The Scientific Basis for Postoperative Respiratory Care

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Postoperative pulmonary complications (PPCs) are common and expensive. Costs, morbidity, and mortality are higher with PPCs than with cardiac or thromboembolic complications. Preventing and treating PPCs is a major focus of respiratory therapists, using a wide variety of techniques and devices, including incentive spirometry, CPAP, positive expiratory pressure, intrapulmonary percussive ventilation, and chest physical therapy. The scientific evidence for these techniques is lacking. CPAP has some evidence of benefit in high risk patients with hypoxemia. Incentive spirometry is used frequently, but the evidence suggests that incentive spirometry alone has no impact on PPC. Chest physical therapy, which includes mechanical clapping and postural drainage, appears to worsen atelectasis secondary to pain and splinting. As with many past respiratory therapy techniques, the profession needs to take a hard look at these techniques and work to provide only practices based on good evidence. The idea of a PPC bundle has merit and should be studied in larger, multicenter trials. Additionally, intraoperative ventilation may play a key role in the development of PPCs and should receive greater attention. *Key words: complications; postoperative pulmonary complications; incentive spirometry*. [Respir Care 2013;58(11):1974–1984.

Introduction

Postoperative pulmonary complications (PPCs) following upper abdominal and thoracic surgery are the most common surgical complications. Additionally, PPCs are the leading cause of prolonged hospital stay, morbidity, and mortality in surgical patients.[1-3] Simply stated by Smetana, "Postoperative pulmonary complications are common, serious, and expensive."[4] Healthcare costs asso-

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ciated with the treatment of PPCs are 50% greater than costs for treating postoperative cardiac complications.[4-6] This finding has a number of explanations, including the complexity of the surgical procedures, the age of the patients, and the severity of the comorbidities.

The costs associated with PPCs are very high. In an analysis of data from the National Surgical Quality Improvement Program, the attributable cost of a PPC was over $52,000 per patient.[5] It is important to note that the National Surgical Quality Improvement Program data captures prolonged mechanical ventilation (> 48 h), the need for intubation, and pneumonia as important PPCs. The finding of atelectasis on chest radiograph without any physiologic sequelae is not included in those data. Compared to other postoperative complications, including infection, thromboembolic (eg, pulmonary embolus), and cardiovascular complications, PPCs were associated with the greatest costs. Compared to patients who did not develop postoperative complications, patients with PPCs had an increased stay of 2 weeks.

This paper will focus on the use of respiratory therapy techniques for the treatment of PPCs. Given the financial impact of a single PPC, prevention and treatment are critical for the healthcare team, and the respiratory therapist plays an important role. However, it is important to understand the preoperative risk factors, intraoperative management, and interventions that may impact PPCs. These issues will be covered first, as a precursor for understanding the causes and best treatments for PPCs.

Definitions and Incidence

The reported incidence of PPCs ranges from 2–40%.[4-6] Reporting varies widely, as a consequence of surveillance and diagnostic criteria. In a general sense, a PPC is any event that occurs in the postoperative period that produces physiologic dysfunction or clinical disease. This unfortunately leads to wide interpretation. A PPC may be diagnosed based on symptoms (cough, fever, abnormal breath sounds), laboratory values (hypoxemia, leukocytosis), or radiographic criteria (atelectasis or infiltrate). As a result, a PPC can be defined as simply atelectasis on a chest radiograph or as respiratory failure necessitating intubation and mechanical ventilation. Clearly, the severity of these 2 complications is quite disparate, but each is recorded as a PPC. This complicates reporting the incidence and importance of a PPC. Pulmonary embolus is an important PPC, but the pathology and treatment are quite different than those addressed by this paper. Table 1 lists the range of variables used to define a PPC.

