Best Practice & Research Clinical Anaesthesiology 29 (2015) 397–410

Contents lists available at ScienceDirect

Best Practice & Research Clinical Anaesthesiology

journal homepage: www.elsevier.com/locate/bean

10

Non-ventilatory approaches to prevent postoperative pulmonary complications

Andreas Güldner, MD, Resident *,
Peter M. Spieth, MD, MSc, Consultant Anesthesiologist,
Marcelo Gama de Abreu, MD, MSc, PhD, DESA, Consultant Anesthesiologist, Head of Research

University Hospital Carl Gustav Carus, Department of Anesthesiology and Critical Care Medicine, Technische Universität Dresden, Fetscherstrasse, 74 01307 Dresden, Germany

Keywords:
postoperative pulmonary complications
comorbidities
anesthesia
analgesia
neuromuscular blockade
physiotherapy

This educational narrative review provides a summary of non-ventilatory strategies to prevent postoperative pulmonary complications (PPCs). It highlights patient- and procedure-related risk factors for PPCs that are non-modifiable, potentially modifiable, or well modifiable. Non-ventilatory strategies, mainly based on the modification of risk factors, play a key role in reducing PPCs. Non-modifiable risk factors, most importantly age, American Society of Anesthesiologists (ASA) class, and risk of the procedure, should be recognized and patients intensively screened for the potential to optimize other, potentially or well-modifiable, risk factors. Potentially modifiable risk factors, mainly comorbidities and the surgical approach, increase the risk of PPCs. Patient-related factors can be improved while procedure-related factors may be adapted in high-risk patients. Well-modifiable risk factors, mainly certain anesthesia techniques, for example, general anesthesia, intravenous opioids or liberal fluid management, and smoking or alcohol abuse, should be avoided as far as possible in order to prevent PPCs.

* Corresponding author. University Hospital Carl Gustav Carus, Department of Anesthesiology and Critical Care Medicine, Technische Universität Dresden, Fetscherstrasse, 74 01307 Dresden, Germany.

E-mail address: andreas.gueldner@uniklinikum-dresden.de (A. Güldner).

http://dx.doi.org/10.1016/j.bpa.2015.08.007
1521-6896/

Introduction

Postoperative pulmonary complications (PPCs) represent the most important cause of death after cardiac [1] and non-cardiothoracic [2] surgery, with an incidence of almost 8%, as recently demonstrated [3]. This incidence varies from 2.4% in orthopedic surgery to 31.4% and 39.6% in thoracic and cardiac surgery, respectively [4]. Therefore, measures to prevent the development of PPCs may improve patient outcome. Numerous patient- and procedure-related risk factors for PPC have been identified. Most, if not all, risk factors for PPCs are at least potentially modifiable.

Chronic obstructive pulmonary disease (COPD), asthma, obstructive sleep apnea (OSA), congestive heart failure (CHF), as well as other comorbidities have been shown to increase the risk of PPCs [4–6], and they may be improved to some extent. Cigarette smoking and alcohol abuse also represent relevant risk factors for PPCs, which can be reduced by timely smoking cessation [7] or may be modified by alcohol cessation interventions [8].

A reduction in the maximal inspiratory pressure after symptom-limited exercise is associated with an increase in PPCs [9], and its improvement may reduce their incidence, especially after high-risk surgery [10]. Other important factors that may influence the risk of PPCs – such as the choice of anesthetic strategy, the management of neuromuscular blockade as well as intravascular fluid therapy, the transfusion regimen, postoperative pain therapy, the use of nasogastric decompression, or the choice between open or laparoscopic surgical approach – are under the control of the anesthesiologist and the surgeon, respectively [11]. This review discusses the clinical evidence on non-ventilatory strategies that may be used to prevent PPCs, which are mainly based on the modification of risk factors. Table 1 provides an overview on non-modifiable, potentially modifiable, and well modifiable risk factors for PPCs. The main focus of this review is a general patient population undergoing noncardiac surgery.

Non-modifiable risk factors

Patient related factors

Advanced age and a high American Society of Anesthesiologists (ASA) class represent the most important patient-related non-modifiable risk factors for PPCs. Age independently predisposes patients to PPCs, even after adjustment for the presence of comorbidities [12]. Its importance has been evaluated and confirmed in several large observational studies, defining different thresholds that indicate a significant increase in the risk of PPCs ($\geq$65 years [13] and $\geq$51 years) [4]. Similar to age, a high ASA class ($\geq$3) is independently associated with an increased risk of experiencing a PPC [4]. In addition, it has proven to be more important than age as a risk factor for acute respiratory distress syndrome (ARDS) [14,15] or unanticipated postoperative reintubation [16,17].

