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Original Research Article

An Observational Study on the Role of Ultrasonographic Lung Aeration Score in the Prediction of Postoperative Pulmonary Complications

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Conflict of interest: Nil

Abstract

Aim: The aim of the present study was to identify characteristics with the potential of recognizing patients at risk by comparing the lung ultrasound scores (LUS) of patients with/without PPC in a 24-h postoperative timeframe.

Material & Methods: This prospective, observational study was conducted between the duration of 6 months in the Department of Surgery, IGIMS, Patna. A total of 60 patients were enrolled. We recruited ASA 2–3 patients undergoing elective major abdominal surgery under general anaesthesia. LUS was assessed preoperatively, and also 1 and 24 h after surgery. Baseline and operative characteristics were also collected. A one-week follow up identified PPC+ and PPC- patients.

Results:20 patients were assigned to the PPC+ group, 40 were evaluated in the PPC- population. Most conditions were similarly represented in both groups, none of the potential predictors were significantly different. Patients conforming to ASA 3 class were significantly more represented in the PPC+ group. LUS at baseline and in the postoperative hour were similar in both populations. Values of ARISCAT scores were significantly higher among PPC+ participants, otherwise, we did not detect important intergroup differences. LUS at 1 h was not significantly associated with PPCs with an OR of 0.7280. By contrast, 24th postoperative hour's LUS was verified to be an independent and significant risk factor for PPCs, having an OR of 2.6348.

Conclusion: Postoperative LUS at 24 h can identify patients at risk of or in an early phase of PPCs.

Keywords: Lung ultrasound, Point-of-care ultrasound, Postoperative pulmonary complications, Ultrasonography, Perioperative care.

Introduction

Postoperative pulmonary complications (PPCs) are important causes of mortality after major noncardiac surgeries, and they adversely affect several aspects of morbidity, including the length of hospital stay and unexpected intensive care unit admissions. [1–4] Their incidence is reported in a wide range (2.8–40%) depending mostly on the represented patient population and PPC definitions. [3] Conventional chest X-rays remained routine in thoracic diagnostics, but the widespread use of ultrasound by anaesthesiologists and intensive care physicians made this modality a real point of care alternative. As a non-invasive tool offering practically unlimited repetitions, ultrasound became a valuable method in critical care for the assessment of pleural effusions, [5] pneumothorax, and complex protocols exist to diagnose the various causes of respiratory insufficiency or cardiac arrest. [6] Lung ultrasound is a new and increasingly used method for studying lung aeration during MV in both a semi-quantitative and quantitative manner.[7] The perioperative use also seems sensitive and specific for PPCs. Lung ultrasound is reported to be superior to radiography in detecting any of the PPCs after cardiothoracic surgery. [8]

Lung ultrasounds have also proven capable of detecting lung lesions before the development of hypoxemia in ARDS patients. [9] Ultrasounds can accurately quantify the loss of pulmonary aeration before, after, and during the weaning trial by calculating the lung ultrasound score (LUS). [10] A quantitative scoring system originally described by Bouhemad et al. was effectively used to drive ventilation strategy in ARDS patients or to predict weaning failure. [11] This scoring system relies heavily on 'B-lines'; their increased numbers and subsequently confluent profiles are threshold steps in forming categories.

B-lines are discrete laser-like vertical hyperechoic reverberation artifacts arising from the pleural line (previously described as 'comet tails'), extend to the bottom of the screen without fading, and move synchronously with lung sliding. [12] They are considered to be corresponding to widened interlobular septa and can appear bilaterally, conforming to the diagnosis of interstitial syndrome of the lung including pulmonary oedema irrespective to its cause [6,13] but non-symmetric appearance can be linked to other causes of decreased lung aeration or to interstitial pulmonary diseases. [9,14] Hence the aim of the present study was to evaluate the role of the lung aeration score measured on definite time points of the first 24 h after major abdominal surgery in the prediction of developing PPCs.

Material & Methods

This prospective, observational study was conducted between the duration of 6 months in the Department of Surgery, IGIMS, Patna. A total of 60 patients were enrolled. We recruited ASA 2–3 patients undergoing elective major abdominal surgery under general anaesthesia. LUS was assessed preoperatively, and also 1 and 24 h after surgery. Baseline and operative characteristics were also collected. A one-week follow up identified PPC+ and PPC- patients.

Informed consent was obtained from each subject. Subjects were ≥ 18 years, ASA 2 or 3 classified patients, who were scheduled for elective major abdominal surgery under general anaesthesia with endotracheal intubation on predetermined weekdays. Major surgery was defined as predicted duration of ≥120 min, expected need for postoperative intensive therapy or high dependency care, operations involving the thoracic cavity were excluded. The prediction of the operation time and booking for ICU/HDU beds depended on the judgement of the attending surgeons and anaesthesiologists.

