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Postoperative Pulmonary Complications

David A Grooms MSHS, RRT

Postoperative pulmonary complications (PPCs) are a common outcome of cardiothoracic surgery. When allowed to progress, PPCs can result in serious sequelae, such as respiratory failure, pulmonary embolism, acute lung injury, or acute respiratory distress syndrome. The prevention of PPCs requires a comprehensive approach that includes assessment of preoperative risk, smoking cessation, and attention to a number of factors before, during and after surgery. In this article, Dr. Grooms addresses several preventive measures such as intraoperative and postoperative anesthetic/analgesic technique, the use of laparoscopic surgery, selective nasogastric tube decompression, lung expansion modalities, oxygen therapy, deep breathing exercises, physical therapy, and the use of subglottic suction endotracheal tubes. Clinical trials in this area are needed to guide practice, but in the absence of evidence, minimally studied or unproven therapies may still provide clinical benefit if used judiciously.

Panel Discussion: Postoperative Pulmonary Complications

Moderator: *Faisal Masud, MD*
Panelists: *Paul Marik, MD*
Ruben Restrepo, MD, RRT
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Understanding the nature of PPCs is paramount to their prevention and treatment. In this panel discussion, 5 experts in respiratory medicine discuss the many facets of PPCs and measures clinicians can take to reduce their risk. The discussants address the definition of PPCs, their impact on perioperative morbidity and mortality, PPC risk factors, surgical and anesthesia issues, and strategies that can be implemented pre- and post-surgery to reduce the risk of PPCs. Also discussed are issues related to cost, an ever-important consideration in the era of pay-for-performance.

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Postoperative Pulmonary Complications

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Postoperative pulmonary complications (PPC) can adversely influence a patient's clinical course following surgery and are equally as common as cardiac complications for patients undergoing non-cardiothoracic surgery. These complications include atelectasis, bronchospasm, and tracheobronchitis, which are considered self-limiting disorders known to induce perioperative hypoxemia. However, these complications may result in substantial morbidity and mortality when they progress to more severe forms or develop into respiratory failure, pulmonary embolism, postoperative pneumonia (PP), empyema, pneumothorax, acute lung injury (ALI), acute respiratory distress syndrome (ARDS), or the need for mechanical ventilation beyond 48 hours following surgery.[1,2] Special attention is often given to the prevention and development of atelectasis because it is one of the primary mechanisms associated with ALI, a major cause of postoperative hypoxemia, leading to longer stay in the intensive care unit (ICU) and increased length of stay (LOS) in the hospital.[3] Although the clinical evidence regarding PPC prevention is often unclear and moderately strong at best, essential measures must be taken to reduce PPCs. These include carefully individualized strategies for preventing atelectasis and aspiration of oral secretions, restoring functional residual capacity, and increasing the patient's ability to mobilize and expectorate secretions.

Overview of Preoperative Risks

Success of postoperative recovery is dependent not only on pulmonary physiology restoration after surgery, but also on preoperative education and intraoperative clinical care management. Therefore, it is necessary to discuss the appropriateness of common interventions and how they pertain to postoperative recovery. Examples include preoperative smoking cessation, anesthetic and analgesic technique, laparoscopic vs. open procedures, nasogastric decompression, lung expansion therapy, and the use of subglottic-suction endotracheal tubes.

Neuraxial blockade, via spinal or epidural route, may improve recovery and prevent complications by blocking a constellation of stress

Preoperative Smoking Cessation

It is well understood that smoke inhalation contributes to reduced mucociliary activity leading to decreased mucus production and increased coughing due to bronchial irritation. Smoking increases the frequency of complications in minor surgical procedures,[4,5] hernia surgery,[6,7] vascular surgery,[8] gastrointestinal surgery,[9,10] gynecologic surgery,[11] and orthopedic surgery.[12,13] Therefore, cessation of smoking prior to surgery is recommended to reduce postoperative complications. However, there is insufficient evidence regarding the minimum duration of smoking cessation and its association with PPCs.[14] Interventions to reduce smoke inhalation 6 to 8 weeks prior to elective hip and knee arthroplasty surgery proved successful in minimizing complications related to wound and urinary tract infections.[15] However, subsequent trials have demonstrated reductions in wound healing complications in head and neck[16] and breast reduction surgery[17] when smoking was stopped 3 to 4 weeks prior to surgery. Hypothetically, cessation less than 3 to 4 weeks before surgery may benefit postoperative recovery.[18]

Intraoperative Anesthetic and Analgesic Technique

Anesthetics disrupt central regulation of breathing and result in uncoordinated neural messaging, hypoventilation, and positional-dependent regional atelectasis shortly after induction.[19] If these anesthesia effects are unresolved, they can be compounded by limited respiratory excursion due to pain, and disruption of respiratory muscles and neutrally mediated diaphragmatic function.[20] In a landmark investigation assessing mortality rates in 599,548 surgical patients undergoing procedures between 1948 and 1952, Beecher & Todd observed a 6-fold increase in the risk of death in the perioperative period associated with the use of neuromuscular blocking agents (NMBA).[21] Over the last 50 years, second and third generation NMBA's have been developed to minimize hemodynamic compromise and improve rapid onset and offset of effects, and recovery patterns. Despite improvements, residual neuromuscular blockade remains a common and often undetected occurrence in the early postoperative period.[22,23] The use of intermediate-active NMBA (atracurium, vecuronium) in comparison to long-acting NMBA (pancuronium) has not proven to reduce PPCs, however, they have led to significantly reduced incidence of residual neuromuscular blockade (5% vs 26%; $P<.001$).[24] Therefore, patients with residual blockade following pancuronium administration were 3 times more likely to develop PPCs than those without residual block (17% vs. 5%; $P<.02$).

