Indian Journal of Clinical Anaesthesia 2023;10(3):269–275

Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Clinical Anaesthesia

Journal homepage: www.ijca.in

Original Research Article

Role of lung ultrasonography for diagnosing atelectasis in robotic pelvic surgeries

Anita Chandrashekhar Kulkarni[1,*], **Anurag Sharma**[2]

[1]*Rajiv Gandhi Cancer Institute & Research Centre, Delhi, India*
[2]*Ram Lal Anand College, University of Delhi, Delhi, India*

ARTICLE INFO

Article history:
Received 09-08-2023
Accepted 24-08-2023
Available online 07-09-2023

Keywords:
Hypoxaemia
Postoperative pulmonary atelectasis
Robot surgeries
Trendelenburg position
Ultrasonography imaging

ABSTRACT

Background: Patients undergoing robotic pelvic surgery were included in prospective observational study, they are at increased risk of atelectasis and postoperative pulmonary complications.
Materials and Methods: Lung ultrasonography in basal six zones and arterial gas analysis was performed as baseline after induction of GA and on de-docking robotic arms to detect incidence and severity of atelectasis and its effect on arterial oxygenation.
Results: Total fifty patients were recruited in the study with age 61.88 ± 8.49 years, BMI 25.97±4.03, intraoperative with steep trendelenburg position, average duration of docking was 155.32 ± 47.44 minutes, VCV provided to 29 and PCV to 21 patients. [Lung aeration score 0] was noted for all patients in Right anterior basal –Zone I, 50-60% of patients developed mild atelectasis [Lung Aeration score1] in Posterior basal zones III and VI. Total 10% patients developed moderate atelectasis [Lung Aeration score 2] and 4% developed severe atelectasis [Lung Aeration score 3] in zones III and VI. The incidence and severity of atelectasis was not affected by duration of robotic arms docking and mode of ventilation. For both VCV and PCV group statistically significant ($p>0.05$) decrease in Arterial Oxygen Pressure (Pao2) and Alveolar-arterial (A-a)o_2 gradient difference was detected after completion of robotic surgery compared to baselines values.
Conclusion: Atelectasis was detected in 60% patients in bilateral basal posterior zones in patients undergoing robotic pelvic surgeries causing statistically significant decrease in PaO2 compared to baseline values. Early detection of atelectasis by Lung Ultrasonography in the OR and applying optimal PEEP is recommended.

1. Introduction

Atelectasis occurs in the dependent parts of the lungs in almost 90% of patients who undergo general anaesthesia either spontaneously breathing or mechanically ventilated and the atelectasis may include 15±20% of the lung tissue. Pathophysiological effects of atelectasis are decreased lung compliance and decreased oxygenation. The adverse effects of atelectasis include high proportion of postoperative pulmonary complications, delayed recovery and increased hospital stay. Computed Tomography (CT) scan is the gold standard to detect atelectasis, in the operating room Lung ultrasonography offers advantages of rapidity, ease of examination and sensitivity comparable with CT scan without the need for patient transport and radiation exposure.[1–4]

Robotic surgeries have the advantage of decreased intraoperative blood loss, analgesic requirements, early recovery and short length of stay. Robotic Pelvic surgeries are performed in lithotomy position with steep trendelenburg 30-45 degrees. Pneumoperitoneum creation causes increased intra-abdominal pressure leading

* *Corresponding author*.
E-mail address: anitackulkarni@gmail.com (A. C. Kulkarni).

https://doi.org/10.18231/j.ijca.2023.055
2394-4781/© 2023 Author(s), Published by Innovative Publication.

to decreased lung compliance, decreased functional residual capacity, increased airway pressure and atelectasis. Lung Ultrasound imaging is a non-invasive, non-radiant, portable tool to study intraoperative lung atelectasis and also allows tracking of perioperative atelectasis and facilitates the diagnosis of pulmonary complications.[2] This prospective observational study was conducted on 50 patients undergoing robotic pelvic surgeries to detect atelectasis after the completion of surgery with Lung Ultrasonography and its effect on arterial oxygen pressure.

