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Review Article

Postoperative Pulmonary Complications: A Review of the Literature and Implications for Practice

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Abstract

Postoperative pulmonary complications (PPCs) remain a major concern despite advancements in the healthcare system. The rate of occurrence of PPCs can vary greatly according to factors related to the patient and the surgery itself. The term PPCs refers to a variety of respiratory conditions that can occur, typically within the first seven days following surgery. Examples of these conditions are atelectasis, chest infection, and respiratory failure. When functional residual capacity (FRC) is reduced, it can lead to changes in the ventilation-perfusion (V/Q) ratio which can lead to the development of atelectasis. It may take several days for the alveolar-to-arterial oxygen difference to return to normal. There have been numerous published prediction models for PPCs such as ARISCAT score, PERISCOPE, and LAS VEGAS score but many of them have limitations. PPCs have been associated with higher postoperative morbidity and a prolonged hospital stay which in turn results in higher healthcare costs. As such, anesthetists and surgeons need to be cautious of patients at higher risk and take preventative strategies to lower PPCs.

Keywords: Respiratory complications, ARISCAT score, Postoperative morbidity/, Postoperative mortality

Introduction

Despite the improvements in the care given to patients during different surgeries, postoperative pulmonary complications (PPCs) continue to be one of the leading causes of illness and death[1]. PPCs contribute to prolonged hospital stays which in turn results in higher healthcare costs[2].

The reasons for PPCs are complex and can be attributed to several factors related to patient, anesthesia, and surgery. Management of PPCs requires a multidisciplinary approach involving an anesthesiologist, surgeon, physiotherapist, respiratory medicine specialist, and critical care specialist, and can result in economic and health outcome strains[3].

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A- Definition

In 2015, a joint task force from Europe released updates for defining perioperative clinical outcomes (EPCO)[4]. PPCs are considered a combined outcome measure, and their definitions by EPCO are illustrated in Table 1. Researches that assess PPCs may utilize many combinations of these individual outcomes[4].

B- Pathophysiology

Adverse respiratory effects begin shortly after induction of anesthesia[5]. There are changes in respiratory muscle function, the airway can become obstructed, and the diaphragm may move upward in dependent areas. These changes can result in the reduction of functional residual capacity (FRC)[6].

Table 1: Postoperative pulmonary complication as defined by EPCO[4]

Complication	Definition
Respiratory infection	Patient has received antibiotics for a suspected respiratory infection and met one or more of the following criteria: new or changed sputum, new or changed lung opacities, fever, white blood cell count > 12000
Respiratory failure	Postoperative PaO2 < 8 kPa (60 mmHg) on room air, a SpO_2 < 90% and requiring oxygen therapy
Atelectasis	Chest radiograph demonstrating blunting of the costophrenic angle, loss of sharp silhouette of the ipsilateral hemidiaphragm in an upright position, evidence of displacement of adjacent anatomical structures or (in supine position) a hazy opacity in one hemithorax with preserved vascular shadows
Pleural effusion	Lung opacification with a shift of the mediastinum, hilum or hemidiaphragm toward the affected area, and compensatory over-inflation in the adjacent non-atelectatic lung
Pneumothorax	Air in the pleural space with no vascular bed surrounding the visceral pleura
Bronchospasm	Newly detected expiratory wheezing treated with bronchodilators
Aspiration pneumonitis	Acute lung injury after the inhalation of regurgitated gastric contents

The combination of reduced FRC, alongside the abnormal distribution of ventilation, and decreased cardiac output results in ventilation-perfusion (V/Q) changes. The former leads to increased alveolar dead space and the latter causes impaired oxygenation[6]. There are many mechanisms for how ventilator-induced lung injury (VILI) can develop. High airway pressure (barotrauma) or increased tidal volumes may impair alveolar epithelium by stress and strain mechanisms. Repeated expansion and collapse of alveoli can lead to damage known as (atelectrauma)[7]. Fragmentation of the extracellular matrix can result in interstitial edema and the release of inflammatory mediators (biotrauma). The previous mechanisms can explain how VILI can occur in previously healthy lungs[8]. Several factors lead to the development of hypoxia in the post-anesthesia care unit (PACU) including airway obstruction, residual anesthetic and opioid drugs, residual effects of NMBD, and impairment of ventilatory responses to hypoxia and hypercapnia[9]. It may take several days for the alveolar-to-arterial oxygen difference to return to normal.