Table 1. Postoperative Pulmonary Complications Reported in the Literature

Symptoms
Fever (> 38°C)
New-onset productive cough
Change in breath sounds (rales or rhonchi)
Tachypnea
Tachycardia
Dyspnea
Altered mental status
Laboratory values
Hypoxemia (P_{aO_2} < 60 mm Hg on room air)
Leukocytosis
Microbiology of sputum
Radiologic
Atelectasis
New infiltrates
Outcomes
Prolonged postoperative mechanical ventilation (> 48 h)
Pneumonia
Unplanned re-intubation

Lawrence et al studied patients undergoing elective abdominal operations in a Veterans Affairs hospital and found that pulmonary complications occurred in 9.6% of patients.[3] Brooks-Brunn[7] suggested a more specific definition that includes at least 2 of the following findings documented at any time during the first 6 days following surgery: new cough and sputum production, abnormal breath sounds compared to baseline, temperature > 38°C, chest radiograph demonstrating atelectasis or a new infiltrate, and physician documentation of atelectasis or pneumonia. This definition results in a more consistent reporting of the incidence of PPCs, but continues to rely on subjective evaluation of the patient by the caregiver.

The data from the National Surgical Quality Improvement Program suggest that the incidence of PPCs is 2.7–3.4% of patients undergoing non-cardiac surgery.[5] That study categorized complications as minor or major using defined criteria. Interestingly, atelectasis alone was not listed as a PPC. The major respiratory complications included remaining on mechanical ventilation > 48 hours, unplanned intubation, pneumonia, pulmonary embolism, or "other respiratory occurrence." Fleischman reported an incidence of 2.7% in a group of non-cardiac surgery patients: a rate similar to cardiac complications (2.5%) in that same group.[8]

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The actual incidence of important PPCs appears to be 2–5% in patients undergoing thoracic or upper abdominal surgery. The reported incidence varies with a given patient population (eg, COPD, the elderly) and type of procedure. Regardless, given the number of surgical procedures performed in the United States (over 4 million upper abdominal procedures per year) and the cost of a PPC, methods to prevent these complications are warranted.

Risk Factors

A number of risk factors have been identified that increase the likelihood of developing a PPC.[9-18] These factors are listed in Table 2 as preoperative and intraoperative risks. Preoperatively, age > 50 years, American Society of Anesthesiologists score > 2, COPD, congestive heart failure, and smoking are among the greatest risk factors. The risk of age increases with each additional decade. Functional dependence is a significant risk factor, and refers to patients unable to perform the activities of daily living without assistance. Obstructive sleep apnea is new to the list, but results in only a minor increase in the risk of PPC. Current smokers have a higher risk than former smokers, whose risk is greater than never smokers. Interestingly, asthma and obesity do not appear to increase the risk substantially.

Intra-operatively, an upper abdominal incision is the greatest PPC risk factor. From a procedural perspective, open aortic repair, thoracic surgery, head and neck surgery, and neurosurgery are associated with increased risk. Surgery duration is also highly predictive; operations longer than 3 hours are associated with more frequent complications.[9-15]

Recently, a group at Massachusetts General Hospital looked specifically at the risk of reintubation following extubation in the operating room. They found similar risk factors as described above. By combining the risk factors and assigning a score to each risk factor, the authors were able to predict reintubation in a cohort of over 1,000 patients. The 11 point score includes; American Society of Anesthesiologists Score ≥ 3, need for emergency surgery, care by a high-risk surgical service, patient history of congestive heart failure, and chronic pulmonary disease. Point values of 3, 3, 2, 2, and 1 were assigned to the respective items. It is important to note that this score predicts a severe PPC, notably the need for reintubation.[16]

Table 2. Risk Factors for Postoperative Pulmonary Complications

Preoperative
Age > 50 y: risk increases every decade after
American Society of Anesthesiologists Class > 2
Congestive heart failure
COPD
Obstructive sleep apnea
Cigarette use
Functional dependence (unable to perform activities of daily living or requires assistance from caregiver or appliances)
Impaired sensorium
Corticosteroid use
Alcohol use
Intraoperative
Surgery longer than 3 h
Emergency surgery
Perioperative blood transfusion
General anesthesia
Use of neuromuscular blocking agents
Type of surgery
Open aortic resection
Head and neck surgery
Upper abdominal surgery
Thoracic surgery
Neurosurgery
High tidal volume

(Data from references 10–18.)