Primary outcome measure was to assess the degree of atelectasis as Lung aeration score by performing Lung Ultrasonography in six basal zones. Secondary outcome measures were to study the effect of intraoperative atelectasis on Arterial Oxygen pressure [PaO2], Alveolar-arterial Oxygen Gradient [A-a O2] and Arterial carbon di oxide pressure [Paco2]. To study effect of duration of surgery and mode of ventilation on atelectasis.

2. Materials and Methods

Patients undergoing Robotic pelvic surgeries under general anaesthesia between 18 to 80 years of age were included in the study and patients with lung consolidation, lung fibrosis, left ventricular ejection fraction < 40%, previous thoracic surgery, BMI > 32, duration of surgery exceeding 360 minutes were excluded. The study was conducted after obtaining approval from ethics committee and Institutional Review Board Rajiv Gandhi Cancer Institute and Research Centre [RGCIID-473/AN/AKB-04] and registering at Clinical Trials.gov ID: NCT04006665. Written informed consent was obtained from all patients. The study began on 1/9/2019 and was completed on 28/02/2020, at Rajiv Gandhi Cancer Institute and RC, Delhi, India. The sample size was calculated using formula n= $(Z_{\alpha/2})^2$ p (1-p)/d^2X prevalence where n is the required sample size, p=Sensitivity, d=Precision, $Z_{\alpha/2}$ = significance level taking 80% power, 5% significance level with 0.10 precision, the calculated sample size was 44.[5] Figure 1 shows the Consort Flow Diagram, total 61 patients were enrolled 11 had to be excluded, total 50 patients were included belonging to the American Society of Anaesthesiologist Grade I were 8, Grade II were 36 and Grade III were 6. In the Operation Room 5 lead Electrocardiogram (ECG), Pulse Oximetry (SPO2), Non-invasive blood pressure (NIBP), end tidal carbon di Oxide (ETCO2) and core temperature were monitored, intravenous access was established with large bore cannula, preinduction radial artery cannulation was performed, patients were preoxygenated with 100% Oxygen and anaesthesia was induced with Fentanyl 1-2 μg/kg, Morphine 0.5mg/kg, Propofol sleeping dose and Atracurium 0.5mg/kg, oral cuffed endotracheal tube of appropriate size was placed in the trachea, anaesthesia was maintained with Air/O2 FiO2-0.5 Sevoflurane and Propofol infusion @100- 150μg/kg/min to maintain Bi-spectral Index(BIS) between 40-60 and atracurium infusion to maintain Train of Four (TOF Ratio) < 0.5. IPPV was commenced with volume control ventilation (VCV) with tidal volume 6-8ml/kg body weight and respiratory rate 12-14/minute provided to all patients.After intraperitoneal CO2 insufflation and maximum trendelenburg positioning (exact degree not measured) if peak airway pressure exceeded 35 mm Hg than ventilator mode for the particular patient was changed to Pressure control ventilation (PCV) with pressure settings 32-34 mmHg to deliver optimal tidal volume. All patients received Positive End Expiratory Pressure (PEEP) 5 cm H2O. Baseline Lung Ultrasound [LUS] Imaging was performed with SonositeMicromaxx Ultrasound System HFL38 x /13-6MHZ probe to record Lung Aeration Score. As shown in Figure 2 [0 = normal lung, 1=mild aeration loss, 2=moderate aeration loss, 3=severe aeration loss].[6] T1 about 5 minutes after induction of anaesthesia and before docking robotic arms. T2 after de-docking of robotic arms and before extubation. Lung Ultrasound Imaging was performed and Lung Aeration Score was noted in 6 basal zones 3 zones in each lung and labelled as Zone I [Rigth Anterior Basal]area below horizontal line drawn at level of nipple and between right parasternal and anterior axillary line, Zone II [Right Lateral Basal] area between right anterior and posterior axillary line and Zone III [Right Posterior Basal] area beyond right posterior axillary line. Zone IV [Left Anterior Basal] area below the nipple and between left parasternal and anterior axillary line, Zone V [Left Lateral Basal] area between left anterior and posterior axillary line, Zone VI [Left Posterior Basal] area beyond left posterior line. The ultrasound images were saved and analysed with consultation of radiologist, who was blinded regarding mode of ventilation. Ti Arterial blood gas analysis after induction of anaesthesia and before docking robotic arms. Tii -Arterial blood gas analysis after de-docking robotic arms. Intra-abdominal pressure was maintained at 15 cm H2O.