Neuraxial blockade, via spinal or epidural route, may improve recovery and prevent complications by blocking a constellation of stress responses to surgery (e.g. increase in neurodocrines and cytokines, and reduction in pain thresh-

old) which contribute to a reduction in respiratory muscle dysfunction and pain-related hypoventilation. Epidural administration is possible through a single injection or infusion and is commonly used for intraoperative and postoperative analgesia. However, compared to epidural anesthesia, spinal anesthesia has a rapid onset around 5 to10 minutes vs. 15 to 20 minutes, is easier to administer, and produces a denser sensory and motor block. Due to practical constraints of indwelling intrathecal catheters, spinal anesthesia is administered solely as a single injection. Although intraoperative neuraxial blockade (with or without concomitant general anesthesia) may prevent PPCs, data from two recent, good quality, systematic reviews provide conflicting results with regards to reduction in postoperative pneumonia rates.[25,26] Several meta-analyses which include small unblinded studies suggest that epidural anesthesia may reduce pulmonary risk, but recent large randomized controlled trials do not confirm benefit.[19]

Postoperative Analgesic Technique

The intent of postoperative analgesia is to further reduce surgical stress responses which can lead to PPCs and organ dysfunction. Therefore, careful attention is required to interpret scientific findings related to postoperative recovery. The literature has been confounded by many misunderstandings in different narrative reviews and meta-analyses. Studies combining a variety of epidural analgesic techniques can be perceived as irrational because opioid-based regimens have little or no effect on stress response and organ dysfunction compared to local anesthesia regimens.[27] Furthermore, interpreting these studies is difficult because of the inclusion of a variety of surgical procedures that demonstrate less pronounced surgical stress response in abdominal and thoracic procedures compared to lower body procedures.[28] However, a previous meta-analysis revealed a reduction in atelectasis (11 studies) but not pneumonia (5 studies) when using epidural opioids vs systemic opioids.[29] In contrast, a subsequent meta-analysis identified 32 trials of PCA vs the same drug given intravenously, intramuscularly, or subcutaneously and found no difference in opioid consumption, pain scores, hospital length of stay, and adverse effects.[30] However, fewer PPCs occurred in the PCA group (2 studies). Therefore, postoperative epidural and PCA intravenous analgesia both seem superior compared to on-demand delivery of opioids in preventing PPCs.

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Laparoscopic vs Open Surgical Procedures

Few studies have reported PPC rates associated with laparoscopic vs open surgical procedures. In those that have reported them, PPCs were associated with cholecystectomy and colorectal surgery. Although a recent meta-analysis examining laparoscopic vs open resection of colorectal cancer demonstrates faster postoperative recovery defined by spirometry (3 studies), and 21% shorter hospital LOS (9 studies), the difference in risk and complications between the two surgical methods were not statistically different.[31] A subsequent trial of laparoscopic vs open colorectal resection showed a non-significant trend favoring lower rates of pneumonia (1.8% vs. 3.5%) following laparoscopic surgery.[32] Similarly, using ICD-9-CM codes to identify PPCs following laparosopic and open procedures, two studies reported a reduction in atelectasis following laparoscopic surgery compared with open cholecystectomy (2% vs. 4%; P <.001), and less frequent PPCs following laparoscopic vs open sigmoid resection (2.5% vs. 6%; P<.001).[33,34] Although supported by improvements in LOS, postoperative pain, surgical risk, and spirometric data, it is unclear whether clinically important PPC's are minimized with the use of laparoscopic surgical procedures. Many studies did not report PPCs and others lack the ability to detect differences in PPC rate because of small sample size and insufficient statistical power.

Routine Nasogastric Tube Decompression vs Selective Nasogastric Tube Decompression Following Surgery

Nasogastric tube decompression (NTD) is the act of reducing gastric pressure through the use of a large bore tube suction system inserted into the stomach, which aims to minimize abdominal distention, delays in early bowel return, nausea or vomiting, and aspiration. The appropriateness of selective NTD over routine NTD has come to a favorable and convincing consensus. Several studies and meta-analysis have failed to show a statistically significant benefit with regards to improved pneumonia, aspiration, and return to gastrointestinal function rates with routine NTD when compared to selective NTD. A recent prospective randomized controlled trial (RCT) examined the necessity of routine NTD in radical gastrectomy for gastric cancer patients.[35] There was no difference in overall PPCs between a tube group (TG), an intra-operative tube group (ITG), and a no-tube group (NTG). However, the TG group had an increased hospital LOS compared to the NTG group (11.3 vs. 10.2 days; P =.031) and a higher incidence of nausea compared to the ITG and NTG groups (64% vs. 36% vs 29.6%). Another recent meta-analysis of routine NTD reported no statistically significant differences between NTD and no NTD with respect to nausea, wound infection, or intestinal obstruction rates following elective colon and rectum surgery.[36] However, 2 meta-analyses examining the use of routine NGT compared to selective NGT following abdominal surgery reported lower pneumonia, atelectasis, and overall PPC rates with the use of selective NTD. Subsequently, a recent Cochrane Database Systematic Review of prophylactic NTD following abdominal surgeries reflects these findings by reporting a earlier

return to bowel function (P<.00001), a trend toward increase risk of wound infection (P=.22), and a statistically significant decrease in PPC (P=.01).[37] Therefore, the evidence suggests that selective NTD for specific indications improves return to bowel functions and may reduce the risk of PPC compared to routine NTD.

