Original Article

Perioperative Factors Influencing the Incidence of Postoperative Pulmonary Complications in Patients Undergoing Head-and-Neck versus Abdominal Surgeries and their Outcome

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Abstract

Background: Postoperative pulmonary complications (PPCs) are frequent causes for adverse outcomes after major surgeries. **Aim:** The aim of this study was to compare the perioperative factors influencing the incidence of PPCs in two groups of patients undergoing prolonged major surgeries, namely head-and-neck versus abdominal surgeries, receiving postoperative ventilation. **Patients and Methods:** This prospective observational study was designed, and the necessary data were collected from consecutive patients fulfilling all criteria in a single center between August 2017 and March 2018. Correlation of PPCs with duration of surgery, perioperative mechanical ventilation (PMV), and volume of crystalloids used in both the groups was analyzed by multiple binary logistic regression. The inhospital mortality and number of days of intensive care unit (ICU) and hospital stay were analyzed with Student's *t*-test. **Results:** A total of 155 patients were studied in which 77 patients who underwent head-and-neck surgeries (Group 1) and 78 who underwent abdominal surgeries (Group 2). Both the groups had a comparable demographic profile. Group 2 patients had a higher incidence of PPCs. Duration of PMV but not of surgery influenced the occurrence of PPCs independently, showing 8.2% (1.2%–15.7%) increase in PPCs with every hour increase in PMV (odds ratio: 1.08 [95% confidence interval, 1.01–1.16] with $P = 0.002$). PPCs prolonged the ICU and hospital stays and mortality. **Conclusion:** Duration of PMV is an independent risk factor for the development of PPCs. Abdominal surgeries proved to be an independent risk factor for PPCs. Early identification and risk modifications are required to reduce PPCs in high-risk category of patients who receive general anesthesia with prolonged mechanical ventilation.

Keywords: General anesthesia, mechanical ventilation, risk factor

Introduction

Postoperative pulmonary complications (PPCs) are not uncommon after prolonged surgeries that affect the patient outcome adversely and increase hospital stay and utilization of resources. The incidence of PPCs which are heterogeneous depends on its definition and varies in different surgical categories. Even mild PPCs can be associated with increased early mortality and would need special attention for improving the outcome.[1] Identification and optimization of the risk factors are important to reduce or prevent PPCs and to minimize premature deaths in patients undergoing surgery.[2,3] The risk factors for PPCs are identified in multiple studies, and various predictive factors have been recognized in LAS VEGAS risk scoring and by the validated ARISCAT scoring.[4,5] The level of risk of surgery, duration of surgery, volume of intraoperative fluids, inotropic support, and neuromuscular blocking agents used are identified to be associated with PPCs.[4-8]

Currently, major prolonged surgeries are often performed that would need postoperative ventilation for various reasons. Balanced anesthesia techniques are used with neuromuscular blocking agents, fluids, blood transfusions, and inotropic support as part of standard care. Their needs are often inevitable though some of them are modifiable.

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The primary objective of the study was to compare the incidence of PPCs within 7 days after surgery in patients undergoing major head-and-neck surgeries and abdominal surgeries who required continued mechanical ventilation in the immediate postoperative period. The secondary objectives were to find the influence of the duration of surgery, duration of postoperative mechanical ventilation, duration of total perioperative mechanical ventilation (PMV), and volume of intraoperative fluid used on the incidence of early PPCs. The mortality rate, length of stay in the intensive care unit (ICU), and duration of hospital stay were also evaluated related to PPCs.

Patients and Methods

The study was designed as a prospective observational one involving two groups of patients undergoing elective major head-and-neck surgery (Group 1) or abdominal surgery (Group 2) requiring prolonged mechanical ventilation from induction running through the early postoperative period for any clinical reason (s). The study center was a multispecialty university teaching hospital in South India where anesthesia team supervises the postsurgical care, with multidisciplinary input taken as necessary. The Institutional Ethical Committee approval was obtained before commencing the study, and data were collected for analysis after obtaining valid consent.