Procedure-related factors

Procedure-related non-modifiable risk factors contribute substantially to an increased risk of PPCs; a higher-than-moderate risk level of the procedure and its classification as emergency represent the most relevant of these risk factors. Both multiply the risk of experiencing a PPC in general [4], as well as the risk of developing ARDS [14,15] or undergoing unanticipated postoperative reintubation [16,17] in particular.

The potential of non-modifiable risk factors for PPCs to worsen the clinical outcome has to be borne in mind. Therefore, patients presenting with non-modifiable risk factors should be intensively evaluated for their potential to optimize other, potentially or well-modifiable, risk factors in order to reduce the overall risk of PPCs. As critical care-based interventions are able to improve outcome, a planned admission to an intensive care unit after surgery should be considered in these patients [18].

Table 1
Risk factors for postoperative pulmonary complications (adopted from [11,12]), ASA American Society of Anesthesiology, COPD Chronic obstructive pulmonary disease, OSAS Obstructive sleep apnea syndrome, GERD Gastro-esophageal reflux disease.

	Patient related factors	Procedure related factors
Non-modifiable factors	ASA class ≥3 Advanced age Alterations in chest radiograph Functional dependence Impaired sensorium Cancer Genetic variations	Risk of the procedure ≥ medium Emergency procedure
Potentially-modifiable factors	COPD OSAS Asthma Congestive heart failure GERD Arterial hypertension Liver disease Diabetes mellitus Renal disease Low body weight Obesity Positive cough test Low preoperative oxygen saturation	Duration of the procedure Duration of hospitalization Open surgical approach
Well modifiable factors	Smoking Alcohol abuse Impaired physical status Recent respiratory infection Anemia Sepsis Hypoalbuminemia	General anesthesia Transfusion Absent or qualitative Monitoring of neuromuscular blockade Routine reversal of neuromuscular blockade with cholinesterase inhibitors Intravenous anesthetics Analgesia based on intravenous opioids Liberal fluid management Routine nasogastric decompression

Potentially modifiable patient-related factors

The most relevant potentially modifiable patient-related factors are comorbidities that have an important impact on the risk of developing PPCs. Some of them can be modified to different degrees, as discussed in this chapter. However, a complete review on the optimization of all comorbidities relevant to the development of PPCs is beyond the scope of this article.

Chronic obstructive pulmonary disease

COPD has been identified as a major risk factor for PPCs [2,4,5] including ARDS [14], which may be modified to some extent. In patients with COPD, pharmacological optimization may help reduce the incidence of PPCs. In lung cancer patients with moderate to severe COPD, the daily inhalation of bronchodilators proved effective in maintaining postoperative respiratory function and quality of life [19]. Furthermore, the application of low-dose human atrial natriuretic peptide prior to lung cancer surgery was able to reduce the risk of developing PPCs in patients with COPD [20]. Although this pharmacological intervention has proven to be effective in reducing PPCs in a retrospective study, its potential needs to be confirmed in prospective randomized controlled trials.

In addition to drug therapy, pulmonary rehabilitation may be a valuable intervention to prevent PPCs, especially in patients with COPD representing a high-risk population. Pulmonary rehabilitation using muscle training can modify the capacity of respiratory muscle fiber remodeling in cardiac [21] and noncardiac [22] surgery. However, applied to a general patient population, it proved to be effective in preventing PPCs only in cardiac [23] and thoracic surgery [24], but it failed to do so in abdominal surgery [25]. By contrast, in patients with COPD, pulmonary rehabilitation may improve the maximum oxygen consumption [26], but its ability to improve the pulmonary outcome in this subpopulation during all types of surgery needs to be investigated further.

Asthma

Similar to COPD, asthma contributes to the development of PPCs [4]; in particular, acute bronchospasm in the perioperative setting may be fatal [27]. In patients with asthma, the manipulation of the hyperreactive airways during induction and emergence of anesthesia can trigger bronchospasm. Therefore, the likelihood of PPCs in patients with asthma may be decreased by the preoperative application of anti-inflammatory and broncholytic interventions [11]. The intravenous administration of short-acting corticosteroids may be able to prevent PPCs [28]. Furthermore, the application of short-acting bronchodilators and anticholinergic agents may contribute to a reduction in the bronchial tone [27]. Although it may trigger bronchospasm by itself [29], intravenous lidocaine can attenuate airway hyperreactivity [30]. Besides specific interventions, optimization of therapy as well as conditioning of the patient including eradication of respiratory infections and postponing of surgery in asthmatic patients who present with deteriorated symptoms for elective procedures may help reduce the risk of PPCs.