B lines are hyperechoic comet tail artefact arising from pleural line their distribution corresponds thickened interlobular septa and septal oedema. B lines < 3 are considered normal. Presence of any B lines was observed for all patients. Any decrease in Oxygen saturation < 96% and intervention required was noted. At the end of surgery, neuromuscular blockade was reversed, trachea extubated and patient shifted to post anaesthesia care unit.

2.1. *Statistical analysis*

Data is presented as Mean and +/- SD standard deviation for continuous variables and percentage % for categorical variables as appropriate. Independent t-test applied to compare continuous variables. Paired t test has been used to compare different parameters at baseline and after the end of procedure. All the reported p values were two-sided and p values < 0.05 are considered statistically significant. All

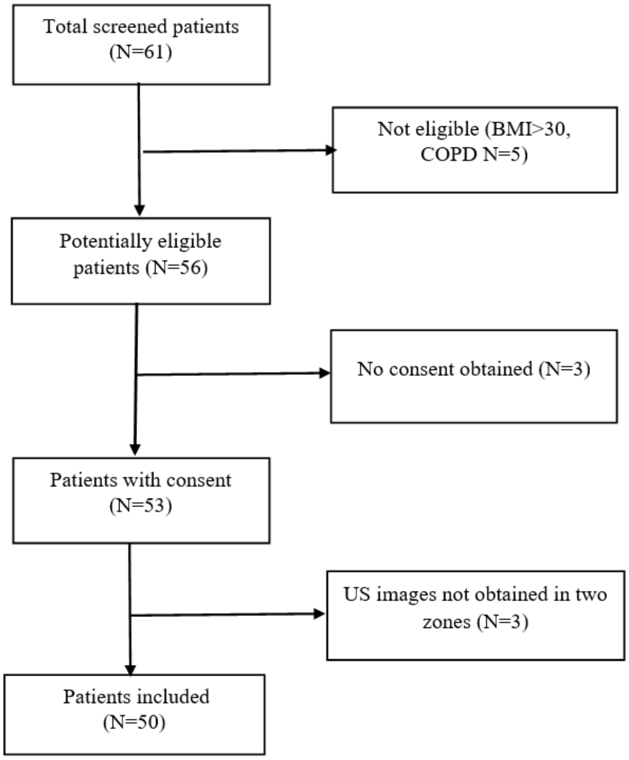

Fig. 1: Consort diagram (Total 50 patients were included) 1 * COPD Chronic Obstructive Pulmonary Disease, †US –Ultrasound

‡BMI –Body Mass Index kg/m2.

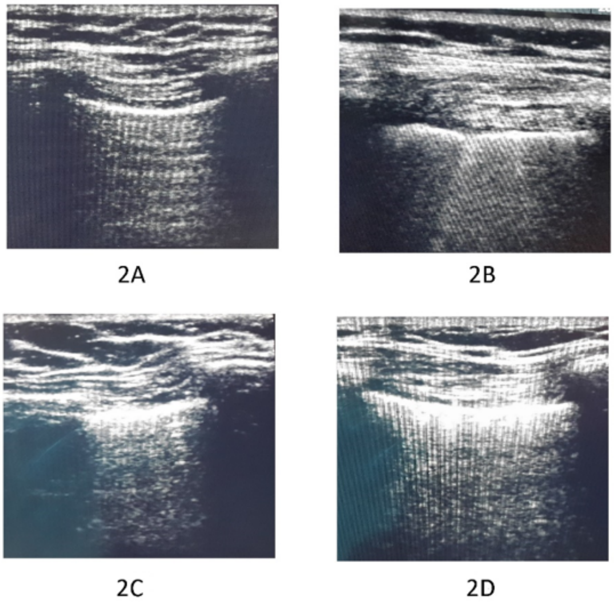

Fig. 2: Lung ultrasound images showing different lung aeration scores (**2A**) Lung Aeration Score 0 Normal lung, †(**2B**) Lung Aeration Score 1 Mild aeration loss,‡(**2C**) Lung Aeration Score 2 Moderate aeration loss, §(**2D**) Lung Aeration Score 3 Severe aeration loss.

data entries and statistical analysis was performed by using SPSS ® Version 23.0 software.