Inclusion Criteria

1. Age 18-60 years
2. ASA class 2 or 3
3. Major abdominal surgeries
4. General anaesthesia

Exclusion criteria

1. Preceding surgery within 30 days
2. Thoracotomy
3. History of lung resection
4. Oxygen therapy at rest
5. Any kind of acute pulmonary morbidity
6. Patient on ventilatory support at surgical admission

Methodology

Baseline characteristics such as co morbidity data, basic demographic data, and ASA class were recorded. Co-morbidity data included history of hypertension, chronic obstructive pulmonary disease (COPD), congestive heart failure (irrespective of EF), diabetes (any type), smoking status by self-report, and active extra pulmonary infection. Preoperative oxygen saturation was recorded on the day of surgery on ambient air. Commonly available biomarker levels with literature relevance as predictors for PPC, such as haemoglobin level and creatinine were also collected. [2,4] The data on the surgical procedure included the type of surgery, duration of the procedure, and epidural use. We also assumed operative fluid balance, [15] which was calculated from intravenous fluid therapy, urine output and content of the suction vessel with surgical sponges(where used) without the quantity of saline used for lavage.

ARISCAT (Assess Respiratory Risk in Surgical Patients in Catalonia) score, a cumulative determinant of PPC risk was also calculated. [2]

Ultrasound Protocol

All examinations were performed using the ultrasound machine (Mindray A7^{TM}). A linear transducer of 10–3 MHz was selected, a study preset of 7.5 MHz without tissue harmonic imaging was activated, and care was taken on focus positioning to the proximity of the parietal pleura. In particular cases, the ultrasonographer could choose a convex probe of 5 MHz to obtain images from obese patients. [16]

Patients were examined in semi-recumbent position. Six fields of each hemithorax were scanned defined by the mamillar line horizontally, the anterior and posterioraxillary lines vertically, following a similar approach used in previous studies.[17,18,19] Laterolateral scanning was performed in at least two interspaces of each field with longitudinal probe position and a representative image or clip was taken for offline validation. Posteriorfields were examined only in the proximity of the posterior axillary lines, not requiring any important activity from the patient or the presence of an assistant to conform to the need of a reproducible situation during postoperative measurements even on mechanically ventilated patients. The scans were performed three times on each patient.

1. First, immediately before inducing anaesthesia in the operative theatre (preoperative).
2. Second, within the first postoperative hour, but at least 15 min after the patients' arrival to the postanaesthetic room or to the ICU to allow a phase for stabilization (postoperative 1 h).

3. Third scan was performed 24 after the second one (postoperative 24 h).

Lung ultrasound scores were calculated using a classification system optimized for perioperative settings described previously by Monastesse et al.[19] A-profile was scored as 0 points, B-profile with more than 2 well-spaced lines/interspace or coalescent B-profile were registered as 1 or 2 points, respectively. For severe atelectasis with diameters exceeding 1 × 2 cm, 3 points were recorded. Small subpleural consolidations with clear pleural line were considered with 1, those multiple consolidations separated by an irregular pleural line with 2 points. The sum of these were calculated as lung ultrasound score (LUS) from 0 to 36. Modified Lung ultrasound scoring system in accordance with the method of Monatesse teal (LUSS):— before induction of anaesthesia, 15 min after extubation, 24 hour after extubation.

LUS calculation was done by the ultrasonographer, and a second observer validated it offline. In case of discrepancy, a third observer chose the final value from the available scores. At the defined postoperative time points, absolute LUS and ΔLUS compared to the preoperative value were calculated.

Anaesthesia protocol

Preoperative epidural catheter insertion was performed in the operation theatre where appropriate. General anaesthesia was induced by administration of 1–2 μg/kg fentanyl and 1.5–2mg/kg propofol. Neuromuscular blockade for the endotracheal intubation was provided by either vecuronium or cis-atracurium dose selected upon the age and comorbid state. General anaesthesia was maintained with sevoflurane/isoflurane. Episodes of intraoperative desaturation (SpO2 < 95% or > 3% decrease from initial) were managed as follows: the position of endotracheal tube was verified by auscultation where appropriate, recruitment manoeuvre of manual inflation to at least 30 cm of water for 30 s was used. Patients were extubated either in the operating room or in the intensive care unit. Residual neuromuscular blockade was reversed by0.03 mg/kg neostigmine and 0.5 mg atropine if needed, based on clinical criteria or TOF values. Criteria for extubation in ICU follow institutional guidelines involving normothermia (> 36 °C), adequate cooperation, and a favourable response to a spontaneous breathing trial of 30min on PEEP of 5 cmH2O plus pressure support of a maximum of 10 cmH2O.Follow up for PPCs. The follow-up period for PPCs lasted 7 days postoperatively or until hospital discharge (the earlier completed).