Specific measures that are under the direct control of the anesthesiologist, such as the use of local or regional instead of general anesthesia as well as the intubation and extubation in deep anesthesia, may prevent PPCs in patients with asthma. Furthermore, the avoidance of potentially critical pharmacologic interventions, such as neuromuscular blocking agents (NMBAs), anesthetic drugs that may induce the release of histamine by mast cells (e.g., atracurium and barbiturates, respectively), as well as anticholinesterase drugs (e.g., neostigmine), for reversal of NMB on the one hand and the preferred use of volatile or intravenous anesthetics that may promote bronchodilation (e.g., sevoflurane, propofol, or ketamine) on the other hand can optimize anesthetic management in patients with asthma [27].

Obstructive sleep apnea

OSA, a common disorder affecting approximately 4% of men and 2% of women of the general population [31], increases the risk of PPCs, often found in association with other comorbidities, such as cardiovascular disease, CHF, arrhythmias, hypertension, cerebrovascular disease, and metabolic syndrome [32]. These comorbidities also amplify the risk of perioperative pulmonary events [11]. Because it is often undiagnosed in patients undergoing elective surgery [33], a careful preoperative evaluation may help to identify subjects with relevant symptoms. Similar to other pulmonary comorbidities, a number of measures – which are in part under control of the anesthesiologist, such as the use of local or regional instead of general anesthesia, anticipation of difficult intubation, extubation in the semi-upright position, management of pain without opioids, monitoring of oxygenation in the postoperative period, early resumption or initiation of continuous positive airway pressure (CPAP) after surgery, and close follow-up at the local sleep center upon discharge from the hospital [34] – may contribute to a reduction in the risk of PPCs in this patient population.

Alterations in preoperative testing

Among other preoperative tests, positive cough test and low preoperative oxygen saturation, known as indicators of poor clinical status of important pulmonary comorbidities, are associated with an increased risk of PPCs in a general patient population [4]. To ensure that the preoperative clinical status is potentially improved or that subjects incapable of further improvement receive the best possible care, patients with a positive cough test or low oxygen saturation during preoperative examination should be further evaluated for an unknown or known but recently worsened pulmonary comorbidity.

Low body weight and obesity

Both low body weight and obesity represent risk factors for PPCs in a general patient population, which can be potentially modified. In a large prospective observational study, a body mass index (BMI) of <18.5 or ≥ 40 was an independent predictor of unanticipated early postoperative tracheal intubation, with low body weight resulting in a higher odds ratio for this complication [16]. Different from the general patient population, a BMI of >30 was associated with a higher incidence of PPCs in patients undergoing lung resection via thoracotomy [35]. Given that a sufficient increase or decrease in body weight cannot always be achieved preoperatively, it is important to apply an aggressive preventive strategy of management in underweight or overweight patients [35]. The use of video-assisted techniques, in particular, can reduce the rate of PPCs in moderately obese patients undergoing lung resection for non-small cell lung cancer to the level of normal-weight patients [36]. Furthermore, during bariatric surgery or even minor abdominal surgery (i.e., appendectomy), a laparoscopic approach is able to reduce the incidence of PPCs [37,38].

Potentially modifiable procedure-related factors

Several important potentially modifiable procedure-related risk factors for PPCs, such as the duration of the procedure and the choice of the surgical approach, are mainly under the control of the surgeon. However, if a patient is identified as being at a high risk of PPCs during preoperative anesthesiological evaluation, the anesthesiologist may influence the choice of the surgical strategy, for example, open versus laparoscopic/thoracoscopic approach, or even the extent of the procedure, mainly determining its duration.

Laparoscopic/thoracoscopic versus open surgery

Similarly to obese subjects, normal-weight patients seem to benefit from a laparoscopic/thoracoscopic surgical approach. Compared with open surgery, mortality following laparoscopic surgery decreased in a general patient population investigated in a recent prospective observational study [18]. Especially during thoracic or combined thoracic–abdominal surgery, a laparoscopic/thoracoscopic approach seems to be associated with a reduction in the incidence of PPCs. During surgery for esophageal cancer, the use of both a laparoscopic approach instead of an open gastric mobilization [39] and a video-assisted thoracoscopic approach during the intrathoracic period [40] can reduce the rate of PPCs, including ARDS [39] and pneumonia [40]. These results are comparable to those obtained in patients undergoing anatomic resection of clinical stage I lung cancer, who experience less PPCs in the case of video-assisted thoracoscopic techniques [41]. Besides thoracic or combined thoracic–abdominal surgery, recent evidence confirms the benefit of a laparoscopic approach over an open surgical approach for patients undergoing minor [42] or major [43] abdominal surgery, with a reported reduction in the rate of PPCs. Thus, laparoscopic/thoracoscopic surgical techniques clearly contribute to the prevention of PPCs.