Lung Expansion Modalities and Oxygen Therapy

The cascade of PPCs usually begins with the onset of atelectasis and decreased lung volumes resulting from surgery-related diaphragmatic dysfunction, immobilization, and impaired mucociliary clearance. Therefore, it is essential to use the correct timing and methods for restoring normal lung capacity and mobilizing secretions in the postoperative phase of recovery. Common techniques that are currently employed to achieve such restoration include deep breathing exercises, such as incentive spirometry (IS), hyperinflation therapy (intermittent positive-pressure breathing [IPPB], continuous positive airway pressure [CPAP], and insufflation/exsufflation), and chest physical therapy (CPT), also known as chest physiotherapy (often combined with aerosolized mucolytic administration, coughing exercises, postural drainage, and percussion and vibration). Despite the clinical indication, lung capacity restoration is dependent on 3 factors: patient cooperation, modality of therapy, and proper caregiver application. Although it is understood that patient cooperation is often necessary, lung expansion is possible in passively ventilated patients (i.e. mechanically ventilated). Therefore, both the chosen therapy and caregiver application are essential in obtaining optimal benefit of lung expansion. These therapies are often used in combination and despite having little individual impact on clinical studies, they are still commonly used.

Deep Breathing Exercises (Incentive Spirometry and Hyperinflation Therapies)

The simple use of deep breathing techniques was described in the late 1960's.[38] In this report, a series of young, unmedicated adults inspiring a fractional inspired oxygen (FIO_2) level of 1.0 demonstrated a significant increase in oxygen tension following a deep breath hold for 3 seconds, in comparison to a deep breath without breath hold, and multiple deep breaths. Furthermore, the oxygen tension was significantly increased when the breath was extended to a 5-second hold. Subsequently, the first reports of such maneuvers used for the treatment of post-surgical patients originated in Great Britain, and revealed a significantly lower incidence of postoperative atelectasis (27% vs. 42%) detected by chest radiograph in patients treated with physical therapy including deep breathing exercises, with a further reduction to 12% in patients who received preoperative instruction in the exercises, when compared to no therapy.[39] Therefore, engineering of instrumentation to guide this therapeutic intervention lead to development of the IS device in 1972. The incentive spirometer (Figure 1) is designed to provide visual feedback to the patient, followed by documentation of the number of successful breathing maneuvers.[40] Although the first report of IS as a treatment option failed to show a significant statistical difference in PPC when compared to IPPB in 30 patients,[41] a subsequent meta-analysis reported that IS, IPPB, and deep breathing exercises appeared to be more effective than no physical therapy intervention for preventing PPCs following upper abdominal surgery.[42] While this study provided valuable insight and contribution to the literature, it failed to provide evidence to support a significance difference between each of the modalities and was limited in scope with regard to surgery and the number of studies involving IS. Previous surveys reported 95% use of IS in US hospitals following cardiothoracic and abdominal surgery,[43] 44% in UK hospitals following coronary bypass graft surgery,[44] and an increased usage rate of IS despite publications which cast doubt on the need for IS.[45] However, a subsequent, systematic review failed to provide evidence to support the use of IS for decreasing the incidence of PPC's following cardiac or upper abdominal surgery.[46] Furthermore, a recent systematic review confirms that no one lung expansion technique is superior over another, however, any type of lung expansion intervention is more clinically beneficial than no prophylaxis.[19] Additionally, combined therapies do not provide additional risk reduction in patients following non-cardiothoracic surgery.[19] Therefore, IS remains attractive because it is less labor intensive, more economical, and patient-driven. For patients who cannot perform IS or deep breathing exercises, alternative hyperinflation therapies such as CPAP, IPPB, and insufflation/exsufflation may be beneficial.

Incentive spirometry remains attractive because it is less labor intensive, more economical, and patient-driven.

Figure 1. Voldyne® Incentive Spirometer, Teleflex

Chest Physical Therapy

Chest physical therapy (CPT), also called chest physiotherapy, is an intervention which incorporates external manipulation of the thorax by a caregiver to mobilize retained secretions. Traditionally, this has been performed by specialized caregivers who performed manual percussion (clapping of the chest wall) and vibration (shaking of the chest wall) during exhalation, targeting specific lobes and lung regions. It is often coupled with postural drainage which involves patient positioning of the effected lung regions to

facilitate gravitational drainage of secretions. Today, percussion and vibration can be performed by a variety of mechanical techniques. Despite the theoretical advantages of CPT, and its common place in health care medicine, a large body of literature fails to demonstrate a clinical benefit associated with its routine use in postoperative and nonsurgical patients. A landmark systematic review reveals the concerns of many authors and their reluctance to endorse CPT as a standard of care. These are highlighted below:[47]

"Although physiotherapy is seen as an integral part of most multidisciplinary intensive care units, there is only limited evidence concerning the effectiveness of physiotherapy in this setting.[48]

The literature concerning CPT and its effect on the pulmonary function of cystic fibrosis patients is extensive and inconsistent in its findings.[49]

In mechanically ventilated children, chest physiotherapy cannot be regarded as a standard treatment modality.[50]

…we conclude that mechanical percussion of the chest as applied by physical /respiratory therapists is ineffective and perhaps even detrimental in the treatment of patients with acute exacerbations of chronic obstructive pulmonary disease.[51]

There continues to be widespread debate as to which airway clearance regimen should be used and when.[52]