Intraoperative Mechanical Ventilation

The paradigm change in mechanical ventilation for use of lung protection, most notably a target tidal volume of 6 mL/kg of predicted body weight, has been slow to manifest in the operating room. In recent years, a number of authors have evaluated the impact of intraoperative tidal volumes on postoperative lung function.[17-19] Lellouche and colleagues found that an intraoperative tidal volume of > 10 mL/kg predicted body weight in patients undergoing coronary artery bypass surgery was associated with postoperative organ dysfunction, morbidity, and mortality.[19] Despite these findings, the use of a lung-protective approach in the operating room remains uncommon in patients with[20] and without[21] acute lung injury.

Severgnini et al studied 56 patients in a prospective, randomized, open-label trial of protective ventilation in patients undergoing > 2 hours of open abdominal surgery. They found that using lower tidal volume, PEEP, and recruitment maneuvers resulted in significantly improved pulmonary function test results up to 5 days after surgery, fewer chest x-ray findings, and improved Clinical Pulmonary Infection Score.[22] These findings need to be replicated in a larger group of patients, but present unique options for preventing PPCs. Very recently, Futier et al demonstrated that the use of PEEP, recruitment, and low tidal volume during open abdominal surgery resulted in fewer PPCs, compared to tidal volume of 10–12 mL/kg and no PEEP.[23] The rates of postoperative atelectasis, pneumonia, and need for postoperative re-institution of venti-

Table 3. Postoperative Complications in a Study Comparing Intraoperative Lung-Protective Ventilation (Low Tidal Volume, PEEP and Every 30 Min Recruitment Maneuvers) to High Tidal Volume and No PEEP

Outcome	High Tidal Volume and No PEEP no. (%)	Lung-Protective Ventilation no. (%)	Adjusted Relative Risk Difference (95% CI)	*P*
Pulmonary complications within 7 d				
Grade 1 or 2	30 (15)	25 (12.5)	0.67 (0.39–1.16)	.16
Grade 3 or higher	42 (21)	10 (5)	0.23 (0.11–0.49)	< .001
Atelectasis	34 (17)	13 (6.5)	0.37 (0.19–0.73)	.004
Pneumonia	16 (8)	3 (1.5)	0.19 (0.05–0.66)	.009
Acute lung injury	6 (3)	1 (0.5)	0.21 (0.02–1.71)	.14
Need for mechanical ventilation				
Invasive ventilation	7 (3.5)	2 (1)	0.40 (0.08–1.97)	.26
Noninvasive ventilation	29 (14.5)	9 (4.5)	0.29 (0.13–0.65)	.002

(Data from reference 23.)

lation were all increased 2- to 3-fold in the group that did not receive lung-protective ventilation (Table 3). These findings are compelling for the careful reconsideration of intraoperative management of ventilation. Intraoperative ventilation management may prevent PPCs and reduce costs by eliminating not only the complications but the required postoperative treatment.

Postoperative Respiratory Care

The combined impact of surgical trauma and anesthesia result in reduced lung volumes, respiratory muscle dysfunction, and atelectasis.[24-26] Positioning, pain and pharmacologic agents can all worsen the reduction in lung volumes, characterized by substantial reductions in functional residual capacity and vital capacity. The development of atelectasis leads to hypoxemia and translocation of bacteria to the bloodstream, and may be important in creating the heterogeneous lung at risk for ventilator-induced lung injury.[27-28]

These physiologic findings led investigators to experiment with methods to increase lung volumes and improve cough postoperatively. These techniques are often referred to in the literature generically as postoperative physiotherapy, which includes coughing and deep breathing, incentive spirometry, percussion and postural drainage, CPAP, positive expiratory pressure (PEP), and other techniques. Save coughing and deep breathing, each of these techniques requires equipment and/or a healthcare provider.