Patients aged ≥18 years undergoing elective head-and-neck or abdominal surgery lasting for ≥3 h and general anesthesia with total intra- and postoperative mechanical ventilation lasting for ≥10 h were included. Exclusion criteria included pregnancy, prior or simultaneous cardiothoracic or neurosurgery, palliative surgery, emergency surgery, progressive neuromuscular weakness, septic shock, trauma, burns and blast-related surgeries, history of mechanical ventilation for any reason within 30 days prior to the current surgery, history of acute respiratory distress syndrome or respiratory failure, major cardiorespiratory event such as pulmonary edema, cardiac arrest, aspiration, pneumothorax, and PaO_2/FiO_2 ratio <200 in the intraoperative period.

The duration of surgery was the time taken from the start of induction to the completion of the surgery. Duration of mechanical ventilation in the ICU was the time of shifting the patient to the ICU to the extubation or disconnection from ventilatory support in case of tracheostomized patients. The sum of the two time periods was considered as total PMV. The volume of crystalloids used intraoperatively was the total volume of all types of crystalloids the patient received while undergoing surgery mentioned in the notes. Transfusion trigger was according to the clinical decision as per case-by-case scenario. Blood loss of ≥20% or hemoglobin <10 g/dL with ongoing bleeding without or with inotropic requirement was considered as a standard indication for transfusion. Albumin was the only colloid used in the department. The necessary data of all consecutive eligible patients were collected by a respiratory therapist over a period of 8 months. Data on the PPCs that occurred in the 1st week after surgery were noted according to the definition used in a previously published study, as shown in Appendix 1.[9] The other variables collected were the days of stay in the ICU, the days of hospital stay, and the inhospital mortality.

The sample size was calculated based on a previous observational study from a single center in which the incidence of PPCs in head-and-neck surgeries and abdominal surgeries was found to be 20.7% and 59.7%, respectively.[10] Based on that study, estimated risk difference was equal to 0.38 with 80% statistical power and 5% allowable error with a two-sided test, the required sample size was calculated to be 25 in each group. As the previous study involved only a small patient population and also in view of the variability of population, three times the calculated sample size was advised, to obtain statistically significant results with 99% power and 99% confidence interval (CI) with $P < 0.01$.

Chi-square test was used to compare the incidence of PPCs as two surgical groups. Independent sample *t*-test or Mann–Whitney test was used to compare the continuous variables among the groups. Multiple binary logistic regression (backward stepwise regression) was used to calculate odds ratio with 99% CI to find the independent predictors of PPCs. The collected data were compiled using Microsoft Excel 2010, and statistical analysis was done using IBM SPSS Statistics 20 Windows (SPSS Inc., Chicago, Illinois, USA).

Results

A total of 155 patients were included in the study who fulfilled the criteria. There were 77 patients in Group 1 and 78 patients in Group 2. Age, body mass index, gender, and the American Society of Anesthesiologists physical status were comparable in both the groups [Table 1]. Twelve patients (15.6%) in Group 1 and 40 patients (51.3%) in Group 2 developed PPCs in the 1st week of surgery [Figure 1], and the difference was statistically significant between the groups, with $P < 0.001$.

The duration of surgery did not show any influence on PPCs when univariate analysis was applied to the selected factors. Surgical category and PMV were found to have a significant association with PPCs independently when the remaining risk factors were analyzed with multiple logistic stepwise regression. Abdominal surgery was an independent risk factor for developing PPCs with odds ratio of 3.84 (1.35–10.96). One-hour increase in PMV was associated with 8.2% (1.2%–15.7%) increase in the odds of getting PPCs [Table 2].

Fourteen patients in the study (9%) died while in the hospital. Two of the four patients who died in Group 1 did not have any PPC. All ten patients in Group 2 who died had various grades of PPCs [Table 3]. The association of PPCs with the number of deaths was significant only in the abdominal surgery group of patients ($P = 0.112$ and 0.001 in Group 1 and Group 2, respectively). Duration of surgery was comparable in both the

Table 1: Comparison of patient characteristics, variables studied that are considered to affect the postoperative pulmonary complications, and the incidence of mortality and postoperative pulmonary complications