3. Results

Demographic data patient's age was 61.88 ± 8.49 years, BMI was 25.97±4.03 kg/m^2, out of 50 patients 28 were hypertensive and 14 were diabetic.34 male patients were posted for robotic prostatectomy.16 female patients for robotic hysterectomy. Intraoperative heart rate was 68.06 ±9.69/minute. Mean arterial pressure was 87.17±9.61mmHg and end tidal CO2 was 33.60±2.13 mmHg. Tidal volume was 454.44 ± 61.18 ml/minute and respiratory rate 13.72±1.40 per minute. Average duration of docking was 155.32±47.44 minutes. Volume controlled ventilation provided in 29 patients and pressure control ventilationin 21 patients. During surgery crystalloid transfused were 555.74±160.19ml. Figure 3 shows distribution of atelectasis in different basal Lung zones. In Zone I no patient had atelectasis 100% patients had Aeration score 0, In Zone II - 92% patients had Aeration score 0 and 8% had score 1. In Zone III - 44% patients had Aeration score 0, 50%had score 1, 4% patients had score 2 and 2% had score 3. In Zone IV- 92% patients had Aeration score 0 and 8% had score1. In Zone V- 84% patients had Aeration score 0 and 16% had score 1. In Zone VI - 32% patients had Aeration score 0, 60% had score 1, 6% had score 2 and 2% had score 3. Investigators observed 50-60% of patients developed mild atelectasis [Lung Aeration score 1] in posterior basal zones III and VI. Total 10% patients developed moderate atelectasis [Aeration score 2] and 4% developed severe atelectasis [Aeration score 3] in basal posterior zone III and VI.

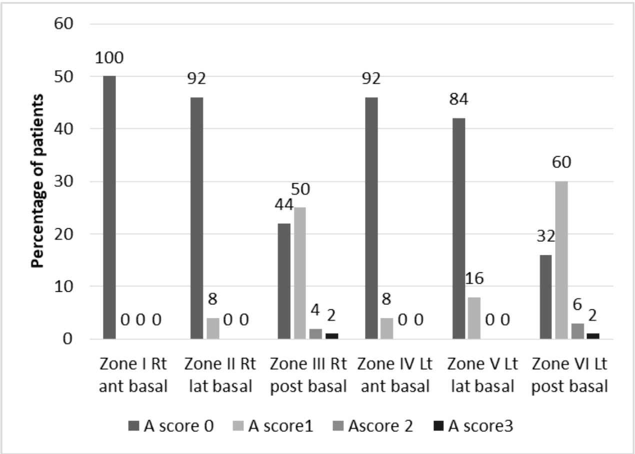

Fig. 3: Distribution of atelectasis in different basal lung zones * Lung aeration scorein six basal zones, †data presented as percentage

Table 1 shows effect of duration of ventilation in steep trendelenburg position and intraperitoneal co_2 insufflation on the incidence and severity of atelectasis. Duration of docking was more than 120 minutes in 40 patients and less than 120 minutes in 10 patients. Lung aeration score for patients with duration of docking more 120 minutes and those with less than 120 minutes in all six zones was statistically comparable with p value >0.05. Two patients with severe atelectasis had duration of docking <2 hours. Patients with duration of docking exceeding 120 minutes did not have increased incidence and severity of postoperative atelectasis. Table 2 shows the effect of Volume control ventilation versus Pressure control ventilation on immediate postoperative atelectasis. There were 29 patients in VCV group and 21 patients in PCV group. The incidence and severity of Lung aeration score for patients receiving Volume control ventilation and Pressure control ventilation is statistically comparable (p value >0.05) for all six Zones. Four patients in VCV and one patient in PCV group had aeration score 2 [Grade II atelectasis] the difference is not statistically significant (P>0.05). One patient each had Aeration score 3 in both ventilation modes. No patient had atelectasis in Zone I with both modes of ventilation.

Table 3 shows Arterial blood gas analysis values for volume control and pressure control ventilation. For both VCV and PCV statistically significant (p>0.05) decrease in Arterial Oxygen Pressure (Pao_2) suggestive of mild hypoxaemia, Alveolar-arterial (A-a) Oxygen Gradient difference, Arterial oxygen tension and Inspired Oxygen (PO2 (a)/FiO2) Ratio was observed after de-docking robotic arms compared to baselines values. Statistically significant increase in $Paco_2$ values from baseline values was also seen. B Lines were not visible in any patient. None of the patient had decrease in Oxygen saturation (SpO_2) below 96%.