A comparison of these studies by intervention is difficult, as in a few studies the control group received no intervention or coughing and deep breathing, in many studies there was no control group, and in some studies the control group received incentive spirometry. Often the studies have compared 2 or more techniques, alone or in combination. Finally, the outcomes have varied from physiologic findings and radiographic appearance to more important outcomes such as the incidence of pneumonia or hospital stay.

Incentive Spirometry

Incentive spirometry was introduced by Bartlett and colleagues as a method to encourage deep breathing and sustained maximal inflations in postoperative patients.[1,29] In the ensuing 40 years a litany of studies evaluating incentive spirometry for preventing PPC have been published. Two main areas of investigation have been pursued: incentive spirometry for PPC prevention following upper abdominal surgery,[30-43] and incentive spirometry for PPC prevention following cardiac/thoracic surgery.[44-60]

Comparison of these studies is difficult, owing to the various study designs (randomized controlled trials and prospective trials), the comparators (none, chest physical therapy [CPT], CPAP, expiratory airway pressure), the frequency of interventions (eg, hourly, every 4 hours), the duration of each intervention (number of maneuvers, minutes of therapy), and the outcomes (radiographic atelectasis, gas exchange, pneumonia, pulmonary function). Of the studies that used PPCs as an outcome, 3 compared incentive spirometry with a control group of no intervention following upper abdominal surgery.[31,34,37] While the most recent of these trials is 25 years old, none showed any advantage for incentive spirometry over no intervention. Incentive spirometry was compared to other interventions in 11 trials following upper abdominal surgery, and included incentive spirometry versus deep breathing exercises, intermittent positive-pressure breathing (IPPB), postural drainage, CPAP, PEP, and early ambulation. In several studies, patients received incentive spirometry and ambulation, CPAP, or PEP. In those trials, 6 studies found no differences between the groups,[30-33,37,40] 3 found incentive spirometry superior to the control intervention,[39,41,42] and 2 found that both CPAP and IPPB were superior to incentive spirometry.[34,36]

Nine studies evaluated changes in pulmonary function with the use of incentive spirometry and other postoperative respiratory therapies following upper abdominal surgery.[30,31-33,35,37,38.40,43] Schwieger et al compared incentive spirometry to no intervention in a group of low risk patients following laparoscopic cholecystectomy and found no differences in lung function.[37] Minschaert and colleagues compared incentive spirometry to conventional physical therapy and found that incentive spirometry was associated with a faster recovery of tidal volume.[43] Stock et al compared CPAP, incentive spirometry, and conservative therapy following upper abdominal surgery, and found that CPAP improved gas exchange and lung volumes, compared to incentive spirometry.[38] Other studies in this category showed no advantage of incentive spirometry over other techniques with respect to restoration of lung volumes.[31-33,35,37,40]

Studies comparing incentive spirometry for PPC prevention after cardiac/thoracic surgery also include a trial with no intervention as the control,[48] and studies that compared incentive spirometry to other techniques.[44,45,47,48,51,52,54,55,58,60] The majority of these trials reported no difference between incentive spirometry and the comparator.[44,47,48,51,52,54,58,60] This creates one of the challenges in evaluating the evidence on incentive spirometry in PPC prevention. A randomized controlled trial with sufficient numbers should compare any of the techniques to a standard regimen of up and out of bed and early ambulation. Similar findings were seen in studies evaluating the impact on postoperative lung volumes; that is, the most common finding was no difference between incentive spirometry and the other intervention or no intervention.[44,47,51,59,60]

A recent paper by Agostini and colleagues compared incentive spirometry to "thoracic expansion exercises" in 180 patients following lung resection.[60] All patients received postoperative breathing exercises, airway clearance, and early mobilization. There was no difference between the groups with respect to the fall in FEV_1 on postoperative day 4 or the frequency of PPCs. They did, however, see a slight reduction in the frequency of PPCs in a cohort of "high risk" subjects using incentive spirometry. These patients were identified by age $\geq$ 75 years, American Society of Anesthesiologists score $\geq$ 3, COPD, smoking status, and body mass index $\geq$ 30 kg/m^2. Patients with 2 or more risk factors were deemed high risk.