Although the above statements address the global use of CPT in the healthcare setting, the only RCT to date that examined the association between CPT and PPC also failed to demonstrate a clinical benefit of CPT following pulmonary resection via open thoracotomy.[53] In contrast, using a propensity score matching method, a recent, prospectively reviewed database of 784 lung cancer patients treated by lobectomy justified the implementation of a perioperative intensive CPT program which reduced overall pulmonary morbidity. Despite the success of the project to minimize the probability of pulmonary complication, this study did not include diffusion lung capacity for carbon monoxide (DLCO) and predicted postoperative diffusion lung capacity for carbon monoxide (ppoDLCO), measures that are currently paramount in preoperative risk evaluation of lung resection candidates.[53] Therefore, the routine use of CPT is not recommended to reduce PPC. Alternative therapy such as ambulation, and earlier extubation may improve clinical outcomes in high-risk surgeries.[54]

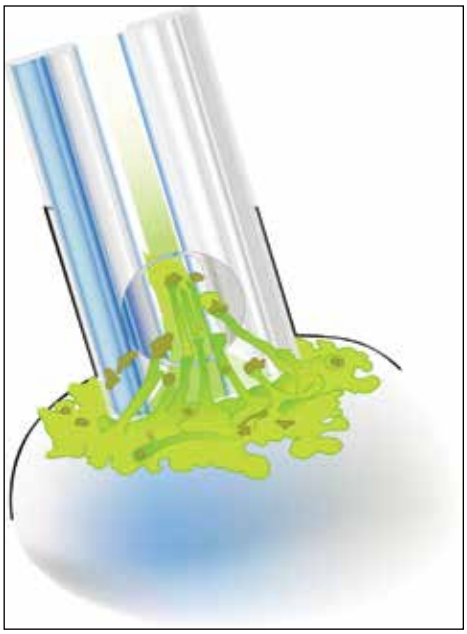

Illustration depicting secretion removal using an ETT with subglottic suction capability. (Courtesy Teleflex)

Subglottic-suction ETT

During mechanical ventilation, the placement of an endotracheal tube (ETT) causes the airway to lose its natural ability to prevent aspiration of oral, nasal, and gastric secretions. These secretions eventually penetrate the lungs via the ETT and accumulate below the epiglottis and above the ETT cuff (subglottic airway). This accumulation is often later aspirated through the inadvertent channels created within the ETT cuff resultant of cuff inflation and placement against the trachea wall. Penetration of these secretions into the lungs can result in development of ventilator-associated pneumonia (VAP), which is associated with increased mortality, morbidity, and ventilator LOS, with an approximate increase in healthcare cost of $11,873.00.[55] Therefore, engineering and creation of specialized ETT's have proven beneficial with regards to minimizing early onset VAP (within 48-72 hours) which may reduce PPC's.

ISIS® HVT™Convertible Endotracheal Tube to remove subglottic secretions. (Courtesy Teleflex)

Subglottic-suction ETT's incorporate an additional dorsal lumen suction channel directly above the cuff which is connected to an external evacuation system. Secretions are extracted either intermittently or continuously.[56] A large number of studies have sought to detect clinical benefit of this tube type compared to standard treatment. Although a recent review of 6 RCT's demonstrate a reduction in the incidence and delay in early onset VAP in a heterogenous patient population, half of the trials showed no statistically significant difference in VAP between subglottic-suction ETT and standard therapy (via chi-square test, intention-to-treat analysis).[57] However, a previous meta-analysis of 5 studies confirms benefit with an approximate 50% decrease in VAP in 896 patients expected to require mechanical ventilation for 72 hours.[58] Therefore, the results of these trials proved powerful enough to support endorsement for VAP prevention by the Center for Disease Control (CDC),[59] the American Association of Respiratory Care (AARC),[60] the American Association of Critical-Care Nurses (AACN),[61] and the American Thoracic Society (ATS).[62]

Summary

Despite the conflicting nature of clinical trials dedicated to reduction of PPCs, most interventions discussed above are still common in today's healthcare. The basis for selection of patient therapy often expands beyond clinical trials, which use statistical significance to validate treatment benefit. Therefore, selection should be driven by economical and practical concerns, as well as the individual needs of patients. In a recent editorial, Dr. Athur Slutsky addresses the phenomenon of the human attraction to physiology and the complex nature in which the foundation of clinical decision-making is constructed. Although healthcare decisions should be clinically and evidence-based, many clinical trials have yet to provide the necessary information we

require as caregivers. This is echoed in his statement, "Does it make sense not to use a novel (or not so novel) therapeutic strategy that has a strong physiological rationale, demonstrates a strong positive trend in an important clinical outcome, has an acceptable adverse effect profile, and is inexpensive?[63]" Therefore, consideration of minimally studied or unproven therapies, which make physiologic and clinical sense, may provide clinical benefit in the absence of an associated clinical trial or science.

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Panel Discussion: Postoperative Pulmonary Complications

Moderator: Faisal Masud, *MD*

Panelists: Paul Marik, *MD*
Ruben Restrepo, *MD, RRT*
Luis Angel, *MD*
David Wheeler, *RRT-NPS*

An increasingly elderly patient population, a high incidence of obesity, and the need for repeated operations all contribute to the complex problems hospitals face today. Yet the expectations of patients and payers are going ever higher. Public reporting, pay-for-performance and shrinking healthcare dollars significantly impacts hospitals and clinicians. Within this setting, postoperative pulmonary complications represent a significant burden on our healthcare system. The short- and long-term impact of pulmonary complications is not fully understood; best practices are not applied consistently, and awareness of the problem is lacking. In this panel discussion, our distinguished experts present an overview of postoperative pulmonary complications and the evidence-based strategies to prevent them.

What are generally considered to be postoperative pulmonary complications (PPCs)?