4. Discussion

Atelectasis develops in the dependent parts of the lungs for about 90% patients who undergo general anaesthesia leading to decreased lung compliance and hypoxemia.[1,7] Atelectasis triggers a cascade of pathophysiological events that culminate in diffuse alveolar damage and respiratory failure in few patients. The physiologic mechanism that causes atelectasis are compression, alveolar gas resorption and surfactant impairment.[8] Advantages of robotic surgery are decrease in intraoperative blood loss, analgesia requirements, and early recovery. Robotic Pelvic surgeries are performed in lithotomy with steep trendelenburg position 30-45 degrees. This positioning along with pneumoperitoneum causes increased intra-abdominal pressure pushing the abdominal contents cephalad leading to increased airway pressure, decreased functional residual capacity (FRC), decreased compliance and development of atelectasis.[7,9]

This prospective observational study was conducted on 50 patients to study the incidence and severity of atelectasis at the completion of robotic surgery in OR with lung ultrasonography and its effect on arterial blood gas analysis.[5] Lung Ultrasound imaging is simple, easily available, non-radiant, rapid and reliable portable tool in OR for examination of lung fields to detect atelectasis without the disadvantages of patient transport.[1,10]

Lichtenstein D et al. prospectively studied 32 patients with ARDS and 10 healthy volunteers in 384 lung regions for alveolar consolidation and found diagnostic accuracy for Lung ultrasonography 97% compared to Thoracic Computer Tomography hence ultrasonography can be considered an equivalent alternative to Computed Tomography.[11]

Acousta CM et al. studied 15 children aged 1-7 years undergoing MRI who received sevoflurane anaesthesia breathing spontaneously, lung ultrasonography showed that 14 patients had developed anaesthesia induced atelectasis in the most dependent parts of the lungs. LUS showed 88% sensitivity, 89% specificity and 88% accuracy for diagnosing atelectasis taking MRI as reference. The agreement between the two radiologists for diagnosing atelectasis by MRI and LUS was good (p< 0.0001).[12] The quantitative correlation between LUS score of aeration and the volumetric data of atelectasis in thoracic CT was evaluated in 56 patients undergoing neurosurgery. LUS had reliable performance in post-operative atelectasis, with a sensitivity of 87.7%, specificity of 92.1% and diagnostic accuracy of 90.8%.[10]

In our study in Zone I no patient had atelectasis as all patients had Aeration score 0. In Zone II 8% patients had mild atelectasis. In Zone IV-8% and V-16% patients had mild atelectasis.In basal posterior zones III and VI - 50 to 60% of patients had Grade I, 10% had Grade II and 4% having Grade III atelectasis. Our results shown less incidence and severity of atelectasis compared to studies with atelectasis upto 90%.[1]

Effect of duration of docking exceeding 120 minutes and less than 120 minutes on the Lung aeration score for all zones was statistically comparable with p value >0.05 as shown in Table 1. Duration of docking did not affect the incidence and severity of atelectasis. Duggan M, Kavanagh B in their review article noted that atelectasis occurs in the dependent parts of the lungs of 90% patients who are anesthetized. The maximum decrease in FRC occurs within the first few minutes of general anaesthesia and authors observed that for surgical operations on the limb decrease in FRC was not influenced by duration of anaesthesia.[1] The PEEP was standardized 5cm H2O for all patients. PEEP more than 5cm H2O and recruitment manoeuvre leads to haemodynamic instability and hence avoided. Investigators noted PEEP 5 cm H2O was effective in decreasing incidence and severity of atelectasis as mild atelectasis was observed in 50-60% and severe atelectasis in 4% patients in basal posterior zones. Talab H L et al. observed that obese patients undergoing laparoscopic bariatric