Foraging these studies for problems and pearls is particularly perplexing. Incentive spirometry seems to be a common procedure performed by patients postoperatively all over the world. Yet the combined analysis of the literature has consistently failed to demonstrate any advantage of incentive spirometry in reducing PPCs or improving lung volumes postoperatively. In 2001, Overend and coworkers systematically reviewed the use of incentive spirometry for PPC prevention, and found that 10 of 11 studies showed no demonstrable impact of incentive spirometry. In fact, in the only remaining study incentive spirometry, deep breathing, and IPPB were equally more effective than no treatment in preventing PPCs following abdominal surgery. They concluded, "Presently, the evidence does not support the use of incentive spirometry for decreasing the incidence of PPCs following cardiac or upper abdominal surgery."[61]

This report was followed by two reviews by Pasquina and colleagues in 2003 and 2006, both of which concluded that incentive spirometry, and, for that matter, other types of postoperative "physiotherapy" failed to impact the incidence of PPC.[62,63] In their most recent review they evaluated 13 trials with a "no intervention" control group, and found that 9 trials with a total of 883 subjects failed to demonstrate any advantage with respect to PPC incidence. In 4 trials, which included 528 subjects, they found a positive impact on either pneumonia or atelectasis with incentive spirometry, coughing and deep breathing, IPPB, postural drainage, or directed cough.[63] In 22 trials, which included 2,734 subjects, there was no control group, and no conclusion could be drawn. They wrote, "There are only a few trials that support the usefulness of prophylactic respiratory physiotherapy. The routine use of respiratory physiotherapy after abdominal surgery does not seem to be justified."[63]

The two most recent Cochrane reviews of incentive spirometry for PPC prevention following upper abdominal surgery and cardiac/thoracic surgery also concluded that there is "no evidence" of benefit in either group.[64,65] These findings are supported by the work of Agostini et al.[66] Finally, a recent detailed systematic review by Carvalho and co-workers evaluated 30 studies that used incentive spirometry after upper abdominal surgery (n = 14) and cardiac/thoracic surgery (n = 16). These authors painstakingly reviewed the study designs, interventions, measured outcomes, and methodological rigor of each trial. They compared the impact of incentive spirometry on PPC and postoperative lung volumes in both upper abdominal surgery and cardiac/thoracic surgery. Most of the studies reviewed that favored incentive spirometry failed to report a sample size calculation, failed to randomize patients, and failed to have a control group, and therefore most likely bias the study outcomes. This excellent review concluded, "No evidence was found that supports the use of incentive spirometry in the management of surgical patients, and there is an urgent need for studies with adequate methodological designs to clarify the effect and to justify this technique."[67]

The perhaps surprising answer to the question "What is the evidence for incentive spirometry in postoperative prevention of PPC?" is that there is no high level evidence, and, in fact, the evidence does not support the routine use of incentive spirometry. If we were to assume that of the 4 million upper abdominal surgeries performed in the United States this year, each had an incentive spirometer and a healthcare provider encouraging and monitoring their progress, the current evidence suggests that the time and cost would be wasted. Rigorous studies of incentive spirometry in high risk patients, with adequate sample size and control groups, are sorely needed. Otherwise, the routine use of incentive spirometry should be abandoned.

CPAP

The use of mask CPAP for the treatment of postoperative hypoxemia, reduced functional residual capacity, and atelectasis was introduced in the late 1970s.[68] The reported advantage of CPAP was that the lung volume facing the most drastic change postoperatively, functional residual capacity, could be restored passively without patient cooperation. That is to say, the application of a CPAP mask increases end-expiratory lung volume without deep breathing and might be associated with less pain and discomfort. CPAP also was reported to reduce the work of breathing and increase oxygenation.[36,38]

Nine studies have evaluated the use of CPAP to prevent PPCs in patients following upper abdominal surgery.[36,38,68-74] As with incentive spirometry, the methodological differences in study design, outcomes, and comparators make comparisons difficult. All 9 were randomized trials, but the differences in equipment precluded blinding. Outcomes in these trials included the incidence of PPC in all 9; the incidence of pneumonia and atelectasis was measured in 4 of the trials. All of the trials included short periods of observation, and only 2 trials included follow-up evaluation beyond 1 week.