Angel: The definition of PPCs has been inconsistent across different studies. Some include complications not associated with symptoms, or poor outcomes such as mild asymptomatic decrease of function on a pulmonary function test or lower oxygen saturation on pulse oximetry; others focus on complications with significant clinical consequences. It is important to classify these complications consistently. The most important postoperative pulmonary complications are atelectasis, pneumonia, respiratory failure, pleural effusion or pneumothorax requiring external drainage, and exacerbation of underlying chronic lung disease.

> In our scope of practice, the most common PPC is atelectasis followed perhaps by retained secretions, compromise in mucocilliary clearance and pulmonary effusion.

Marik: Patients undergoing surgical procedures are at risk for a number of pulmonary complications which may result in postoperative respiratory failure. These complications may be short lived with the patient returning to their previous level of functioning. However, not infrequently, the patient experiences a progressive clinical decline to become permanently ventilator-dependent. The most important postoperative pulmonary complications are atelectasis and mucous plugging, hospital-acquired pneumonia, pulmonary embolism, pleural effusions, diaphragmatic and intercostal muscle weakness (atrophy), aspiration pneumonitis, and postoperative acute respiratory distress syndrome (ARDS) due to delayed transfusion related lung injury (TRALI).

Restrepo: PCCs are defined as respiratory complications that occur within 48-to-72 hours following surgery. Only patients at risk typically develop major PCCs as a result of decreased vital capacity, postsurgical mucus hypersecretion, or retention. Pneumonia is the third most common postoperative infection after urinary tract infection and surgical site infection[1] and needs to be distinguished from ventilator-associated pneumonia. In addition to those mentioned by Dr. Marik, other clinically significant PPCs include respiratory failure requiring mechanical ventilation and pneumothorax or pleural effusion requiring percutaneous intervention.[2,3] Minor PPCs include most atelectasis, bronchospasm, laryngospasm, and the unanticipated need for supplemental oxygen beyond the immediate postoperative period.[4]

Wheeler: Frequently the literature concerning PPCs lumps together pneumonia, respiratory failure, atelectasis, bronchospasm, and exacerbation of chronic obstructive pulmonary disease (COPD). However, I find it easier to think about PPCs as discrete categories of clinically significant complications such as atelectasis, infection (including bronchitis and pneumonia), bronchospasm/reactive airway and respiratory failure requiring noninvasive ventilation. In our scope of practice, the most common PPC is atelectasis followed perhaps by retained secretions, compromise in mucocilliary clearance and pulmonary effusion. Another common yet generally inconsequential PPC in our practice is the appearance of a pneumopericardium.

What is the impact of PPCs on perioperative morbidity and mortality?

Angel: PCCs are the most common postsurgical complications, especially in patients who have major surgical procedures, and more specifically, patients residing in ICUs or telemetry units. PPCs are different than complications associated with the underlying disease or surgical complications, and are more frequently reported than cardiovascular complications. Without medical intervention, PCCs can lead to prolonged hospitalization, and significant morbidity. Even though mortality has decreased significantly with improved surgical techniques, anesthesia and critical care management, PPCs are cited as the most frequent reason for increased hospital length-of-stay (LOS).[2,5]

Restrepo: Almost 25% percent of postoperative deaths that occur during the first week are associated with PCCs.[1,6] Regardless of event rate, patients experiencing a PCC have a significantly increased hospital LOS and significantly decreased short- and long-term survival when compared with patients of similar age and comorbid conditions who experience an

uncomplicated hospital course.[7,8] Without medical intervention, PCCs could prolong hospitalization by as much as 6-fold.[2,5] A recent analysis revealed that more than 1 million US patients experienced a PCC in 2008, and these cases were associated with 46,200 deaths, 2.9 million added days on the hospital floor and 1.9 million added ICU days.[2]

Wheeler: It is rather disheartening that postoperative deaths are predominantly due to PPCs. Indeed, if we examine the most devastating perioperative complication, postoperative respiratory failure, we find that it exhibits significant morbidity. Johnson and colleagues examined the outcomes of patients with respiratory failure as a complication of surgery and found that 26% of the patients with respiratory failure died within 30 days.[9] Additionally, 6% had a myocardial infarction and a devastating 35% developed pneumonia. Furthermore, 10% developed acute renal failure while 3% developed deep vein thrombosis or pulmonary embolism.

Please describe the risk factors for PPCs.

Angel: There is a paucity of well-done clinical studies looking at the risk factors for PPCs, unlike cardiac complications, which have been extensively studied and for which there are better predictors. In the McAllister prospective cohort study, the multivariate regression analysis identified 4 variables that were independently associated with increased risk of complications: advanced age (OR 5.9 for age >65 years, $P<.001$), positive cough test (OR 3.8, $P<.01$), perioperative nasogastric tube (OR 7.7, $P<.001$), and duration of anesthesia (OR 3.3 for operations lasting at least 2.5 hours, $P< .008$).[2]

Many other studies provide conflicting information on which of these variables are independent predictive factors. The low statistical power resulting from small sample sizes, and the heterogeneity between studies further lower confidence in the validity and general applicability of these identified variables to patients undergoing nonthoracic surgery. Only 2 variables (duration of anesthesia and postoperative nasogastric tube placement) were associated significantly with PPCs in more than one study. The identification of nasogastric tube placement in the postoperative period as an independent predictor is surprising as it was not listed as a risk factor in most of the literature. Although postoperative nasogastric tube placement might merely be a marker for upper abdominal surgery, it remained significantly associated with PPCs in multivariate analyses. Several other variables commonly cited in PPC risk assessment, such as hypercapnia or spirometry abnormalities, were not identified as useful or independent predictors.