	Head-and-neck surgery (*n*=77), *n* (%)	Abdominal surgery (*n*=78), *n* (%)	*P*
Age (years)	55.0±14.4	54.1±14.9	0.696
Gender			
Male	57 (74.0)	56 (71.8)	0.755
Female	20 (26.0)	22 (28.2)	
ASA PS (I/II/III/IV)	8/29/30/10	7/26/33/12	0.978
BMI (kg/m^2)	24.3±4.6	24.8±3.9	0.459
Duration of surgery and MV in OT (hours)	10.4±4.2	9.7±3.6	0.258
Duration of MV in ICU (hours)	12.5±4.4	20.3±18.4	<0.001
Total MV (hours)	22.4±5.4	29.8±17.1	<0.001
Days in ICU	6.0±4.3	9.0±11.2	0.214
Hospital days	15.8±9.5	24.1±18.9	0.001
Fluid	3.5±2.34	2.6±1.8	0.007
Mortality			
No	73 (94.8)	68 (87.2)	0.159
Yes	4 (5.2)	10 (12.8)	
Occurrence of PPC			
No	65 (84.4)	38 (48.7)	<0.001
Yes	12 (15.6)	40 (51.3)	

PPC: Postoperative pulmonary complications, ASA PS: American Society of Anesthesiologists physical status, BMI: Body mass index, MV: Mechanical ventilation, ICU: Intensive care unit, OT: Operation theater

Table 2: Independent risk factor for postoperative pulmonary complications

Factors	OR (99% CI)	*P*
Abdominal surgery group	3.84 (1.35-10.96)	0.001
1-h increase in PMV	1.082 (1.012-1.157)	0.002

PMV: Perioperative mechanical ventilation, CI: Confidence interval, OR: Odds ratio

Table 3: Mortality among the groups and postoperative pulmonary complications

Group	PPC	Death (%)		*P*
		No	Yes	
Head-and-neck surgery	No	63 (96.9)	2 (3.1)	0.112
	Yes	10 (83.3)	2 (16.7)	
	Total survived	73 (94.8)	4 (5.2)	
Abdominal surgery	No	38 (100.0)	0 (0.0)	0.001
	Yes	40 (75.0)	10 (25.0)	
	Total survived	68 (87.2)	10 (12.8)	

PPC: Postoperative pulmonary complications

groups. The amount of crystalloids used was 3.5 ± 2.34 L in Group 1 and 2.6 ± 1.8 L in Group 2. The volume of parenteral crystalloids used had statistically no significant difference on PPCs between the groups ($P = 0.032$).

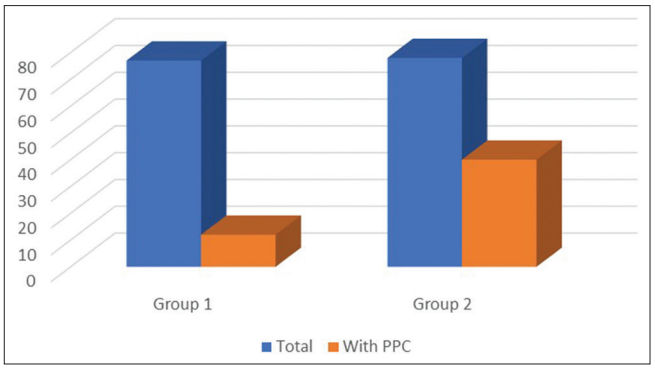

Figure 1: Postoperative pulmonary complications in groups

There was a significant difference between the groups in their number of days of ICU stay and hospital stay. Patients without PPCs stayed for median 2 (1–18) days in the ICU whereas those who had PPCs stayed for median 8 (2–86) days, the difference of which was statically significant ($P = 0.001$) [Table 4]. The number of days of hospital stay was also significantly more for those who had PPCs, 26.58 ± 21.124 days, compared with 16.58 ± 10.29 days for those who were free of PPCs ($P < 0.001$). The distribution of various grades of PPCs in the groups is depicted in Figure 2.

In the present study, we observed that duration of PMV ≥10 h was an independent risk factor for the development of PPCs. It was inferred that addition of every 1 h of PMV was associated with 8.2% increased risk of developing PPCs. Even though both the groups had >10 h of mechanical ventilation with similar protective ventilation, abdominal surgery group had increased incidence of PPCs.

