail: drvsaini@gmail.com
5. Dheemta Toshkhani, Postgraduate Institute of Medical Education and Research (PGIMER), Sector 12, Chandigarh-160012, India; E-mail: tdheemta@gmail.com
6. Pankaj Kushal, Postgraduate Institute of Medical Education and Research (PGIMER), Sector 12, Chandigarh-160012, India; E-mail: pankajkushal23@gmail.com

Correspondence: Tanvir Samra; **E-mail:** drtanvirsamra@yahoo.co.in; **Phone:** 09910703609

ABSTRACT

Introduction: Robot-assisted laparoscopic pelvic surgeries are minimally invasive techniques that require the patient to be placed in the steep Trendelenburg position. Pneumoperitoneum further increases the risk of postoperative pulmonary complications. We used lung ultrasound score (LUSS) to detect post-operative atelectasis in this subset of patients.

Methodology: Patients aged 18 to 70 y with ASA physical status I/II undergoing robot assisted pelvic surgeries in steep Trendelenburg position were enrolled. Patients were mechanically ventilated with 50% oxygen in air with a tidal volume of 6 to 8 ml/kg in volume control mode to maintain an end tidal carbon dioxide at 35−45 mmHg with positive end-expiratory pressure (PEEP) of 5 cmH_2O. Ultrasonographic assessment was done; before induction (A), after extubation (F), 12 h (G) and 24 h after surgery (H) by dividing chest into 12 regions.

Results: A total of 1152 cine-loops acquired during the study period in 32 patients were analyzed. Incidence of postoperative atelectasis was 87.5% and each lung ultrasound examination required 12.35 ± 4.68 min. Statistically significant fall in PaO_2 was recorded at extubation from baseline and intra-operative values ($P < 0.0001$). Statistically significant difference was established between change in baseline and post-extubation LUSS to the total volume of fluid given ($P = 0.002$).

Conclusion: A high incidence (87.5%) of atelectasis in adults after robot assisted laparoscopic pelvic surgeries was detected using lung ultrasound score. Lung oxygenation decreased significantly after steep Trendelenburg position and extubation. The observed statistical difference in total IV fluids administered between patient subgroups who showed increased ultrasound signs of lung edema from the A period to the F period, although suggestive of association, is no evidence of causation.

Abbreviations: ARISCOT- Assess Respiratory Risk in Surgical patients in Catalonia; LUS- Lung Ultrasound; LUSS- Lung Ultrasound Score; OR- Operating room; PEEP- Positive End-Expiratory Pressure

Key words: LUSS; Lung ultrasound score; Pneumoperitoneum; Robotic Surgery; Ultrasonography

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1. INTRODUCTION

Incidence of postoperative pulmonary atelectasis in adults undergoing general anesthesia with muscle relaxation is reported to be as high as 90% and is known to persist for at least 24 h following surgery.[1] Airway closure from reduced functional residual capacity, mechanical compression of lung tissue and absorption atelectasis are some of the contributing factors.[2] In adults undergoing robot assisted laparoscopic pelvic surgeries the combination of prolonged Trendelenburg position and abdominal insufflation results in an increased incidence of atelectasis.[3]

Anesthesia-induced atelectasis is invisible on standard chest radiograph but can be diagnosed by computed tomography or magnetic resonance imaging.[4] Ultrasonography is a simple bedside non-invasive method for detecting obstructive and non-obstructive atelectasis of different origins.[5,6,7] Values of lung ultrasound score (LUSS) correlate with the oxygenation status of the patient.[8,9] We used LUSS to detect post-operative atelectasis in adults undergoing robot assisted pelvic laparoscopic surgery in steep Trendelenburg position. Change in sequential values of LUSS were correlated with changes in arterial oxygenation of the subjects.

2. METHODOLOGY

This prospective observational single-center trial was conducted after approval from the institute's ethics committee and registration in clinicaltrials.gov (No. NCT03144310). Patients aged 18 to 70 y with ASA physical status I/II undergoing robot assisted pelvic surgeries in steep Trendelenburg position were enrolled after written informed consent. Subjects with cardiac, severe obstructive and restrictive respiratory disease, BMI > 31 kg/m^2, upper airway infections and aeration loss on pre-operative lung sonography were excluded.