Of the 9 studies, only the work by Squadrone et al demonstrated a significant reduction in the incidence of PPC.[74] The remaining 8 trials did not demonstrate a difference in the rate of PPC.[36,38,68-73] This finding is in part due to the small number of subjects in each trial, potentially resulting in failure to demonstrate differences because the studies were underpowered. The Squadrone study also demonstrated a reduction in the rate of postoperative pneumonia in the group receiving CPAP.[74] Pneumonia rates were unchanged in the remaining trials. A consistent positive finding in these studies is the improvement of oxygenation associated with CPAP. In a study using nasal CPAP following post operative care of cardiac bypass patients, hypoxemia was prevented and sleep was improved with the addition of CPAP.[75]

Ferreyra et al completed a systematic review and meta-analysis of these 9 trials, evaluating the impact on PPCs in patients undergoing upper abdominal surgery.[76] By combining trials, the number of patients available for analysis increased to 654. Of these studies, the trials by Böhner[72] and Squadrone[74] represented over 400 (63%) of the subjects. These trials used CPAP applied by face mask, nasal mask, mouthpiece, and helmet. The most common outcomes were radiographic demonstration of atelectasis and clinical diagnosis of pneumonia. It is important to note that none of the trials used the same criteria for diagnosing pneumonia.

By combining trials, Ferreyra and co-workers found that CPAP was associated with a significantly lower rate of PPCs than standard treatment, with a risk reduction of 0.34 (95% CI 0.15–0.48). These findings suggest a number-needed-to-treat to benefit of 14.2 (95% CI 9.9−32.4). This systematic review demonstrated the effectiveness of CPAP in reducing the risk of PPCs, atelectasis, and pneumonia following upper abdominal surgery. Ferreyra et al also found that postoperative CPAP reduces the risk of endotracheal intubation.[76] Total mortality in the 654 patients was too small to allow any meaningful comparisons. These data are the strongest evidence for any of the techniques used to prevent PPCs following upper abdominal surgery.

The trials used in this analysis included a number of different patient populations, and the impact of preoperative condition of the patients on the role of CPAP could not be evaluated. This analysis also suggested that CPAP should be applied postoperatively, immediately following the presentation of hypoxemia, and that CPAP should be applied continuously for 6 hours, with no interruption, until hypoxemia is abated.

Zarbock and colleagues published a trial of prophylactic nasal CPAP following elective cardiac surgery. This study of 500 subjects delivered nasal CPAP after extubation in the operating room (early extubation) or in the ICU (late extubation). Standard treatment (control) consisted of 10 min of intermittent nasal CPAP at 10 cm H_2O every 4 h or prophylactic nasal CPAP (intervention) at 10 cm H_2O for a minimum of 6 hours. They found that prophylactic nasal CPAP improved arterial oxygenation (P_{aO_2}/F_{IO_2}) without hemodynamic consequences. PPCs, including hypoxemia ($P_{aO_2}/F_{IO_2} < 100$ mm Hg), pneumonia, and reintubation rate, were reduced in the prophylactic CPAP group (12 of 232 patients vs 25 of 236 patients, respectively, $P = .03$). Readmission rate to the ICU was also significantly lower in the nasal-CPAP-treated patients (7 of 232 patients vs 14 of 236 patients, respectively, $P = .03$).

The long-term administration of prophylactic nasal CPAP following cardiac surgery improved arterial oxygenation, reduced the incidence of PPCs, including pneumonia and reintubation, and reduced the ICU readmission rate. The authors concluded that nasal CPAP, administered prophylactically for 6 hours, reduced pulmonary morbidity following elective cardiac surgery.[77]

Recently, Barabagallo and colleagues found that CPAP provided by a helmet following thoracic surgery and lobectomy improved oxygenation, compared to a control group, for the first 24 hours. Patients receiving CPAP had a significantly shorter hospital stay, in comparison to control (7 ± 4 d and 8 ± 13 d, respectively, $P = .042$). However, there were no differences in PPCs, ICU readmission, or mortality. This was a small study ($n = 50$) of high risk subjects.[78]

The utility of these data with respect to the scientific basis for postoperative respiratory care requires some interpretation. CPAP in high risk patients appears to improve oxygenation, increase functional residual capacity, and reduce PPCs. The widespread use of CPAP in patients without preoperative risk factors cannot be recommended.