FRC gradually returns to normal values after 5–7 days after major abdominal operations. FVC and FEV_1 are decreased after surgery, particularly with severe pain. Episodes of hypoxemia and affection of respiratory muscles are common after major surgery[10].

C- Perioperative Risk factors of PPC

Positioning

During the supine position, abdominal contents are displaced upwards, the diaphragm is pushed up and the dependent lung regions are compressed. These changes can be reduced by positioning the patients with their heads elevated or in a ramped position[11].

Intraoperative F_iO_2

To prevent or correct hypoxemia, an increased fraction of inspired oxygen (FiO2) is administered; however, it can lead to hyperoxia which in turn can increase oxidative stress and atelectasis. For this reason, unnecessarily high F_iO_2 should be avoided[12].

Modes of mechanical ventilation

Pressure-controlled ventilation (PCV) is associated with lower peak inspiratory pressure and improved oxygenation in many studies. On the other hand, volume-controlled ventilation (VCV) was linked to greater VT, and decreased dead-space ventilation[13]. VCV with an inspiratory pause has the advantage of measurement of plateau pressure, allowing for accurate calculation of driving pressure. Therefore, no one mode is better than another[14].

Inspiratory/expiratory ratio

Increased inspiratory to expiratory (I:E) ratio increases mean airway pressure and reduces peak airway pressure when compared to the usual 1:2 ratio, while a ratio of 1:1 was linked to a decrease in lung damage[15].

Intraoperative monitoring of lung mechanics

The respiratory functions can be affected by both anesthesia and surgery, so it is important to continuously evaluate the components of the lung mechanics such as compliance, driving pressure (DP), and plateau pressure. Interventions to optimize lung mechanics could be checked by measuring compliance with fixed tidal volume. It is important to keep DP as low as possible with the individualized setting of PEEP[16]. Disconnection of the circuit or turning to a manual mode of ventilation can lead to an immediate drop in lung volume and is associated with decreased compliance and increased driving pressure[17]. Recruitment maneuver (RM) can prevent alveolar collapse however; it should be followed by individualized PEEP to avoid alveolar collapse or overdistension[18].

Emergence from anesthesia

During the emergence from anesthesia, certain conditions can undo the efforts made during surgery to recruit and keep the lungs open. These include zero positive end-expiratory pressure (ZEEP), supine position, routine endotracheal suctioning before extubation[19]. Higher $F_iO_2 > 0.8$ during emergence can increase the risk of atelectasis[20].

D- Prediction models for PPCs

Patients should go through a preoperative evaluation that includes a score for pulmonary risk assessment. PPC risk can be estimated using a variety of scoring methods, but many of them are either overly complex or lack external validation[21]. In recent years, many models have been developed to predict PPCs, but most of them have limitations because they only considered one type of unfavorable event, such as pneumonia[22].

The most used models are ARISCAT score and the LAS VEGAS score. ARISCAT score is considered the preferred prediction model for the prediction of PPCs[22].

1-ARISCAT score

ARISCAT (assess respiratory risk in surgical patients in Catalonia) is a model with seven variables dividing the patients into low, intermediate, and high-risk groups for developing PPCs. PPC incidences were 1.6, 13.3, and 42.1% respectively as illustrated in Table 2[23]. The score is considered a good predictor of PPCs. Anemia is an essential contributing factor to the incidence and mortality of PPCs irrespective of risk stratification. Emergency surgery and a duration of more than three hours have also significantly contributed to the incidence and mortality of PPCs.