All participants were subjected to detailed pre-anesthetic evaluation. Patients were fasted according to the standard guidelines and wheeled into the robotic OR complex. Intra-venous line was secured, baseline heart rate, non-invasive blood pressure and oxygen saturation were recorded. In the operating room anesthesia was induced with 2 mg/kg of propofol and 0.1 mg/kg of morphine. To facilitate orotracheal intubation, patients were given 0.1 mg/kg of vecuronium. Maintenance of anesthesia was done by desflurane to achieve a MAC of 1.2. Patients were mechanically ventilated with 50% oxygen in air with a tidal volume of 6 to 8 ml/kg in volume control mode. The respiratory rate was adjusted to maintain an $EtCO_2$ of 35−45 mmHg with an inspiratory/expiratory ratio of 1:2. A positive end-expiratory pressure of 5 cmH_2O was applied. Invasive blood pressure monitoring was established.

Patients were placed in lithotomy position and restrained using shoulder support. Following CO_2 insufflation, patients were positioned in steep Trendelenburg position (angle was standardized to 45 degrees). The docking of the robot (Da Vinci Si system) was done subsequently. After the surgery was over, undocking of the robot was done and position of the patient was changed to supine. Residual effect of muscle relaxant was reversed by 0.05 mg/kg of neostigmine and 0.01 mg/kg of glycopyrrolate and post-operative analgesia was provided by 1 mg/kg diclofenac given 30 min before the end of surgery. All patients were given 100% oxygen before extubation. After extubation, 40% oxygen in air via venturi mask was given to maintain SpO_2 > 95%.

2.1. Lung ultrasonography

Ultrasonographic assessment was done using linear probe of frequency 5 to 12 MHz at 4 time points- A: Before induction (in pre-operative area); F: After extubation in post-operative period; G: 12 h after surgery; H: 24 h after surgery. Chest was divided into 12 regions and aeration loss was assessed by calculating the LUSS (Figure 1).

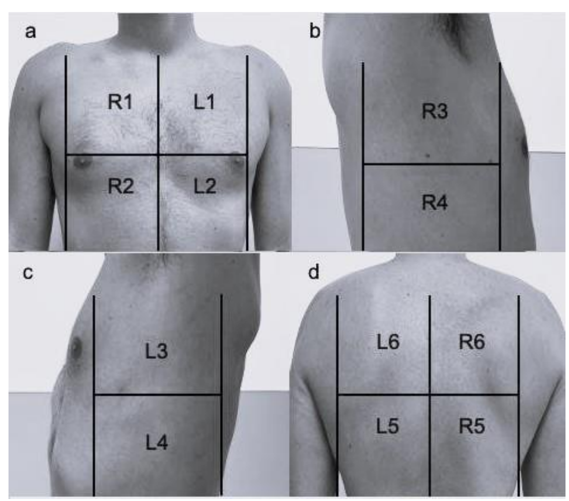

Figure 1: Each hemi-thorax is divided into 3 zones; anterior (A), lateral (L) and posterior (P) zones

Table 1: Demographic, clinical and surgical characteristics

Variables	Value
Age (y)	59.59 ± 12.48
Sex (Males)	23 (71.9%)
ASA I:II*	15:17
Height (cm)	162.31 ± 4.96
Weight (kg)	66.19 ± 10.10
Body Mass Index (kg/m^2)	25.18 ± 4.01
Duration of docking (min)	177.34± 53.28
Duration of steep Trendelenburg (min)	195.72 ± 52.15
Duration of anesthesia (min)	232.00 ± 56.53
Total fluid given (ml)	1157.18 ± 389.63
Comorbidity	
Diabetes mellitus	2 (6.3%)
Hypertension	13(40.6%)
Overweight	2 (6.3%)
Type of surgery	
Robot assisted hysterectomy	8 (25%)
Robot assisted radical cystectomy	1 (3.1%)
Robot assisted radical prostatectomy	20 (62.5%)
Robot seminal vesiculotomy	1 (3.1%)
Robot assisted vesicovaginal fistula repair	2 (6.3%)