> Almost 25% percent of postoperative deaths that occur during the first week are associated with PCCs.
>
> - Restrepo -

Clearly, better-quality prospective studies are required to identify which elements of the history, clinical examination, preoperative laboratory testing, surgery, and anesthesia are independently predictive of PPCs. Ultimately, these studies should lead to the development and prospective validation of a multivariate risk assessment model for PPCs, which would make preoperative assessments simpler, more efficient, and accurate while avoiding unnecessary, harmful, or costly evaluations.

Marik: The most important risk factor for PPCs is underlying, preexistent lung disease. Patients with significant obstructive and restrictive lung disease are at high risk of PPCs. In such patients, preoperative lung function tests are absolutely mandatory to assess risk-benefit. In patients with very poor preoperative lung function tests (i.e. minimal respiratory reserve), alternative treatment strategies may be more appropriate.

Furthermore, in patients with marked abnormalities of lung function, preoperative optimization, local or spinal anesthesia and an aggressive postoperative respiratory program may be indicated. Additional patient factors such as morbid obesity, malnutrition, history of smoking, diabetes, cardiac failure, liver failure and renal failure increase the risk of PPCs.

Restrepo: Since the great majority of patient-related risk factors can be identified during a good presurgical assessment, a good evaluation of preoperative pulmonary risks is the main priority in determining the potential for PCCs as their presence may predict long-term mortality after surgery.[5] According to the American College of Physicians (ACP), the major patient-related risk factors are advanced age, American Society of Anesthesiologists (ASA) Physical Status >2, COPD, functional dependence, and congestive heart failure.[10-13] Even in situations where preoperative and operative conditions are optimal, postoperative factors such as the quality, quantity, and duration of postoperative pain, anticipated analgesic requirements and analgesic techniques, and length of time at bed rest all need to be considered.

Wheeler: The ACP guideline clearly delineates between patient- and procedure-related risk factors. In addition to the patient-related risk factors Dr. Restrepo listed, the guideline adds smoking history, impaired sensorium, alcohol ingestion, abnormal chest exam, obesity and obstructive sleep apnea. The ACP review identifies procedure-related risk factors such as aortic aneurysm repair, thoracic surgery, abdominal surgery, upper abdominal surgery, prolonged surgery, head and neck surgery, emergency surgery, vascular surgery, perioperative transfusion and general anesthesia.

Does type of surgery and anesthesia play a role?

Angel: The surgical site is the single most important factor in predicting the overall risk of PPCs—the incidence of complications is inversely related to the distance of the surgical incision from the diaphragm. Thus, the complication rate is significantly higher for thoracic and upper abdominal surgery than for lower abdominal and all other procedures. PCC rates range from 5% to 10% for lower abdominal surgery to as high as 20% to 25% for upper abdominal, aortic, or esophageal surgeries. The higher rates of complications in upper versus lower abdominal surgery relate to the effect upon respiratory muscles and diaphragmatic function. Surgical procedures lasting more than 3-to-4 hours are associated with a higher risk of pulmonary complications. This observation suggests that, when available, a less ambitious, briefer procedure should be considered in a very high-risk patient.

There are conflicting data with regard to the pulmonary risk of spinal or epidural anesthesia when compared with general anesthesia. It appears likely that general anesthesia leads to a higher risk of clinically important pulmonary complications than does epidural or spinal anesthesia, although further studies are required to confirm this observation. Regional nerve block is associated with lower risk and should be considered when possible for high-risk patients.

Marik: The type and duration of surgery are major risk factors for PPCs. Patients with cardiothoracic and upper abdominal surgery are at an increased risk of PPCs. This may be related to pain which "splints" respiratory efforts and leads to decreased coughing as well as the presence of chest tubes. Longer surgery times with increased tissue trauma will result in a greater degree of immune suppression, increasing the risk of infectious complications. Furthermore, multiple intra and postoperative blood transfusions increase the risk of the delayed TRALI syndrome. Patients who undergo surgery under spinal anesthesia rather than general anesthesia, and who undergo laparoscopic surgery are at a lower risk of postoperative pulmonary complications.

Restrepo: While general anesthesia, in comparison to neuraxial blockade (spinal or epidural anesthesia), may represent a greater risk for PPCs, this remains an area of controversy.[14] If required, intermediate-active neuromuscular blocking agents such as atracurium and vecuronium should be preferred over long-acting agents.[15,16]

Whenever possible, alternatives to open surgical procedures should be considered. Laparoscopic rather than open bariatric surgery has been found to be an effective strategy to reduce PCC, since it is associated with less postoperative pain.[5,6,17]

Wheeler: Definitely, upper abdominal surgery manifests the greatest degree of PPC. Aortic aneurysm repair, thoracic surgery of any kind, cardiac surgery and lower abdominal surgery all have potential for PPCs. When surgery takes more than 2 hours, the risk for PPCs increases. The patient receiving general anesthesia with its attendant artificial airway and required mechanical ventilation is at much greater risk for PPCs than a patient receiving a neuromuscular block or local anesthesia. Any patient with a prior history of cardiopulmonary disease who requires endotracheal intubation and general anesthesia will be at much greater risk for PPCs. It is imperative that we assess and identify patients at greater risk for PPCs so that we may intervene and employ preventive measures.

> The incidence of complications is inversely related to the distance of the surgical incision from the diaphragm.
>
> - Angel -

Describe strategies that can be implemented pre-and immediately post-surgery to reduce the risk of PPCs.