Chest Physiotherapy

CPT and percussion and postural drainage are secretion mobilization methods that have been applied for PPC prevention and treatment for decades. CPT for treatment of PPCs owing to secretions obstructing small airways leading to atelectasis has some physiologic basis. However, the use of these techniques in the setting of atelectasis without retained airway secretions does not appear to have a rational cause and effect basis. This is particularly true in the face of upper abdominal and thoracic incisions, where performance of the treatment is likely to increase pain and splinting, and further impair lung function and cough.[79]

The literature on CPT must be read with care, as "postoperative physiotherapy" does not always equate to percussion and postural drainage. Just as frequently it includes coughing and deep breathing, incentive spirometry, and other techniques.

In an early study, Reines et al[79] compared CPT to no CPT in a group of pediatric patients following cardiac surgery. The study goal was prevention of postoperative atelectasis. In this small study of 44 patients, CPT was associated with significantly more frequent ($P < .01$) and more severe ($P < .01$) atelectasis than no CPT. The authors concluded that the pain created by the procedure may have increased splinting and reduced lung volumes. The following year, Morran and colleagues published a study comparing CPT to no CPT in a group of patients following open cholecystectomy. They enrolled 102 patients, of whom 47 had no PPC, 29 had atelectasis, and 26 developed chest infection. Fifty-one patients did not receive CPT, of whom 11 developed atelectasis and 19 chest infection. Of the 51 patients who received CPT, 18 developed atelectasis and 7 chest infection. The authors concluded that routine prophylactic postoperative CPT significantly reduced the incidence of postoperative chest infection,[80] Torrington et al compared traditional postoperative therapy with and without CPT in a group of 52 morbidly obese subjects following gastric bypass, and concluded that CPT caused patient discomfort, increased hospital cost, and failed to alter the incidence of PPCs.[81]

Christensen and colleagues[82] studied 3 postoperative regimens of respiratory therapy on PPCs and lung function in high-risk patients. Fifty-one patients were randomized to conventional CPT alone; CPT and PEP; or CPT with both PEP and inspiratory resistance. Treatments were given twice daily by a physiotherapist, and self-administered between caregiver visits. The incidences of PPC were 71%, 76%, and 65% in the 3 groups. The incidence of PPCs requiring treatment with antibiotics, bronchodilators, or supplementary oxygen was lower in the group that received CPT plus PEP plus inspiratory resistance, as was the rate of pneumonia. However, owing to the small sample size, those differences were not statistically significant. The authors observed, "Insufficient self-administration of treatment was probably one of the causes of the overall high incidence of PPCs in this study." This study treated CPT as the control group, again making it difficult to know if eliminating CPT would have been just as successful.

Park and co-workers evaluated CPT and high-frequency chest-wall oscillation in a group of patients following lung resection. They found that high-frequency chest-wall oscillation improved gas exchange and forced vital capacity, but no outcomes were studied.[83] This represents the conundrum in these trials: a new therapy is compared to a therapy with unproven benefit (CPT) and is shown to be similar of better. The importance of either cannot be judged without a control group.