Discussion

PPCs are newly identified diseases or dysfunctions affecting the respiratory system that adversely influences patient outcome after the surgery.[3,11] Pulmonary complications can lead to additional requirement of oxygen or respiratory support, which include noninvasive or invasive mechanical ventilation. PPCs are more common than postoperative cardiac complications leading to mortality and increasing hospital expenses.[12,13] The criteria used in this study to define and grade PPCs were taken from the first publication of the IMPROVE study group [Appendix 1].[9] The absence of any pulmonary complication was considered as Grade 0, and most severe pulmonary complication was taken as Grade 4. The occurrence of the highest grade of pulmonary complication was considered as a single event for comparison. The heterogeneous PPC definitions and the variability of reporting the severity of the event of postoperative complications were seen in many studies. PPC has been a popular subject for research. The recently published studies and articles have tried to recognize modifiable and nonmodifiable risk factors that would lead to changes in the morbidity and mortality due to PPCs. Abdominal surgeries, especially upper abdominal, longer duration of surgery lasting for >3 h, emergency surgery, hemodynamic

Table 4: Intensive care unit stay

Group	PPCs	*n*	Number of days in ICU			*P*
			Median	Minimum	Maximum	
Head-and-neck surgery	Nil	65	5	1	12	0.022
	+	12	8.5	2	24	
	Total	77	5	1	24	
Abdominal surgery	Nil	38	4	1	18	0.002
	+	40	8	2	86	
	Total	78	6	1	86	
Total	Nil	103	5	1	18	<0.001
	+	52	8	2	86	
	Total	155	6	1	86	

ICU: Intensive care unit, PPC: Postoperative pulmonary complications

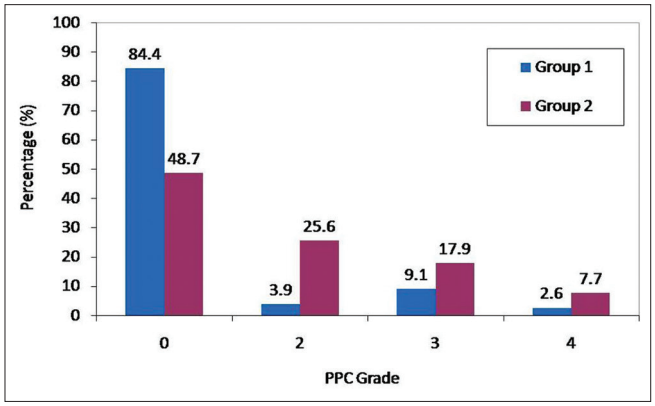

Figure 2: Distribution of various grades of postoperative pulmonary complications

instability, and increased fluid shifts with massive fluid transfusions have been identified as risk factors in several studies done earlier.[1,3,6,14,15]

Lung-protective ventilation strategies including low tidal volumes of 6–8 ml/kg body weight and 5–8 cm H_2O of positive end-expiratory pressure (PEEP) were practiced routinely at our center for all patients who received general anesthesia and mechanical ventilation ever since the IMPROVE study was published. Our study definitions of PPCs were adapted from the same study where protective ventilation strategies were observed to have improved outcome by reducing the postoperative complications.[9] The lung dynamics begin to change from the induction of general anesthesia. Atelectasis commences mainly by three mechanisms: compression of the dependent lungs, resorption of gasses, and impairment of surfactant from local and systemic inflammatory responses happening in the perioperative period.[9,16] The presence of the endotracheal tube obtunds the protective cough reflex and mucociliary function of the airway that may lead to airway micro-aspirations.[3,15,17]

In this study population, the impact of the changes in lung dynamics, impaired mucociliary clearance and the obtunded cough reflex affected by the endotracheal or tracheostomy tube had been continued beyond the operation theatre to the intensive care unit where patients were stabilized later on. The reason for continuing the ventilation postoperatively might also have contributed to the development of PPCs. The use of nondepolarizing muscle relaxants all through the long hours of surgeries, fluid resuscitation leading to massive fluid shifts, inotropic support, refractory hypothermia, and transfusions of blood products and rarely re-explorations might have contributed to the prolongation of mechanical ventilation beyond the operation theater.