*Continuous variables are expressed as mean ± SD and categorical variables as n (%); *Expressed as ratio*

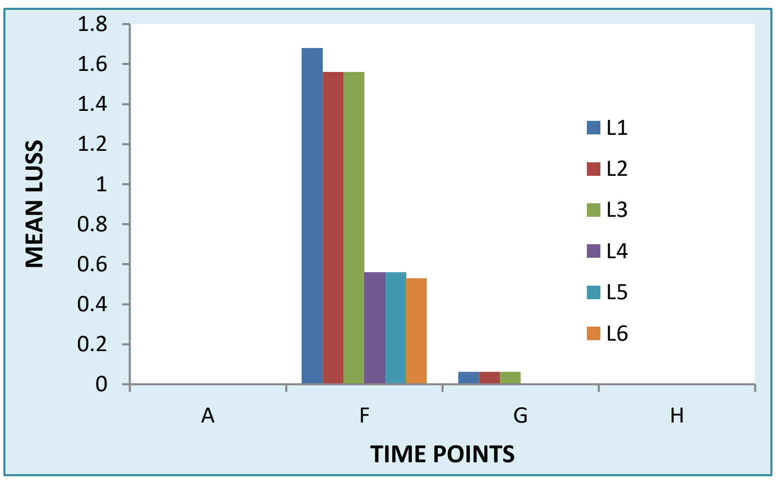

Figure 2: Values of LUSS at four time points in each quadrant in each hemisphere (Time points A: before general anesthesia induction, F: after extubation, G: 12 hours after extubation, H: 24 hours after extubation)

Examination sequence was from L1 to L6 on left hemi-thorax and then on the right side from R1 to R6.

Aeration loss was assessed by calculating the LUSS.

Each of the 12 quadrants was assigned a score of 0 to 3 adding to the simple grading system.

The combined LUS score (0−36) was then calculated by adding up the 12 individual quadrant scores.

Total anesthesia and surgery duration, time in steep Trendelenburg position, time of docking and undocking were recorded. Chest auscultation was done by another anesthesiologist blinded to USG findings at above-mentioned 4 time points in all 12 quadrants (A, F, G, and H).

Arterial blood gas analysis was done at 3 time points to correlate with ultrasonographic assessment findings: A- preoperatively; C- 15 min after steep Trendelenburg position; F- 15 min after extubation.

2.2. Hemodynamic parameters

These were recorded and their mean values averaged for the following time periods: A- preoperatively (3 values before induction at 1 min intervals); C- till 5 min after steep Trendelenburg position (at 1 min intervals); F- till 5 min after extubation (at 1 min intervals).

2.3. Statistical analysis

Data analysis was done using IBM Statistical Package for Social Sciences (SPSS Inc., Version 22.0 for windows). Continuous variables were expressed as means ± standard deviations (SD), or median with inter-quartile range (IQR). Categorical variables were described using frequency distributions and presented as frequency (%). Komolgorov- Smirnov one-sample and Shapiro-Wick tests were used to assess the normality of distribution of the continuous data. Spearman correlation was used to assess relationship between change in both LUSS and change in PaO_2/FiO_2 ratio. All tests were two tailed with 95% confidence interval and P-value was considered significant below 0.05.

3. RESULTS

Thirty-three patients were assessed for eligibility and one was excluded, leaving 32 patients for enrollment. Table 1 summarizes the baseline characteristics of the study population. All the cases were performed using Da

Table 2: Gas exchange parameters

Parameters	Time points		
	A	C	F
pH	7.35 ± 0.03	7.34 ± 0.02	7.33 ± 0.03
pO_2	143.49 ± 26.26.	156.20 ± 41.98	102.73 ± 25.49
pCO_2	35.13 ± 4.52	39.18 ± 5.15	37.72 ± 6.55
HCO_3	20.95 ± 2.19	20.03 ± 2.56	20.91 ± 2.75
Lactate	1.33 ± 0.62	1.31 ± 0.51	1.69 ± 0.54
P/F ratio	359.27 ± 65.24	312.41 ± 83.97	256.84 ± 63.74