Well-modifiable patient-related factors

Smoking cessation

Given a sufficient time frame prior to surgery and good patient compliance, smoking is a well-modifiable yet important risk factor for PPCs. Smoking increases the risk of pneumonia, weaning failure, and unanticipated postoperative reintubation [44], and its associated mortality is mainly mediated by PPCs [45]. Smoking can impair pulmonary function by different mechanisms including damage of the ciliated epithelium causing impaired tracheobronchial clearance, increased reactivity of the tracheobronchial system, increased secretion of hyperviscous mucus, and small airway narrowing causing an increase in closing volume [46]. Based on its pathophysiology, preoperative smoking cessation should reduce the risk of PPCs. Compared with ongoing smoking, a cessation >4 weeks prior to surgery is able to decrease the incidence of PPCs. After quitting smoking for >8 weeks, a smoker has a comparable risk of developing PPCs to a nonsmoker. Abstinence from smoking for <4 weeks seems to be insufficient for an effect on the incidence of PPCs [47]. Short-term smoking cessation interventions, especially when pharmacologically supported (e.g., nicotine replacement therapy, varenicline), may increase the rate of abstinence from smoking at the time of surgery, but they cannot decrease the rate of postoperative complications [48]. However, a recent prospective observational study found an increase in the odds ratio for PPC (i.e., pneumonia and atelectasis) only in the group of patients who quit smoking for <2 weeks. It is worth noting that the group of patients who abstained from smoking for 2–4 weeks was too small to include one single case of PPC. Nevertheless, the risk of any complication was equivalent to that of nonsmokers after abstaining from smoking for >2 weeks [49]. Given the low number of patients enrolled in this study, further studies are warranted to confirm the benefits of short-term smoking cessation. Even if short-term smoking cessation should prove not to reduce the incidence of PPCs, it certainly does not increase this incidence and can improve important respiratory parameters (level of carbon monoxide hemoglobin, ciliary activity, and reactivity of the tracheobronchial system) [46]. Therefore, patients should always be encouraged to quit smoking prior to surgery as early as possible, and access to psychological as well as pharmacological support should be offered.

Alcohol cessation

Alcohol abuse represents an established risk factor for PPCs increasing the risk of unanticipated early postoperative tracheal intubation [16] and respiratory failure [13]. The mechanisms behind this phenomenon are multifactorial: alcohol abuse impairs pulmonary immune as well as alveolar epithelial barrier function, antioxidative capacity, and surfactant production [50]. Only very few studies on the effect of preoperative alcohol cessation on PPCs are available. A pharmacologically supported (i.e., disulfiram) alcohol abstinence of 1 month prior to surgery was able to reduce the incidence of postoperative hypoxemia as well as myocardial ischemia and arrhythmias compared with continuous drinking [51]. A meta-analysis of published and unpublished data regarding preoperative alcohol cessation confirmed its beneficial effect on general postoperative complications [8]. Besides preoperative alcohol cessation, pharmacological interventions aimed at restoring antioxidant capacity, which proved to increase the number of organ failure-free days in patients with ARDS [52], used additionally to or instead of alcohol cessation, may represent a valuable tool to reduce the incidence of PPCs in patients without preexisting lung diseases. However, considering the information available thus far, further investigations of the different types of alcohol-related interventions are needed to determine their value in the perioperative setting.

Physical status and physiotherapy

An impaired physical status seems to be an important risk factor for PPCs after cardiac and noncardiac surgery [53]. As a non-ventilatory strategy, perioperative physiotherapy may improve the patient's physical condition preoperatively and prevent consequences as well as complications of immobilization potentiated by the original problem, the surgical intervention, anesthesia, and comorbidities [54]. In contrast to cardiac surgery, where preoperative physiotherapy has been proven to reduce the risk of atelectasis and pneumonia [23], the evidence in noncardiac surgery appears less clear. While several studies found an improvement in pulmonary function in patients undergoing thoracic and abdominal surgery, a similarly beneficial effect on PPCs could not always be detected [24,25]. However, in patients undergoing esophagectomy, high-intensity inspiratory muscle training was able to reduce not only the rate of PPCs but also the length of hospital stay [55]. Importantly, physiotherapy seems to be most effective when started preoperatively and continued postoperatively [24] and when applied as part of a multimodal approach further including oral care, patient and family education, and head-of-bed elevation [56]. Although physiotherapy may not always be able to decrease the risk of PPCs, its ability to improve pulmonary function justifies its application in general.

Respiratory infection

Not surprisingly, an ongoing or recent respiratory infection within the last month prior to surgery significantly increases the risk of PPCs [4]. Therefore, it is crucial to screen every patient for signs of respiratory infection preoperatively. After diagnosis, any respiratory infection should be thoroughly treated and surgery postponed for at least 1 month, whenever possible.