Many modifiable and nonmodifiable risk factors were identified in the causation of PPCs.[4,5,14,18,19] In the occurrence of PPCs, the relevance of the type of surgery, duration of surgery, duration of intensive care ventilation, total duration of perioperative ventilation (PMV), and the total volume of different crystalloids used during surgery were examined in the current study using multivariate analysis. The abdominal type of surgery and the duration of PMV were the only two independent risk factors found to be associated with PPCs. PPCs are known to be the cause for increased mortality and hospital stay.[4,12,17,19] In our study, patients with PPCs had a higher mortality rate than those who did not have PPCs and were significant in the abdominal surgery group ($P < 0.001$). The all-cause mortality was 9% without showing any difference between the two surgical groups of patients. The length of hospital stay was higher in those patients who had PPCs, showing the financial implications caused by this complication. It is advised by many researchers that modifiable risk factors need to be identified early and optimized before or during surgery in order to prevent or mitigate the risks using "care bundles" for patients at high risk for pulmonary complications.[11] However, the feasibility of "care bundles" should be validated for future use.

The current study was from a single center where universal standard of care was delivered for all patients with low tidal volumes and normal range of PEEP as recommended by many other studies. This study focused on prolonged duration of the procedure in two different categories of patients who had longer exposure to mechanical ventilation and anesthetic agents. The data were collected prospectively on the site by a respiratory therapist who had followed uniformity and strict diagnostic criteria in identifying the PPCs.

The limitation of the study included fast tracking of certain patients, such as those with malignancy, which might have compromised uniform optimization before surgery. Some patients who had free flap surgeries had received a small flow of oxygen therapy in postoperative period as a local practice and also in certain patients who were on opioids for pain relief for up to 3 days after surgery in some of whom minor atelectasis and hypoxemia might have been masked. The use of blood and blood products was not analyzed in this study. Restricted fluid strategy was used in abdominal surgeries, and hemodilution was aimed in major head-and-neck reconstructive surgeries with free flap which might have caused disparity in intraoperative fluid transfusions bringing forth inconsistency with other reports.[4,19] Both the groups had wide spectrum of patients falling under head and neck or abdominal surgery without much stratification, use of complimentary regional anaesthesia, type or site of abdominal incision were also not subclassified in this study. Smoking, a well-recognized predictive factor, was more common in Group 1 patients in whom PPC was found be lower in our study; failure of explanation of the multifactorial influence on each case by case may be considered as a drawback of this study.

Conclusion

PPCs are not uncommon after major surgeries of prolonged duration in which abdominal surgeries carry higher risk compared to major head-and-neck surgeries. Duration of PMV ≥10 h is an independent risk factor for PPC in the study. Modifiable risk factors need to be identified early and focused perioperative care may improve postoperative outcome.

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Conflicts of interest

There are no conflicts of interest.

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Appendix 1: Grade scale for postoperative pulmonary complications

Grade 1	Cough, dry
	Microatelectasis: Abnormal lung findings and temperature 37.5°C
	without other documented cause; results of chest radiograph either normal
	Dyspnea, not due to other documented cause
Grade 2	Cough, productive, not due to other documented cause
	Bronchospasm: New wheezing or preexistent wheezing resulting in change therapy
	Hypoxemia
	Atelectasis: Radiological confirmation plus either temperature >37.5°C or abnormal lung findings
	Hypercarbia, transient, requiring treatment, such as naloxone or increased manual or mechanical ventilation
Grade 3	Pleural effusion, resulting in thoracentesis
	Pneumonia suspected: radiological evidence without bacteriological confirmation
	Pneumonia proved: radiological evidence and documentation of pathological organism by gram stain or culture
	Pneumothorax
	Re-intubation postoperative or intubation, period of ventilator dependence (noninvasive or invasive ventilation) ≤48 h
Grade 4	Respiratory failure: postoperative noninvasive ventilation dependence ≥48 h, or re-intubation with a subsequent period of ventilator dependence ≥48 h

Postoperative hypoxemia was defined as a PaO_2 <60 mmHg or SpO_2 <90% on room air

Pneumonia was suspected on the presence of new and/or progressive pulmonary infiltrates on chest radiograph plus two or more of the following criteria

- Fever ≥38.5°C or hypothermia <36°C
- Leukocytosis ≥12,000 WBC/mm^3 or leukopenia <4000 WBC/mm^3
- Purulent sputum and/or a new onset or worsening cough or dyspnea
- Atelectasis was defined as lung opacification with shift of the mediastinum, hilum, or hemidiaphragm toward the affected area and compensatory overinflation in the adjacent nonatelectatic lung

WBC: White blood cell