Table 2: ARISCAT score and its risk stratification[23]

Score number	Ariscat score component	Score
1	Age in years *50≤* *51-80* *> 80*	 0 3 16
2	Preoperative SpO_2 in % *96≥* *91-95* *90≤*	 0 8 24
3	Respiratory infection in the last month	17
4	Preoperative anemia (Hb ≤ 10 g/dl)	11
5	Surgical incision *Peripheral* *Upper Abdominal* *Intrathoracic*	 0 15 24
6	Duration if surgery in hours *2≤* *2-3* *3>*	 0 16 23
7	Emergency procedures	8
	Total score *Low risk* *Intermediate risk* *High risk*	 26< 26-44 ≥45

However, age, preoperative SpO_2, and respiratory infection in the last month did not seem to have a significant contribution to the incidence and mortality of PPCs[23]. The main limitation of the ARISCAT score is being composed of preoperative characteristics, such as age, comorbidities, type of surgery, and expected duration of the surgical intervention, without the inclusion of intraoperative events, such as intra-operative ventilation, and intra-operative events that are associated with the development of PPCs[24]. PERISCOPE (prospective evaluation of a risk score for postoperative pulmonary complications in Europe) is a multicentered study conducted to validate the results of ARISCAT score study using the same seven variables as ARISCAT and showing good discrimination c-statistic 0.80 (confidence interval 0.78–0.82)[24]. PERISCOPE categorizes the patients into low, intermediate, and high-risk groups. Respective incidences of PPCs were 1.1, 4.6, and 18.8%[25]. However, the independent variables differ slightly from those found in ARISCAT; low preoperative SpO_2, at least one preoperative respiratory symptom, chronic liver disease, congestive heart failure, intrathoracic/upper abdominal surgery, procedure>2 hours, and emergency surgery[25]. PERISCOPE concluded that ARISCAT score can be used to differentiate between the three levels of PPC risk in hospitals although performance differs significantly between geographic areas[25].

2-LAS VEGAS score

Thirteen perioperative variables make up LAS VEGAS (Local Assessment of Ventilatory Management during General Anesthesia for Surgery score). It is used for predicting patients with high risk for development of PPCs as illustrated in table 3[26]. The LAS VEGAS score performed better than the ARISCAT score. The main advantage of The LAS VEGAS score over ARISCAT score is the inclusion of intraoperative factors in addition to preoperative factors and this could explain its better performance. Furthermore, a larger number of patients, and consequently a larger number of events, was used than for the development of the LAS VEGAS risk score. The main limitation of the LAS VEGAS score is that external validation is still required to confirm the accuracy of this score[26].

E- Strategies to reduce PPCs

1-Preoperative strategies

PPCs can be reduced by optimizing patient's preoperative pulmonary diseases. For patients with chronic obstructive pulmonary disease (COPD), it is important to continue using inhaled beta-2 agonists and anticholinergics. Using inhaled bronchodilators before surgery may improve pulmonary functions and help maintain normal respiratory function after surgery. Systemic or inhaled corticosteroids can be used for a short time before surgery with cautious if indicated[27]. Antibiotics can be used to treat active respiratory infections. For patients with asthma, it is important to continue treatment before to surgery to relief any bronchospasm. In severe obstructive sleep apnea (OSA), using continuous positive airway pressure (CPAP) before surgery may be helpful as well as weight loss and mandibular advancement device[27]. Several studies suggest that quitting smoking before surgery decreases the incidence of PPCs. However, the evidence is weak and the benefit of stop smoking prior to surgery depending mainly on how long the patient quits smoking before surgery. For example, the risk of PPCs in smokers who stop smoking two weeks before surgery is almost the same as active smokers. However, The risk of PPCs is marginally lower in individuals who gave up smoking more than eight weeks prior to surgery[28]. Inspiratory muscle training (IMT) can help improve the strength of muscles used for breathing. This is often when the patient generates enough inspiratory pressure to open an inspiratory valve and allow air to flow. IMT decreases early PPCs. However, the effect of other forms of rehabilitation on PPCs is questionable[29].

2-Intraoperative strategies

Using less invasive surgical methods may help lower the risk of PPCs, especially in obese patients. For bariatric surgeries, PPCs were increased in open gastric bypass compared to laparoscopic techniques. This may be due to less blood loss, pain, inflammation, and as a result shorter length of stay[30]. Nasogastric tubes can be beneficial in certain conditions after surgery like nausea, vomiting, abdominal distension, and difficulties tolerating oral food as they decompress the stomach even though their routine use is not recommended and associated with a higher incidence of PPCs[30].