Well-modifiable procedure-related factors

General versus regional anesthesia

General anesthesia is accompanied by a loss of functional residual capacity and the occurrence of atelectasis in almost every patient [57]. Thus, avoiding general anesthesia, that is, local or regional anesthesia, should be able to prevent changes in lung volumes as well as lung function and consequently reduce the incidence of PPC [11]. To address this issue, numerous studies have been performed in different patient populations. Their results were recently summarized in a systematic review of relevant Cochrane meta-analyses by Guay and colleagues. The authors concluded that neuraxial blockade is able to reduce the risk of pneumonia and also the 30-day mortality compared with general anesthesia. The risk of myocardial infarction is not affected by the anesthesia technique [58]. Even for procedures usually performed under general anesthesia, such as open abdominal or laparoscopic surgery, regional anesthesia may represent a valuable alternative in patients with severe pulmonary impairment [59,60]. During high thoracic and cervical epidural anesthesia (EA), neuraxial blockade can reduce respiratory muscle force and, consequently, affect lung volumes [61], but this effect seems to be well tolerated [62]. However, neuraxial blockade bears the risk of relevant complications (e.g., epidural hematoma or abscess, or postspinal neurological deficit) and should only be used after judicious evaluation of its potential benefits and harms. Provided there are no contraindications, anesthesia with peripheral nerve blocks may represent a valuable alternative to general anesthesia in patients at a risk of PPCs [11].

Neuromuscular blockade

Although NMBAs represent a standard of care during general anesthesia, their use poses a risk of postoperative residual curarization (PORC), a well-known risk factor for PPCs [63]. Monitoring of neuromuscular blockade and antagonization of NMBAs are established treatments to prevent PORC and have been extensively studied. Based on the quantitative analysis of the train-of-four ratio (TOF ratio), acceleromyography was found to be superior in the detection of PORC over standard clinical tests [64] as well as the qualitative analysis, with a reduced incidence of PPCs in the postanesthesia care unit [65]. At present, acetylcholinesterase inhibitors (e.g., neostigmine) and the cyclodextrine sugammadex, which antagonize the effect of NMBAs, are available. Although effective antagonists, acetylcholinesterase inhibitors can increase the incidence of PPCs, if used without quantitative monitoring of the neuromuscular blockade [66,67]. A depolarization block, caused by the accumulation of acetylcholine induced by the application of acetylcholinesterase inhibitors in the absence of residual neuromuscular blockade, may underlie this phenomenon [66]. Moreover, acetylcholinesterase inhibitors may fail to reverse the neuromuscular blockade in the presence of inhalational anesthetics [68]. Considering these disadvantages of acetylcholinesterase inhibitors, sugammadex, which works only after rocuronoium- and vecuronium-induced neuromuscular blockade, is preferred for reversing the residual neuromuscular blockade. In fact, in an observational study, sugammadex was able to reduce the incidence of PORC compared with neostigmine [69]. However, if applied without quantitative monitoring of the neuromuscular blockade, PORC may still occur in some patients [70]. Therefore, the neuromuscular blockade should always be quantitatively monitored, followed by careful antagonization. The role of sugammadex should be further investigated.

Intravenous versus volatile anesthetics

There is clear evidence that volatile anesthetics, due to their protective effects against myocardial damage caused by ischemia and reperfusion, improve not only morbidity (i.e., myocardial infarction) but also mortality compared to intravenous anesthetics in patients undergoing cardiac surgery [71]. Similar to these findings, recent experimental studies revealed the protective properties of volatile anesthetics in the lungs. For example, isoflurane can prevent ventilator-induced lung injury in mice [72], whereas sevoflurane attenuates pulmonary inflammation in a two-hit lung injury model in rats [73]. Furthermore, clinical investigations confirmed the lung-protective effects of volatile anesthetics, found in animal models, during one lung ventilation. Compared with intravenous anesthetics, they are able to dampen the inflammatory response in the non-ventilated and the ventilated lung [74,75]. However, there is no evidence for a positive effect on clinical outcome. A recent meta-analysis showed that the choice of drug used to maintain anesthesia during one-lung ventilation did not affect the outcome [76]. Given the low quality of the studies included, further investigations addressing this issue are warranted.