Traditional physiotherapy, meaning chest percussion and vibration and postural drainage, has been ordered indiscriminately in the past.[84] In the absence of retained secretions, the use of CPT to resolve atelectasis has no basis in fact. The current evidence, much of it old, demonstrates no role for CPT or high-frequency chest-wall oscillation in preventing PPCs.[63]

Positive Expiratory Pressure

PEP is a modification of the CPAP treatments used in the early 1980s. PEP does not require a continuous-flow gas source or supplemental oxygen, making it simpler and less expensive than CPAP. The use of PEP for PPC prevention has been reported sparingly in the literature.[85-91]

Munro et al found that using airway clearance after lung transplantation was not associated with a reduced incidence of respiratory infection or radiographic improvement of atelectasis.[85] A Swedish study demonstrated that CPAP decreased the risk of respiratory distress requiring reintubation and the need for mechanical ventilation, com-

Table 4. Components of the I COUGH Regimen

Key Phrase	Explanation
*I*ncentive spirometry	Educate the patient. Keep the incentive spirometer within reach and use it 10 times per hour: 3–5 breaths per set. Document incentive spirometry results every 4 h.
*C*oughing and deep breathing	Encourage coughing and deep breathing every 2 h.
*O*ral care	Mouthwash and tooth brushing twice a day.
*U*nderstanding	Educate the patient and family regarding postoperative care and expectations.
*G*et out of bed early and often	Walk once the day of the surgery and thereafter at least 3 times a day. Get out of bed to a chair 3 times a day for meals.
*H*ead of bed elevation	Elevate the head of the bed to ≥ 30°.

(Data from reference 96.)

pared with inspiratory resistive muscle training and PEP.[86] Additional studies have not demonstrated benefits of PEP in preventing or treating PPCs. The evidence does not support the routine use of PEP in treating PPCs.

Other Techniques

Use of intrapulmonary percussive ventilation has been reported in postoperative patients, but none of these studies specifically addressed the issue of PPCs.[90-93] Similarly, IPPB has not shown to improve postoperative outcomes.[65,94] In both instances the data are not available to support routine use.

A PPC Bundle

The success of the Institute for Healthcare Improvement ventilator-associated pneumonia bundle has changed ICU practice around the world.[95] The concept of a group of related treatments and practices to reduce an important clinical burden has advantages to the search for a single silver bullet. This same approach was recently used by Cassiday et al in reducing PPCs.[96] Using a system named I COUGH (for *i*ncentive spirometry, *c*oughing and deep breathing, *o*ral care, *u*nderstanding, *g*etting out of bed, and *h*ead of bed elevation), this group studied over 1,500 surgical cases, compared to a historical control group. See Table 4 for a more detailed description of the I COUGH methodology. The goal of this kind of trial is to develop a culture of education and improvement applied to patients and staff. To create and meet expectations with all stakeholders, the authors assembled educational materials, including pamphlets and a video, to educate patients and families, as well as encourage adherence to the protocol. As with any protocol, standardization tends to improve care through experience and reinforcement. The I COUGH methodology is simple and achievable, which is an important issue for implementation. The use of incentive spirometry in the treatment suite may or may not be important, but the authors suggested that the availability of incentive spirometry allows goal setting related to deep inspirations, and is helpful with patients who do not speak English.

Following all this praise, it is important to note that the study results did not reach statistical significance. However implementation of the program altered nursing practice (at the time of the protocol audits 80% of patients were in bed before the protocol was implemented vs 31% after). The incentive spirometer was within reach of the patient 53% of the time prior to the protocol and 77% of the time following implementation. The incidence of postoperative pneumonia fell from 2.6% to 1.6% after I COUGH was initiated. The incidence of unplanned intubations was 2% before I COUGH and 1.2% after. Again, these changes were not statistically significant.

On the heels of bundles for VAP and sepsis, it is an attractive idea that a PPC bundle, involving a multidisciplinary team implementing simple measures, might improve outcomes and reduce costs. Further multicenter trials should follow this study to determine the impact.

Summary

The use of postoperative respiratory care is frequently indiscriminate and without support from the literature. Local tradition and experience dictate care, and caregiver time and consumables are used that may prove of no value. Of the techniques studied, CPAP in high risk patients with hypoxemia postoperatively has the greatest supporting evidence. Incentive spirometry, PEP, and other devices have either little support from the literature or have been shown not to be of value. CPT appears to have no role in reducing PPCs, despite the frequency with which it is ordered. A multidisciplinary PPC bundle is an attractive concept, but requires additional study.

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