Table 1: Effect of duration of ventilation on lung aeration scores

Lung Zones	Docking duration	Lung Aeration Scores				P value
		0 No/percentage	1	2	3	
Zone I	<2h	10(100%)	0	0	0	—-
	>2h	40(100%)	0	0	0	
Zone II	<2h	8(80%)	2(20%)	0	0	0.714
	>2h	38(95%)	2(5%)	0	0	
Zone III	<2h	3(30%)	5(50%)	1(10%)	1(10%)	0.128
	>2h	19(47.5%)	10(25%)	1(2.5%)	0	
Zone IV	<2h	9(90%)	1(10%)	0	0	1.000
	>2h	37(92.5%)	3(7.5%)	0	0	
Zone V	<2h	9 (90%)	1(10%)	0	0	1.000
	>2h	33(82.5%)	7(17.5%)	0	0	
Zone VI	<2h	3(30%)	5(50%)	1(10%)	1(10%)	0.207
	>2h	13(32.5%)	25(62.5%)	2(5%)	0	

Values presented as percentage, * Lung zones are basal lung zones

Table 2: Lung aeration scores for volume control and pressure control ventilation.

Lung Zones	Mode of vent	Lung Aeration Scores				P value
		0	1	2	3	
Zone I	VCV	29(100%)	0	0	0	
	PCV	21(100%)	0	0	0	
Zone II	VCV	26(89.65%)	3(10.34%)	0	0	0.630
	PCV	20(95.28%)	1(4.76%)	0	0	
Zone III	VCV	11(37.93%)	16(55.17%)	2(6.89%)	0	0.287
	PCV	11(52.38%)	9(42.85%)	0	1(4.76%)	
Zone IV	VCV	26(89.65%)	3(10.43%)	0	0	0.630
	PCV	20(95.28%)	1(4.76%)	0	0	
Zone V	VCV	26(89.65%)	3(10.43%)	0	0	0.255
	PCV	16(76.19%)	5(23.80%)	0	0	
ZoneVI	VCV	10(34.48%)	16(55.17%)	2(6.89%)	1(3.44%)	0.749
	PCV	6(28.57%)	14(66.66%)	1(4.76%)	0	

Values are presented as mean ±SD, * Lung Zones - Basal lung zones, †VCV -Volume control ventilation, ‡PCV - Pressure control ventilation. §data presented as percentage.

surgery receiving intraoperative alveolar recruitment with VCM for 8 seconds followed by PEEP10cms H2O had lower atelectasis score on chest CT scan and less postoperative pulmonary complications than the Zero end expiratory pressure (ZEEP) and PEEP 5cm H20.[13] Hedenstierna G, Rothen H studied causes of atelectasis formation during anaesthesia concluded that maintenance of anaesthesia with fraction of inspired oxygen FiO2/0.3-0.4. Intermittent vital capacity manoeuvres together with PEEP reduces the amount of atelectasis and pulmonary shunt. Investigators maintained anaesthesia with Fio2 - 0.5 and applied PEEP 5 cm H2O.[14] In study designated by the acronym 'PROVHILO', outcomes revealed that postoperative pulmonary complications [PPCs] which included atelectasis in 40% of 445 patients in the higher PEEP group versus 39% in the lower PEEP group. Patients in the higher PEEP group developed intraoperative hypotension and required more vasoactive drugs. The current recommended intraoperative protective strategy, consistent with the results of the meta-analysis above,

Table 3: Arterial blood gas values for volume control and pressure control ventilation

Arterial Gas Analysis	VCV Mode			PCV Mode		
	Mean	SD	P value	Mean	SD	P value
Baseline PaO2 mmHg	192.06	±51.70	0.000	178.33	±46.27	0.002
End PaO2 mmHg	154.25	±43.96		146.24	±30.0	
Baseline Paco2mmHg	42.26	±6.38	0.000	41.04	±6.94	0.016
End Paco2 mmHg	53.00	±8.00		44.98	±7.49	
BasePO2(A-a)gradient	204.09	±58.66	0.024	190.49	±45.98	0.009
End PO2(A-a) gradient	174.53	±38.94		150.20	±49.80	
BasePO2(a)/FiO2Ratio	841.45	±265.71	0.000	835.05	±317.59	0.006
End Po2(a)/FiO2Ratio	661.02	±247.83		670.75	±202.26	