Systemic versus regional anesthesia for postoperative pain therapy

Regional anesthesia techniques are able to reduce pain and attenuate the reflex inhibition of respiratory muscles [77]. The resultant improved muscle force facilitates effective coughing and elimination of lung secretions; consequently, the risk of PPCs may be decreased. There is evidence that strongly supports this hypothesis. EA is able to reduce the risk of PPCs compared with systemic analgesia using opioids, including pneumonia, prolonged mechanical ventilation, and hypoxemia, in patients undergoing major abdominal or thoracic surgery [78,79]. A recent meta-analysis proved that, in a general patient population including all types of surgery, that is, thoracic, abdominal, vascular, gynecologic, urologic, and orthopedic, EA not only decreases the rate of PPCs but also reduces postoperative mortality [80]. However, in abdominal surgery, these results are debatable. After general abdominal surgery, EA offers superior pain control and faster return of gut function, but it may increase the overall postoperative complications [81]. A recently published retrospective matched cohort analysis found no advantage of EA in the reduction of overall postoperative complications over systemic analgesia, but EA was found to be associated with a higher transfusion rate and a longer hospital stay in patients after major liver resections [82]. By contrast, after pancreatectomy, in-hospital mortality was reduced in patients with EA compared to those without EA [83]. Non-neuraxial regional anesthesia techniques, such as paravertebral blockade (PVB) during thoracic surgery and transversus abdominis plane (TAP) blockade during abdominal surgery, have been used as alternatives to EA. While PVB is able to reduce the incidence of PPCs compared with systemic analgesia after thoracotomy, possibly decreasing the overall complication rate compared to EA [84], the evidence for TAP is unclear. It was found to be superior to systemic analgesia with opioids, but inferior to EA for controlling pain after abdominal surgery [85]. However, no conclusion on its effect on PPCs can be drawn from the data available to date. Continuous wound infiltration has been suggested as an alternative to regional or neuraxial anesthesia techniques. It was found to be less effective in thoracic surgery [86], but it may be an alternative in abdominal surgery [87]. Its effect on PPCs needs to be evaluated further. It is clear that more studies are needed to investigate the effect of the available analgesia techniques on patient outcome in surgical procedures specifically relevant for PPCs.

Perioperative fluid management

Based on studies in patients with ARDS, a restrictive fluid management strategy is known to improve outcome. Numerous clinical studies using different fluid management strategies (i.e., restrictive, liberal, or goal directed) and different types of fluids (i.e., crystalloid or colloid) have been performed to investigate whether this beneficial effect can be transferred to patients with healthy lungs in the perioperative setting. During minor surgery, a restrictive approach transiently decreases the forced vital capacity postoperatively, but this effect may be mainly related to a higher incidence of postoperative nausea and vomiting [88]. In thoracic surgery, liberal fluid management is clearly associated with a higher incidence of PPCs [89]. Different limits, above which the rate of PPCs increases, have been suggested (1.500 ml or 6 ml/kg/h) [90,91]. In abdominal surgery, an extensive number of studies are available in favor of restrictive, liberal, or goal-directed fluid management strategies. While Blum and colleagues identified a higher level of intraoperative crystalloid infusion as a risk factor for postoperative ARDS [14], Futier and colleagues found an increase in the rate of postoperative ARDS using a restrictive approach compared with a liberal [92]. By contrast, a goal-directed approach based on the optimization of blood flow decreased the incidence of postoperative respiratory failure and ARDS [93]. As with the optimal amount, the best type of fluid has been studied in depth, applying the experience of the crystalloids/colloids debate in critically ill patient to this perioperative setting. Not surprisingly, recent studies show heterogeneous results, favoring crystalloid or colloid fluids with respect to the incidence of PPCs. Certainly, further investigations are needed to determine the optimal perioperative fluid management strategy. An individualized strategy adapted to the patient- and procedure-related risks may represent a valuable approach guiding fluid therapy in the perioperative setting [94].

Nasogastric decompression

Nasogastric decompression is commonly used during general anesthesia and in the early postoperative period, especially after major abdominal surgery. On the one hand, it may reduce vomiting, thus potentially avoiding complications at the surgical site. On the other hand, it may increase the risk of aspiration events, an important cause of pulmonary complications in the early postoperative period [11]. However, there is clear evidence that the early removal of nasogastric tubes not only fastens the return of bowel function but also reduces the rate of PPCs in patients undergoing abdominal surgery [95], even when the incidence of postoperative vomiting is increased [96]. Two recent meta-analyses confirm these results in part, also showing a faster return of bowel function without any effect on postoperative pulmonary or overall complications in patients having their nasogastric tube removed early after upper [97] or lower [98] abdominal surgery. Although some of these meta-analyses included single studies investigating the total avoidance [95,96], the majority of the analyzed studies compared the intraoperative use and early postoperative removal of nasogastric tubes with prolonged postoperative nasogastric decompression. Based on these results, the routine use of nasogastric tubes during the postoperative period can no longer be recommended. Whether the total avoidance of nasogastric tubes can further contribute to a reduction in the risk of PPCs remains unclear. However, as the benefit of intraoperative nasogastric decompression in postoperative nausea and vomiting has been challenged in several investigations [99,100], its routine use should be debated as well.