The check for PPCs was done by investigators unaware of LUS values and was based on patient records. No extra diagnostic or treatment activities were initiated by the investigators. The definitions included those of Canet et al.[2] including clinical and/or radiographic criteria: respiratory infection, respiratory failure, atelectasis, pleural effusion, bronchospasm, pneumothorax, and aspiration pneumonitis. Of note, screening was not limited to plain chest X-rays; all available medical imaging records were checked, and we added pulmonary oedema defined by presence of rales and tachypnoea with the need and suitable response to diuretics. The criteria of respiratory failure (PaO2 < 60 mmHg and/orSpO2 < 90% on room air and/or PaO2/FiO2 < 300 mmHg necessitating at least oxygen therapy) were extended by adding unplanned reintubation, need for non-invasive ventilation, or the inability to extubate a mechanically ventilated patient after 24 h. At the first verified PPC, we terminated the follow-up. Reoperation during the observation time resulted in exclusion, except in the cases where a case-definition of PPC was reached earlier. APPC+ and a PPC- group were formed.

Statistical analysis

Data were pooled for analysis in Microsoft Excel for Office 365, for the statistical analysis, StatsDirect3.1.20 Statistical Software (Stats Direct Ltd., Grantchester, Cambridge, UK) was used. Continuous variables are presented as the means±standard deviation. Non-normally distributed data are shown as the medians and interquartile ranges. Student's two-sample-test and the Mann-Whitney U test were used for comparisons as appropriate. The χ2and Fisher exact test were used for contingency table analysis as appropriate. Two-sided p-values are shown, and the limit of statistical significance was set top < 0.05. The diagnostic value of postoperative LUS was evaluated by calculating the sensitivity, specificity, and positive and negative predictive values at an optimal cutoff determined by the receiver operating characteristics(ROC) curve. A bootstrap validation was performed for the confidence interval of the AUC as well.

Results

Table 1: Baseline characteristics of the patients

Variable	PPC N=20	PPC N=40	p- value
Age, years	67.3±10.6	64.6±8.2	0.4785
Male, N(%)	12(60)	22(55)	0.5475
ASA3, N(%)	20(66.66)	10(25)	0.0024
BMI, kg/m2	26.8±5.3	26.5±5.5	0.9690

COPD, N(%)	5(25)	4(10)	0.1365
Hypertension, N(%)	12(60)	25(62.50)	0.6375
Congestive heart failure, N(%)	5(25)	5(12.50)	0.1427
Diabetes, N(%)	2(10)	8(20)	0.4912
Smoker, N(%)	2(10)	4(10)	1.0000
Active extrapulmonary infection, N(%)	3(15)	5(12.50)	0.6960
SpO2 onambientair, %, median (IQR)	96(91–94)	98(92–96)	0.2512
Haemoglobin, g/dl	12.8±2.8	13.5±1.4	0.2840
Creatinine, µmol/l	84.6±32.4	75.5±18.2	0.1414

20 patients were assigned to the PPC+ group, 40 were evaluated in the PPC- population. Most conditions were similarly represented in both groups, none of the potential predictors were significantly different. Patients conforming to ASA 3 class were significantly more represented in the PPC+ group.

Table 2: Postoperative characteristics of the patients

Variable	PPC+ N=20	PPC- N=40	p-value
Operation time, min, median (IQR)	196(120–266)	132(86–177)	0.0679
Surgeries with upper quadrant involvement, N(%)	16(80)	28(70)	0.7597
Upper gastrointestinal tract, N	4	8	
Pancreatic-biliary, N	8	10	
Liver resection, N	4	6	
Other, N	0	4	
Surgeries limited to lower quadrants, N(%)	4(20)	12(30)	
Colorectal, N	3	10	
Other, N	1	2	
Laparoscopy, N(%)	1(5)	7(17.50)	0.4260
Epidural catheter, N(%)	7(35)	14(35)	1.0000
Intravenous fluid, ml/kg/h, median (IQR)	10.7(7.6–16.1)	10.9(7.9–15.6)	0.9060
Estimated fluid balance, ml/kg, median (IQR)	23.7(13.1–28.7)	19.1(13–0-28.7)	0.1914
ARISCAT score	38±12	25±13	0.0006

LUS at baseline and in the postoperative hour were similar in both populations.