Continuous variables are expressed as mean ± SD; Time point A- Preoperative, C- After Steep Trendelenburg, F- After extubation

Table 3: Correlation of change in PaO2/FiO2 with various factors

Parameters	ΔPaO2/FiO2 between time points A and C, spearman correlation (P)	ΔPaO2/FiO2 between time points A and F, spearman correlation (P)	ΔPaO2/FiO2 between time points C and F, spearman correlation (P)
Age (y)	0.206 (0.258)	0.093 (0.614)	-0.104 (0.57)
Weight (kg)	0.438 (0.012)	-0.183 (0.317)	-0.490 (0.004)
Height (cm)	0.209 (0.252)	0.122 (0.507)	-0.086 (0.639)
BMI (kg/m^2)	0.354 (0.047)	-0.245 (0.177)	-0.465 (0.007)
Total duration of anesthesia (min)	0.409 (0.02)	-0.122 (0.506)	-.0465 (0.007)
Total duration of docking (min)	0.466 (0.007)	-0.038 (0.837)	-0.411 (0.019)
Duration in steep Trendelenburg position (min)	0.422 (0.016)	-0.059 (0.748)	-0.390(0.027)
Total fluid given (ml)	-0.282 (0.118)	0.150 (0.411)	0.338 (0.058)

Table 4: Hemodynamic parameters

Parameters	Time Points		
	A- Preoperative	C- After steep Trendelenburg	F- After extubation
HR (beats/min)	79.09 ± 11.69	77.25 ± 14.62	76.31 ± 14.07
MAP (mmHg)	88.63 ± 16.90	86.00 ± 16.05	85.56 ± 11.94
SpO_2 (%)	98.22 ± 3.20	99.06 ± 1.86	98.53 ± 1.43

Continuous variables are expressed as mean ± SD; Abbreviations: HR - heart rate, MAP - mean arterial pressure, SpO_2 - saturation of oxygen in blood, EtCO2- end-tidal CO_2

Vinci robotic system laparoscopically and there was no conversion to open surgery

LUSS were 0 pre-operatively and 24 h after extubation for all patients recruited in the study. Combined LUS scores of 28 patients were more than 1 at time point F, i.e., after extubation and thus the incidence of postoperative atelectasis was 87.5%. Each LUS examination required an average of 12.35 ± 4.68 min to complete at each time point. A total of 1152 cine-loops acquired during the study period were analyzed. Loss of aeration was recorded in L1, L2 and L3 quadrants in the left hemi thorax and in R1, R2 and R3 quadrants in right