Conclusion

In high-risk populations and selected types of surgery, PPCs can be prevented by different non-ventilatory strategies based on the modification of risk factors. A thorough evaluation of comorbidities associated with a high risk of PPCs, including COPD, asthma, and OSAS, facilitates optimization of the patient status through different measures, including pulmonary rehabilitation and drug therapies. Depending on the time frame and patient compliance, smoking represents a well-modifiable risk factor for PPCs. Smoking cessation at least 4 weeks prior to surgery is able to decrease the incidence of PPCs. Improvement of the patient's physical status by perioperative physical therapy may prevent adverse pulmonary events. Depending on the type of surgery and individual risk of PPCs, the choice of the anesthesia strategy, including the type of anesthesia (regional vs. general), neuromuscular blockade and reversal, anesthetic drugs (volatile vs. intravenous), a well-adapted fluid management strategy, and regional instead of systemic analgesia may further reduce the risk of PPCs. The use of laparoscopic surgery instead of open surgery can help prevent PPCs in different types of surgery.

Practice points

- Non-ventilatory strategies based on the modification of risk factors can reduce the incidence of postoperative pulmonary complications.
- Comorbidities are important risk factors for adverse pulmonary events, and patients should be evaluated for the potential to optimize their preoperative condition.
- Compared with open surgery, laparoscopic surgery improves postoperative pulmonary function and may reduce postoperative pulmonary complications in high-risk patients.
- Smoking cessation at least 4 weeks before surgery can prevent postoperative pulmonary complications. Patients should always be encouraged and professionally supported to quit smoking as early as possible.
- Pre- and postoperative physiotherapy improves physical status and reduces the incidence of postoperative pulmonary complications.
- Certain anesthesia and analgesia techniques and drugs, judicious perioperative fluid management, as well as the use of nasogastric decompression are able to prevent adverse pulmonary events; thus, they should be adapted to the patient's individual risk of PPCs.

Research agenda

- The possible role of preoperative alcohol cessation in the prevention of postoperative pulmonary complications needs to be studied further
- Further investigations are needed to confirm a possible benefit of the lung-protective effect of volatile anesthetics over intravenous anesthetics in noncardiac surgery.
- Approaches to postoperative analgesia considering all available techniques in different types of surgery should be evaluated further.
- The optimal perioperative fluid management strategy in different types of surgery regarding the amount and type of fluids needs to be determined.

Conflict of interest

None.

References

[1] Rahmanian PB, Kroner A, Langebartels G, et al. Impact of major non-cardiac complications on outcome following cardiac surgery procedures: logistic regression analysis in a very recent patient cohort. Interact Cardiovasc Thorac Surg 2013;17: 319–26. discussion 326–317.

[2] Smetana GW, Lawrence VA, Cornell JE. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med 2006;144:581–95.

*[3] Mazo V, Sabate S, Canet J, et al. Prospective external validation of a predictive score for postoperative pulmonary complications. Anesthesiology 2014;121:219–31.

[4] Canet J, Gallart L, Gomar C, et al. Prediction of postoperative pulmonary complications in a population-based surgical cohort. Anesthesiology 2010;113:1338–50.

[5] Scholes RL, Browning L, Sztendur EM, et al. Duration of anaesthesia, type of surgery, respiratory co-morbidity, predicted VO_2max and smoking predict postoperative pulmonary complications after upper abdominal surgery: an observational study. Aust J Physiother 2009;55:191–8.

[6] Kor DJ, Warner DO, Alsara A, et al. Derivation and diagnostic accuracy of the surgical lung injury prediction model. Anesthesiology 2011;115:117–28.

[7] Hawn MT, Houston TK, Campagna EJ, et al. The attributable risk of smoking on surgical complications. Ann Surg 2011; 254:914–20.

[8] Oppedal K, Moller AM, Pedersen B, et al. Preoperative alcohol cessation prior to elective surgery. Cochrane Database Syst Rev 2012;7. CD008343.

[9] Refai M, Pompili C, Salati M, et al. Can maximal inspiratory and expiratory pressures during exercise predict complications in patients submitted to major lung resections? A prospective cohort study. Eur J Cardiothorac Surg 2014;45: 665–9. discussion 669–670.

[10] Agrelli TF, de Carvalho Ramos M, Guglielminetti R, et al. Preoperative ambulatory inspiratory muscle training in patients undergoing esophagectomy. A pilot Study. Int Surg 2012;97:198–202.

[11] Güldner A, Pelosi P, de Abreu MG. Nonventilatory strategies to prevent postoperative pulmonary complications. Curr Opin Anaesthesiol 2013;26:141–51.

[12] Smetana GW. Postoperative pulmonary complications: an update on risk assessment and reduction. Cleve Clin J Med 2009;76(Suppl. 4):S60–5.