Angel: Patients undergoing upper abdominal or thoracic surgery or aortic aneurysm repair with additional risk factors for PPCs are candidates for risk reduction strategies. Interventions should begin in the preoperative period and continue through the postsurgical period. Clinicians should employ multiple strategies to reduce the risk of PPCs to the fullest possible extent. Patient education regarding lung expansion maneuvers should begin prior to surgery. The preoperative evaluation provides an opportunity to discuss the benefits of smoking cessation. Current cigarette smokers have an increased risk for PPCs, although the incremental risk is small in the absence of chronic lung disease. Patients undergoing elective surgery should be advised to stop smoking at least 8 weeks before surgery; a brief period of abstinence does not improve perioperative pulmonary outcomes and may increase the risk of PPCs.

A program of preoperative inspiratory muscle training may reduce the risk of PPCs. The program is intensive and involves breathing exercises, incentive spirometry, education in active breathing techniques, and forced expiration techniques. Postoperative pulmonary complication rates are lower and median LOS is shorter for patients completing inspiratory muscle training. While it is time intensive and potentially expensive, this strategy appears to have no risk and offers an additional approach to the preoperative preparation of high-risk patients.

Lung expansion techniques include incentive spirometry; chest physical therapy, including deep breathing exercises; coughing; postural drainage; percussion and vibration; suctioning and ambulation; intermittent positive-pressure breathing; and continuous positive-airway pressure. Deep breathing exercises and incentive spirometry appear to be equally effective and capable of reducing the risk of PPCs by about one-half. Deep breathing exercises are a component of chest physical therapy. Incentive spirometry involves deep breathing facilitated by a simple mechanical device.

Adequate postoperative pain control may help to minimize PPCs by enabling earlier ambulation and improving the patient's ability to take deep breaths. This is particularly important after thoracic and upper abdominal surgery. Studies of the effect of postoperative pain management on pulmonary complications have focused on the use of epidural analgesia and intercostal nerve blocks as alternatives to more traditional parenteral opioids. Epidural analgesia seems superior to other methods for delivering opioids in preventing PPCs.

Marik: The most important strategy to reduce the risk of PPCs is to identify those patients who are at an increased risk of respiratory problems prior to surgery. These patients are likely to benefit from preoperative optimization, the use of anesthetic techniques that limit the likelihood of pulmonary complications and scrupulous attention in the postoperative period. Pain management, restricted use of sedative agents, aggressive postoperative physiotherapy and early mobilization are key interventions likely to reduce the risks of respiratory complications. All patients undergoing surgery should be stratified according to their risk of developing thromboembolic complications, and an appropriate level of prophylaxis should then be instituted.

Restrepo: Adequate treatment of co-

morbidities plays an essential role in preventing PPCs. Cigarette cessation,[3,4,18,19] treatment of underlying lung infections, a peak flow of >80% predicted and absence of wheezing should be the goals prior to any surgical procedure. The role of lung expansion maneuvers such as incentive spirometry alone in preventing PPCs is questionable.[20] However, a combination of deep breathing, incentive spirometry, adequate postsurgical pain control, early ambulation, and in some patients continuous positive airway pressure (CPAP) may prevent PPCs.[21,22,23]

Wheeler: The presurgical assessment of every patient is critically important. The most important of these preoperative interventions is of course, smoking cessation. Patients scheduled for elective surgery should quit smoking at least 8 weeks prior to their scheduled surgery. It must be noted that a brief period of smoking cessation may not have any effect of postoperative complications. Any patient presenting with a prior history of cardiopulmonary impairment must have this impairment managed effectively prior to surgery. Perhaps the most difficult patients are those with COPD. This is an extremely important patient-related risk factor for PPCs and these patients should be aggressively treated.

The patient with asthma is another very troubling preoperative management challenge. Asthma that is not well-controlled poses a noteworthy risk for the development of PPCs, however, asthma that is well-controlled may attenuate this risk. It is imperative that any asthmatic patient undergo a thorough preoperative assessment and management strategy in order to reduce the risk for PPCs.

In patients presenting with elevated risk factors, a preoperative inspiratory muscle training program may lessen the possibility of PPCs. Another essential strategy for high-risk patients is a thorough patient education program that includes a discussion of the type of surgery, anesthesia and recovery procedures they will be asked to undergo. The education of the patient must include an orientation to any lung expansion or mucous clearing devices they may be asked to use in the postoperative period. Lung expansion therapy such as deep breathing, incentive spirometry, PEP and CPAP are all extremely effective in the prevention and attenuation of PPCs. The key is to match the patient and device effectively.

The most important strategy to reduce the risk of PPCs is to identify those patients who are at an increased risk of respiratory problems prior to surgery.

Perhaps the most important postoperative procedure to prevent PPCs is an aggressive extubation protocol. The literature examines this issue from the perspective of systems dynamics and delineates between mediator variables (i.e. patient-centric variables) and moderator variables (related to the treatment and support of the patient). Mechanical ventilation falls in the category of moderator variable and has tremendous potential to either attenuate or exacerbate the postoperative course. Indeed, the significance of an aggressive assessment-based, evidence-driven weaning protocol cannot be understated. The liberation from mechanical ventilation of the postoperative patient will eliminate their risk of ventilator-associated pneumonia and significantly decrease the potential for PPCs of any kind.

With increased emphasis on pay for performance is prevention of PPC a relevant issue for hospitals? If so, what are the ramifications?