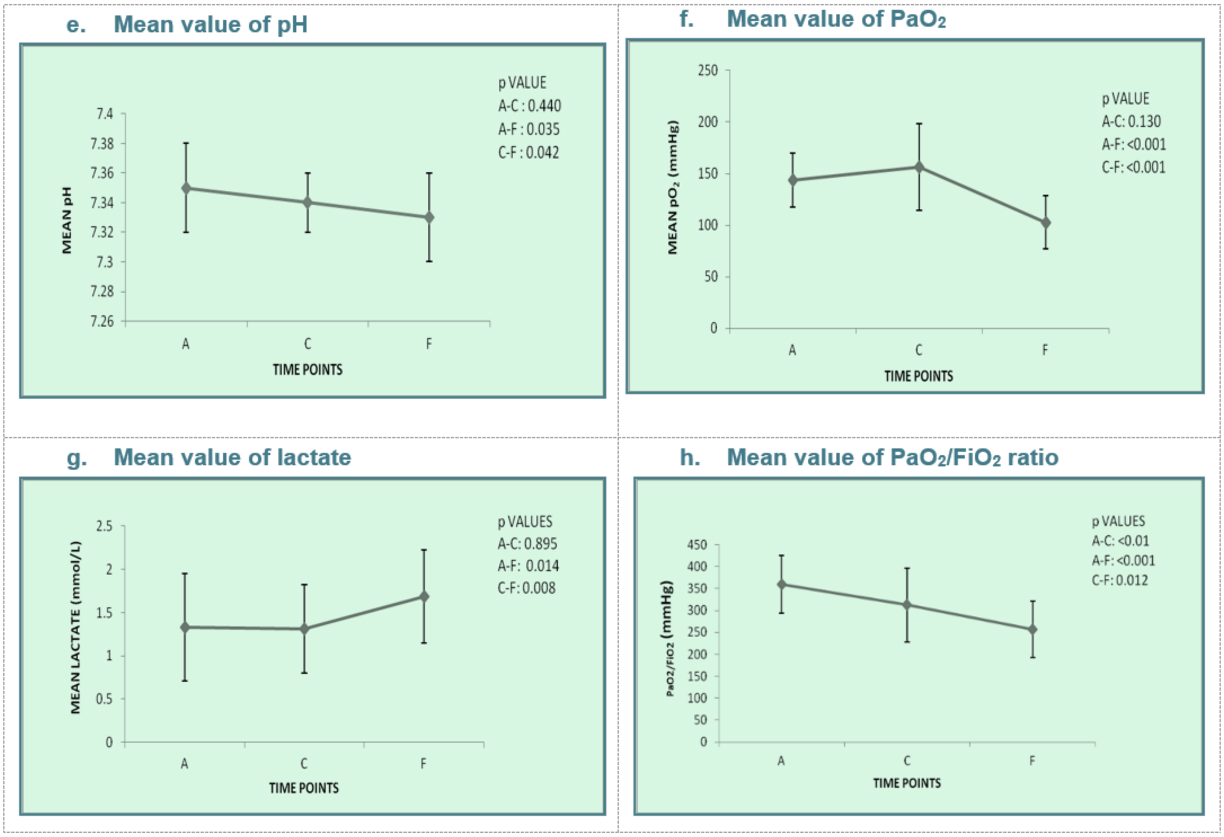

Figure 3 (a-d): Results of arterial blood gas analysis at various time intervals (Time points A: before general anesthesia induction, C: after steep Trendelenburg, F: after extubation)

hemi thorax at the time of extubation (Figure 2). No abnormality was detected on chest auscultation in any quadrant at any time point (A, F, G or H).

Fall in PaO_2 (102.73 ± 25.49 mmHg) at extubation was noted from the baseline value of 143.49 ± 26.26 mmHg; $P < 0.0001$ (Table 2). Intra-operative values were 156.20 ± 41.98 mmHg and significantly higher than post-operative values; $P < 0.0001$. A significant increase in pCO_2 between time points A and C (35.13 ± 4.52 mmHg vs 39.18 ± 5.15 mmHg; $P < 0.001$) was also noticed. There was a significant fall in PaO_2/FiO_2 ratio at the time points C and F when compared to time point A (Figure 3).

Fall in pH at extubation (7.33 ± 0.03) was statistically significant ($P = 0.035$) when compared to baseline (7.35 ± 0.03) and intraoperative values (7.34 ± 0.02) during steep Trendelenburg position ($P = 0.042$).

Changes in LUS scores between time points A and F did not correlate with changes in PaO_2/FiO_2 ratio ($P = 0.754$; Figure 4). There was a significant correlation between $\Delta PaO_2/FiO_2$ with patient's weight, BMI, total duration of anesthesia, total duration of docking and total duration in steep Trendelenburg position as shown in Table 3.

In the post-hoc analysis, no significant difference was observed in change of LUSS between time points A and F when compared with patients' age, weight, height,

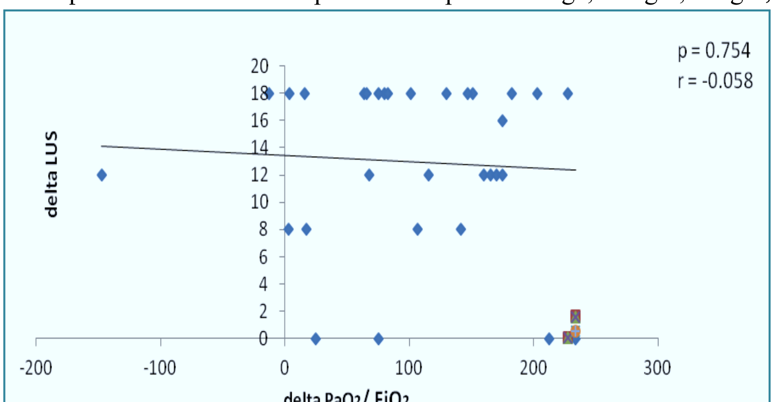

Figure 4: Relationship of changes lung ultrasound (LUS) and changes in PaO2/ FiO2 ratio using Spearman correlation coefficients. FiO2 - inspired oxygen fraction: PaO2 - arterial partial pressure of oxygen.