* values are presented as mean±SD** VCV –Volume control ventilation, †PCV – Pressure control ventilation, ‡(Pao2) Arterial oxygen pressure mmHg, §(A-aO2) Alveolar- arterial Oxygen Gradient, ||(Paco2) Arterial carbon di oxide pressure mmHg, ¶(Pao2/FiO2)- Arterial partial pressure of oxygen and fraction of inspired oxygen ratio

should include a low tidal volume and low PEEP without recruitment manoeuvres.[15] Martin JB, Garbee D, Bonanno L, in systematic review of 10 studies with a total 427 participants evaluated the effectiveness of interventions in the prevention of postoperative atelectasis during general anaesthesia. Atelectasis was measured by lung density measurements in the CT scans, decreased PaO2 levels and pulmonary function tests. Fio2 <0.6in combination with vital capacity recruitment manoeuvre (VCR) manoeuvre +40cm H20 for 15 second and PEEP 10cm H2O decreased atelectasis significantly [p= 0.024].[16] Reinius H et al. concluded that recruitment manoeuvre followed by PEEP reduced atelectasis and improved oxygenation in morbidly obese patients, whereas PEEP or a recruitment manoeuvre alone did not.[17]

In our study the incidence and severity of Lung aeration score for patients receiving Volume control and Pressure Control ventilation is statistically comparable [p value >0.05] for all six Zonesas shown in Table 2. One patient each had Aeration score 3 in both ventilation modes. The mode of ventilation does not influence atelectasis. Wang P, Zhao S, Gao Z et al[18] studied 80 elderly patients who underwent laparoscopic surgery using an LMA and concluded that pressure controlled ventilation volume guarantee (PCV-VG) was superior to volume controlled ventilation (VCV) in its ability to provide ventilation with lower peak inspiratory pressure and greater dynamic compliance.

For both volume control and pressure control ventilation we observed statistically significant (p>0.05) decrease in Arterial Oxygen Tension (Pao2), Alveolar-arterial (A-a) gradient difference, Arterial oxygen tension and Inspired Oxygen Ratio (PO2 (a)/FiO2) after de-docking robotic arms compared to baselines values as shown in Table 3. Statistically significant increase in Paco2 from baseline values was also noted. None of the patient had decrease in Oxygen saturation less than 96%.

The alveolar-arterial (A-a)o_2 gradient measures difference between the oxygen concentration in the alveoli and arterial system. Patients with atelectasis have a normal alveolar oxygen concentration with poor diffusion of oxygen across the alveolar-capillary unit and thus lower oxygen levels in the arterial blood. Thus, patients have elevated A-a gradient. General anaesthesia causes atelectasis leading to impairment of gas exchange and decreased oxygenation of the blood.[16] Duggan Mand Kavanagh B in their review article on pulmonary atelectasis consider increased mismatch of ventilation with perfusion as the cause of impaired oxygenation.[1] Monastesse A, Girard F, Massicotte N studied patients scheduled for laparoscopic surgery in prospective observational study. Lung ultrasound score was performed at 5 predefined time points in 12 pulmonary quadrants. Induction of GA was associated with an increase in the LUS score, which gradually worsened at all time points until recovery room discharge. This increase was significantly worse in the basal and dependent lung zones. The evolution of aeration loss correlates moderately with changes in oxygenation.[2] These observations are comparable with our findings.

5. Limitations of Study

The clinical impact and resolution of atelectasis beyond the operating Room was not studied.

6. Conclusion

In patients undergoing robotic pelvic surgeries atelectasis was detected in about 60% patients in bilateral basal posterior zones causing statistically significant decrease in PaO2 indicating hypoxaemia compared to baseline values. Investigators recommend Lung Ultrasonography for early detection of atelectasis in the OR and applying optimal PEEP to reduce atelectasis, postoperative pulmonary complications and enhance early recovery. Mode of ventilation and duration of robotic arms docking did not influence the incidence and severity of atelectasis. The adverse effects of atelectasis can persist in the postoperative period up to 24 hours hence continuous SPO2 monitoring and supplemental oxygenation if needed is recommended.

7. Source of Funding

None.

8. Conflict of Interest

None.

9. Data Availability

The data generated and analysed during the current study are available from the corresponding author on reasonable request.

10. Author Contributions

Anita Kulkarni: Conceptualization, writing original draft and editing. Anurag Sharma: Statistical analysis of results.