Angel: The National Surgical Quality Improvement Program (NSQIP) compared hospitalization costs and LOS among patients with various postoperative complications.[24] Among infectious, cardiovascular, venous thromboembolic, and pulmonary complications, the latter were by far the most costly. Pulmonary complications and venous thromboembolic complications required the longest mean hospital stay. Projecting to national levels, the study determined that more than 1 million patients experienced a PPC in the US in 2008, and these cases were associated with 46,200 deaths, 2.9 million added days on the hospital floor, 1.9 million added ICU days and $11.9 billion in additional costs.[24]

Marik: A comprehensive program to reduce postoperative respiratory complications has enormous value for both the patient and the institution. Postoperative respiratory complications lead to increased morbidity and mortality which increase patient distress and suffering. From the hospital's perspective, these complications lead to an increase in the LOS and use of hospital resources, both of which have significant financial implications.

Restrepo: A postoperative complication results in additional and often unexpected medical costs. These are primarily associated with increased length of hospitalization requiring intensive therapeutic intervention, pharmacological intervention, diagnostics, and increased use of health disciplines.[5] Pulmonary complications may double or triple the associated costs of other postsurgical complications and increase by 12-fold the median hospital cost when compared to the cost of not having respiratory complications.[25] In 2004, postoperative complications accounted for nearly $2 billion dollars.[26]

Wheeler: Hospitals must respond to the immense and ever-changing pressures and demands of payers. PPCs increase mechanical ventilation length-of-stay intensive care unit LOS and overall hospital stay. In the mindset of the data-driven, outcome driven, cost conscious, nonclinical performance examiner, any postoperative complication may be viewed as iatrogenic in nature and therefore a nonreimbursable service. Increasingly, healthcare systems will be told to absorb the significant cost and burden of PPCs that are deemed to be preventable. If past experience is a predictor of future behavior, one must assume that the payers will deem every postoperative complication as preventable and therefore will feel no compulsion to reimburse for the increased cost to the healthcare system. It has been estimated that all postoperative complications cost approximately $2 billion a year. I trust we can all appreciate the enormity of these forces and their implications both for our patients and the future of our systems as well.

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Questions

1. **Smoke inhalation prior to surgery has been shown to increase the frequency of complications in all of the following surgeries except:**
   - A. Hernia surgery
   - B. Vascular surgery
   - C. Neurosurgery
   - D. Gastrointestinal surgery
2. **Smoking cessation six to eight weeks prior to hip and knee arthroplasty surgery proved successful in minimizing complications related to wound and urinary tract infections.**
   - A. True
   - B. False
3. **Which neuromuscular blocking agent (NMBA) is associated with a higher incidence of residual neuromuscular blockade possibly leading to increased PPC?**
   - A. Pancuronium
   - B. Vecuronium
   - C. Atracurium
   - D. Rocuronium
4. **Spinal anesthesia has a more rapid onset compared to intravenous anesthesia.**
   - A. True
   - B. False
5. **On-demand delivery of opioids is superior to postoperative epidural and PCA intravenous analgesia in preventing PPC.**
   - A. True
   - B. False
6. **Using ICD-9-CM codes to identify PPC, two studies reported a significant decrease in one PPC when laparoscopic surgery was compared to open cholecystectomy? Which one was it?**
   - A. Pneumonia
   - B. Cough
   - C. Sore throat
   - D. Atelectasis
7. **Which postoperative intervention is associated with an earlier return to bowel function, and a statistically significant decrease in PPC?**
   - A. Hyperinflation therapy
   - B. Selective Nasogastric Tube Decompression (NTD).
   - C. Routine Nasogastric Tube Decompression (NTD).
   - D. Oxygen therapy
8. **Of the listed deep breathing exercises and hyperinflation therapies (IS, IPPB, CPAP, & Insufflation/Exsufflation), which one has demonstrated superiority with regards to improved patient outcomes?**
   - A. IPPB
   - B. CPAP
   - C. IS
   - D. None, they are all equivalent
9. **Development of VAP is associated with a significant increase in healthcare cost.**
   - A. True
   - B. False
10. **The use of subglottic-suction ETT is endorsed by:**
    - A. Centers of Disease Control and Prevention (CDC)
    - B. American Association of Respiratory Care (AARC)
    - C. American Association of Critical-Care Nurses (AACN)
    - D. All of the above.

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Participant's Evaluation

1. What is the highest degree you have earned? Circle one. 1. Diploma 2. Associate 3. Bachelor 4. Masters 5. Doctorate
2. Indicate to what degree the program met the objectives:

Objectives

Upon completion of the course, the reader was able to:

1. Discuss clinical benefit of smoking cessation prior to surgery.

   Strongly Agree 1 2 3 4 5 6 Strongly Disagree
2. Discuss clinical benefit of postoperative epidural and PCA intravenous analgesia compared to on-demand delivery of opioids.

   Strongly Agree 1 2 3 4 5 6 Strongly Disagree
3. Discuss the clinical equality of deep breathing exercises among a variety of therapies and establish its superiority in comparison to no prophylactic treatment.

   Strongly Agree 1 2 3 4 5 6 Strongly Disagree
4. Discuss the clinical benefit of using subglottic-suction ETT.

   Strongly Agree 1 2 3 4 5 6 Strongly Disagree
5. Please indicate your agreement with the following statement. "The content of this course was presented without bias toward any product or drug."

   Strongly Agree 1 2 3 4 5 6 Strongly Disagree

Answers

1	☐	☐	☐	☐	9	☐	☐		
2	☐	☐			10	☐	☐	☐	☐
3	☐	☐	☐	☐	11				
4	☐	☐			12				
5	☐	☐			13				
6	☐	☐	☐	☐	14				
7	☐	☐	☐	☐	15				
8	☐	☐	☐	☐	16				

All tests must be taken online at http://www.saxetesting.com/cf/