BMI, total duration of anesthesia, docking and steep Trendelenburg position. However, statistically significant difference was established between change in LUSS between time points A and F to the total volume of fluid given (P = 0.002).

There was a significant increase in heart rate after intubation and extubation (Table 4). The MAPs were comparable at all time points.

4. DISCUSSION

This study used the LUSS and detected atelectasis in the immediate post-extubation period in 87.5% of adults operated in steep Trendelenburg position with a robot assisted pelvic laparoscopic technique. There were no clinical complaints in any patients and the atelectasis resolved within the subsequent 12 h. Presence of localized iso- or hypoechoic areas, static air bronchograms, juxtapleural consolidations, absent lung sliding sign and presence of the pulse sign are some of the direct and indirect sonographic characteristics of various lung pathologies and all were looked for in this study.[10–14]

The sensitivity, specificity and diagnostic accuracy of LUS in detecting postoperative atelectasis is 87.7%, 92.1% and 90.8% respectively.[15] Routine use of LUS in patients at risk of development of postoperative pulmonary complications [based on *A*ssess *R*espiratory *R*isk *in* *S*urgical patients in *Cat*alonia (ARISCAT) score] is advocated.[16] The feasibility of performing a LUS in postoperative period in patients after major abdominal and cardiothoracic surgery has been documented despite the presence of chest drains and dressings.[17,18,19] The excellent interobserver agreement in performance LUS is an added advantage.

In our study the aeration loss did not correlate with patients' age, weight, duration of anesthesia, docking and Trendelenburg position, while positive correlation was found with the amount of fluid administered. Restrictive fluid therapy during robotic surgeries is advocated as it minimizes the incidence of cerebral edema and obtunds intraoperative rise in intraocular pressure.[20,21] We report a beneficial effect of restrictive fluid therapy on the lungs.

In long duration surgeries, resorption atelectasis occurs in lung units with a critically low V/Q. The mean duration of anesthesia in our study was 3 h and 42 min; suggesting resorption atelectasis as a possible etiological factor for aeration loss. An association between anesthesia duration and atelectasis has been reported in previous studies.[22,23]

5. LIMITATIONS

The small number of patients enrolled resulted in insufficient statistical power for some of our outcomes and is the major limitation of the study. The ability of LUS to 'monitor' the lungs, intraoperatively in patients undergoing robot assisted surgeries is limited by the spatial restrictions due to the bulky equipment. Lack of consensus on use of 8 zone examination vis a vis 12 zone examination for lung sonography and use of LUSS vs. BLUE protocol needs to be studied in details. In our study we used LUSS which is a longitudinal scan and detects the number/coalescence of B lines.

Visualization of pleura in longitudinal scan is limited by width of intercostal space. Another limitation of LUSS is that non-homogeneous lung pathologies might have focal coalescence of B lines.

Results of our study do not imply to patients with pre-existing cardio-pulmonary co-morbidities; the baseline and intra-operative LUS scores are expected to be different. Studies with use of total intravenous anesthesia are presumed to have different results as use of intravenous drugs eliminates the confounding effects of inhalation anesthetics on pulmonary physiology.

6. CONCLUSION

Incidence of atelectasis in adults after robot assisted laparoscopic pelvic surgeries detected using Lung Ultrasound Score was 87.5%. Lung oxygenation decreased significantly after steep Trendelenburg position and extubation and the amount of change correlated with the number of intravenous fluids administered.

7. Data availability

The numerical data generated during this research is available with the authors.

8. Acknowledgement

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9. Conflict of interest

The study utilized the hospital resources only, and no external or industry funding was involved.

10. Authors' contribution

All authors took part in the conduct of this study, literature search, manuscript preparation, editing and the final approval.

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