Table 3: LAS VEGAS score and its risk stratification[26]

Score number	LAS VEGAS score components	Score
1	Age in years *≤46* *47 - 67* *≥68*	 0 3 4
2	American society of anesthesiology (ASA) physical score *< 3* *≥3*	 0 6
3	Preoperative SpO_2 *> 96* *≤96*	 0 2
4	Preoperative anemia (Hb ≤ 10 g/dl)	5
5	Duration of surgery in minutes *≤55* *56 - 134* *≥135*	 0 4 11
6	Cancer	5
7	Obstructive sleep apnea	9
8	Elective surgery Urgent surgery Emergent surgery	0 8 9
9	Use of supraglottic device	-6
10	Type of anesthesia *Totally intravenous* *Volatile* *Balanced*	 0 0 5
11	Desaturation	12
12	Need of vasoactive drug	5
13	PEEP (cmH_2O) *≤ 2* *3 – 4* *≥ 5*	 0 3 4
	Total score *Low risk* *Intermediate risk* *High risk*	 ≤ 7 8 - 16 ≥ 17

Using intraoperative protective pulmonary ventilation refers to adjusting ventilator settings to decrease lung injury. There is strong evidence that using tidal volume of 6 ml/kg of predicted body weight can help prevent PPCs[31]. It is also widely accepted that plateau pressure should be kept less than 30 cm H_2O, driving pressure below 15 cm H_2O, FiO_2 is 0.4 when oxygen saturation is above 92% [32]. However, the optimal level of PEEP and the use of intraoperative RM are more challenging with the concerns about the potential of high PEEP to affect hemodynamics[33]. Although the time of intubation during surgery is generally less than that in intensive care, There is controversy that a shorter duration for surgeries is safer[34]. The use of quantitative neuromuscular monitoring can lower the risk of PPCs when using muscle relaxants[34]. Reversal with Neostigmine is linked to higher PPCs. However, when Neostigmine and Sugammadex are used with quantitative neuromuscular monitoring, they can decrease the risk PPCs[35]. Neuraxial anesthesia has been related to lower PPCs and Mortality when compared to general anesthesia[27]. Neuraxial anesthesia is particularly helpful in patients with higher pulmonary such as OSA or pulmonary diseases, although the evidence is not consistent[27]. For patients with COPD who need general anesthesia, all volatile except Desflurane can be used, as it may cause cough, laryngospasm, and bronchospasm. Supraglottic airway devices are less irritating to the airway than endotracheal intubation. Receiving Large amounts of intraoperative intravenous fluids increases the risk of pneumonia and pulmonary edema, and is associated with longer hospital stay[36].

3-Postoperative strategies

Postoperative strategies should concentrate on effective postoperative analgesia, early mobilization, chest physiotherapy, and expansion techniques. Postoperative pain management with multi-modal analgesia is crucial as pain can affect pulmonary function, coughing, and mobilization leading to atelectasis and subsequent respiratory infection[37]. Analgesia is important because pain, especially from abdominal wounds, compromises pulmonary function, coughing, and mobilization, resulting in atelectasis and chest infection. Postoperative thoracic epidural analgesia may decrease respiratory muscle dysfunction and pain-related hypoventilation after abdominal surgeries, by facilitating early extubation and lowering the risk of respiratory failure[37]. In patients undergoing open aortic aneurysm repair, and coronary bypass surgery, PPCs have been lowered by one-third with the use of thoracic epidural analgesia. Thoracic epidural analgesia may help COPD patients perform abdominal surgery by lowering the requirements for parenteral opiates and which can cause respiratory depression. Moreover, they may lower the work of breathing and facilitate respiratory physiotherapy and lung recruitment maneuvers[22]. A combination of physiotherapy, mobilization, and oral hygiene seems to be beneficial for reducing PPCs. Incentive spirometry, deep breathing techniques, and coughing could be encouraged during waking hours until discharge. Patients are ideally sat in a chair, or the head of the bed is elevated to thirty degrees, with mobilization three times a day. Oral hygiene is maintained with twice daily teeth brushing and mouthwash[22].

Conclusion

Postoperative pulmonary complications (PPCs) continue to be a major contributor to postoperative morbidity and mortality and have a considerable effect on the quality and cost of medical care. Understanding the causes and mechanisms of PPCs is crucial for developing effective strategies for preventing and managing PPCs using a multidisciplinary approach.

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