References

1. Duggan M, Kavanagh BP. Pulmonary atelectasis: a pathogenic perioperative entity. *Anesthesiology*. 2005;102(4):838–54.
2. Monastesse A, Girard F, Massicotte N, Chartrand L, Girard M. Lung Ultrasonography for the Assessment of Perioperative Atelectasis: A Pilot Feasibility Study. *Anesth Analg*. 2017;124(2):494–504.
3. Magnusson L, Spahn DR. New concepts of atelectasis during general anaesthesia. *Br J Anaesth*. 2003;91(1):61–72.
4. Ray K, Bodenham A, Paramasivam E. Pulmonary atelectasis in anaesthesia and critical care. *Continuing Educ Anaesth Crit Care Pain*. 2014;14(55):236–45.
5. Tilaki KH. Sample size estimation in diagnostic test studies of biomedical informatics. *J Biomed Inform*. 2014;48:193–204.
6. Millera A. Practical approach to Lung Ultrasound. *BJA Educ*. 2016;16(2):39–45.
7. Abreu MG, Schultz MJ, Pelosi P. Atelectasis during general anaesthesia for surgery: should we treat atelectasis or the patient? *Br J Anaesth*. 2020;124(6):662–4.
8. Restrepo RD, Braverman J. Current challenges in the recognition, prevention and treatment of perioperative pulmonary atelectasis. *Expert Rev Respir Med*. 2015;9(1):97–107.
9. Irvine M, Patil V. Anaesthesia for robot-assisted laparoscopic surgery. *Continuing Educ Anaesth Crit Care Pain*. 2009;9(4):125–9.
10. Yu X, Zhai Z, Zhaoy, Zhu Z, Tong J, Yan J. Performance of Lung Ultrasound in detecting peri-operative atelectasis after general anaesthesia. *Ultrasound Med Biol*. 2016;42(12):2775–84.
11. Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. *Anesthesiology*. 2004;100(1):9–15.
12. Acosta CM, Maidana GA, Jacovitti D, Belaunzaran A, Cereceda S, Rae E, et al. Accuracy of transthoracic lung ultrasound for diagnosing anesthesia-induced atelectasis in children. *Anesthesiology*. 2014;120(6):1370–9.
13. Talab HF, Zabani IA, Abdelrahman HS, Bukhari WL, Mamoun I, Ashour M, et al. Intraoperative ventilatory strategies for prevention of pulmonary atelectasis in obese patients undergoing laparoscopic bariatric surgery. *Anesth Analg*. 2009;109(5):1511–6.
14. Hedenstierna G, Rothen HU. Atelectasis formation during anaesthesia causes and measures to prevent it. *J Clinical*. 2000;16(5-6):329–364.
15. Hemmes SNT, deAbreu MG, Schultz MJ. High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. *Lancet*. 2014;384(9942):495–503.
16. Martin JB, Garbee D, Bonanno L. Effectiveness of positive end-expiratory pressure, decreased fraction of inspired oxygen and vital capacity recruitment maneuver in the prevention of pulmonary atelectasis in patients undergoing general anesthesia: a systematic review. *JBI Database System Rev Implement Rep*. 2015;13(8):211–49.
17. Reinius H, Jonsson L, Gustafsson S, Sundbom M, Duvernoy O, Pelosi P, et al. Prevention of atelectasis in morbidly obese patients during general anesthesia and paralysis: a computerized tomography study. *Anesthesiology*. 2009;111(5):979–87.
18. Wang P, Zhao S, Gao Z, Hu J, Lu Y, Chen J. Use of volume controlled vs. pressure controlled volume guaranteed ventilation in elderly patients undergoing laparoscopic surgery with laryngeal mask airway. *BMC Anesthesiol*. 2021;21(1):69.

Author biography

Anita Chandrashekhar Kulkarni, Senior Consultant https://orcid.org/0000-0002-2342-3669

Anurag Sharma, Senior Biostatisican https://orcid.org/0000-0002-3482-0774

Cite this article: Kulkarni AC, Sharma A. Role of lung ultrasonography for diagnosing atelectasis in robotic pelvic surgeries. *Indian J Clin Anaesth* 2023;10(3):269-275.