Table 3: Type and frequency of detected PPC

Type of PPC	N (%)
Respiratory failure	6(30)
Pulmonary congestion	2(10)
Pleural effusion (with or without atelectasis)	7(35)
Bronchospasm	3(15)
Respiratory tract infection 2(6.66	2 (10)

Values of ARISCAT scores were significantly higher among PPC+ participants, otherwise, we did not detect important intergroup differences.

Table 4: Odds Ratios of predictors for PPCs retained in the multivariate analysis

Variable	OR	CI95%	BootstrapvalidatedCI95%	p-value
Creatinine	1.0332	1.0022–1.0688	0.9957–1.0966	0.0359
LUSat1 h	0.7280	0.4934–1.0599	0.4458–1.1629	0.0940
LUSat24 h	2.6348	1.5555–4.4971	1.9341–4.2005	0.0002

LUS at 1 h was not significantly associated with PPCs with an OR of 0.7280. By contrast, 24th postoperative hour's LUS was verified to be an independent and significant risk factor for PPCs, having an OR of 2.6348.

Discussion

Major abdominal surgeries under general anaesthesia is associated with high risk of pulmonary complications (24-41%). [20] The most frequent complications are acute respiratory failure, ateliectasis, pneumopathy. [21] and is frequent in the first postoperative day. The stress and the pain following the surgery will lead to an increase in the respiratory work, restrictive syndrome, hypoxemia, and respiratory muscle dysfunction in the postoperative period. [21,22] We evaluate the value of lung ultrasonographic variables in a 24-h timeframe for predicting PPCs which is very valuable tool with high sensitivity and good specificity.

Lung ultrasound was proven to be valuable in screening for postoperative pulmonary pathologies after cardiac surgery with superiority compared to chest X-rays. [23] The quantitative evaluation of the lung deaeration is feasible in perioperative settings. [18] Therefore, the potential inclusion of this modality in a prediction model is an attractive option. Choosing a relatively rough endpoint for their study, a French centre reported that patients postoperatively admitted to ICU needed more frequently postoperative ventilatory support, and had a lower PaO2/FiO2 ratio if their LUS was at least 10 immediately after admission. [24] In a recent study, the authors reported that among non-ICU postoperative patients, LUS can be a predictor of not only respiratory failure, but other PPCs as well. According to their results, higher postoperative LUS was typical in patients who developed PPCs. [25]

20 patients were assigned to the PPC+ group, 40 were evaluated in the PPC- population. Most conditions were similarly represented in both groups, none of the potential predictors were significantly different. Patients conforming to ASA 3 class were significantly more represented in the PPC+ group. LUS at baseline and in the postoperative hour were similar in both populations. Values of ARISCAT scores were significantly higher among PPC+ participants, otherwise, we did not detect important intergroup differences. LUS at 1 h was not significantly associated with PPCs with an OR of 0.7280. By contrast, 24th postoperative hour's LUS was verified to be an independent and significant risk factor for PPCs, having an OR of 2.6348.For the calculation of the reaeration score, day-0 was chosen as a reference for several reasons. First, the calculation of the reaeration score was originally invented to measure the lung ultrasound evolution to evaluate the efficacy of therapeutic measures such as antibiotic therapy in ventilator acquired pneumonia [26] or PEEP level during ARDS. [11] It seemed more relevant to evaluate the lung's evolution after it had undergone the trauma of the operation, rather than performing a comparison before and after surgery knowing the anatomical changes that it entails.

In our study population, a transient increase in LUS at the earlier postoperative checkpoint did not increase risk of PPCs, but persistently elevated scores over 24 h identified a group of patients who are at significantly higher risk with high specificity and sensitivity. In our multivariate model, apart from LUS, preoperative creatinine level was also a mild risk factor, a finding hard to interpret in our study not focusing to the topic, while both PPC+ and PPC- groups had means in the normal range. Possible limited ability to empty extra fluid postoperatively can contribute to putting some patients at increased risk.

Conclusion

Lung ultrasound may be of help in the diagnosis of respiratory complications after general anaesthesia for patient undergoing major abdominal surgeries. However, the appearance of ultrasound signs does not precede the onset of clinical signs. It is interesting to note that most of patients have B-lines on both lungs after surgery. Persistently high postoperative lung aeration score at 24 h identify patients at risk of or in an early phase of postoperative pulmonary complications. Further investigation could implement these findings into the individualization of postoperative high-dependency care of these patients.

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