[13] Johnson RG, Arozullah AM, Neumayer L, et al. Multivariable predictors of postoperative respiratory failure after general and vascular surgery: results from the patient safety in surgery study. J Am Coll Surg 2007;204:1188–98.

*[14] Blum JM, Stentz MJ, Dechert R, et al. Preoperative and intraoperative predictors of postoperative acute respiratory distress syndrome in a general surgical population. Anesthesiology 2013;118:19–29.

*[15] Kor DJ, Lingineni RK, Gajic O, et al. Predicting risk of postoperative lung injury in high-risk surgical patients: a multicenter cohort study. Anesthesiology 2014;120:1168–81.

[16] Ramachandran SK, Nafiu OO, Ghaferi A, et al. Independent predictors and outcomes of unanticipated early postoperative tracheal intubation after nonemergent, noncardiac surgery. Anesthesiology 2011;115:44–53.

[17] Brueckmann B, Villa-Uribe JL, Bateman BT, et al. Development and validation of a score for prediction of postoperative respiratory complications. Anesthesiology 2013;118:1276–85.

*[18] Pearse RM, Moreno RP, Bauer P, et al. Mortality after surgery in Europe: a 7 day cohort study. Lancet 2012;380:1059–65.

[19] Suzuki H, Sekine Y, Yoshida S, et al. Efficacy of perioperative administration of long-acting bronchodilator on postoperative pulmonary function and quality of life in lung cancer patients with chronic obstructive pulmonary disease. Preliminary results of a randomized control study. Surg Today 2010;40:923–30.

[20] Nojiri T, Inoue M, Maeda H, et al. Low-dose human atrial natriuretic peptide for the prevention of postoperative cardiopulmonary complications in chronic obstructive pulmonary disease patients undergoing lung cancer surgery. Eur J Cardiothorac Surg 2013;44:98–103.

[21] Hulzebos EH, Helders PJ, Favie NJ, et al. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. JAMA 2006;296: 1851–7.

[22] Vogiatzis I, Terzis G, Stratakos G, et al. Effect of pulmonary rehabilitation on peripheral muscle fiber remodeling in patients with COPD in GOLD stages II to IV. Chest 2011;140:744–52.

[23] Hulzebos EH, Smit Y, Helders PP, et al. Preoperative physical therapy for elective cardiac surgery patients. Cochrane Database Syst Rev 2012;11. CD010118.

[24] Rodriguez-Larrad A, Lascurain-Aguirrebena I, Abecia-Inchaurregui LC, et al. Perioperative physiotherapy in patients undergoing lung cancer resection. Interact Cardiovasc Thorac Surg 2014;19:269–81.

*[25] do Nascimento Junior P, Modolo NS, Andrade S, et al. Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. Cochrane Database Syst Rev 2014;2. CD006058.

[26] Nagarajan K, Bennett A, Agostini P, et al. Is preoperative physiotherapy/pulmonary rehabilitation beneficial in lung resection patients? Interact Cardiovasc Thorac Surg 2011;13:300–2.

[27] Woods BD, Sladen RN. Perioperative considerations for the patient with asthma and bronchospasm. Br J Anaesth 2009; 103(Suppl. 1):i57–65.

[28] Expert Panel Report 3 (EPR-3). Guidelines for the diagnosis and management of asthma-summary Report. J Allergy Clin Immunol 2007;2007(120):S94–138.

[29] Burches Jr BR, Warner DO. Bronchospasm after intravenous lidocaine. Anesth Analg 2008;107:1260–2.
[30] Groeben H, Silvanus MT, Beste M, et al. Combined lidocaine and salbutamol inhalation for airway anesthesia markedly protects against reflex bronchoconstriction. Chest 2000;118:509–15.
[31] Stradling JR, Davies RJ. Sleep. 1: obstructive sleep apnoea/hypopnoea syndrome: definitions, epidemiology, and natural history. Thorax 2004;59:73–8.
[32] Kaw R, Chung F, Pasupuleti V, et al. Meta-analysis of the association between obstructive sleep apnoea and postoperative outcome. Br J Anaesth 2012;109:897–906.
[33] Chung F, Ward B, Ho J, et al. Preoperative identification of sleep apnea risk in elective surgical patients, using the Berlin questionnaire. J Clin Anesth 2007;19:130–4.
[34] Vasu TS, Grewal R, Doghramji K. Obstructive sleep apnea syndrome and perioperative complications: a systematic review of the literature. J Clin Sleep Med 2012;8:199–207.
[35] Agostini P, Cieslik H, Rathinam S, et al. Postoperative pulmonary complications following thoracic surgery: are there any modifiable risk factors? Thorax 2010;65:815–8.
[36] Smith PW, Wang H, Gazoni LM, et al. Obesity does not increase complications after anatomic resection for non-small cell lung cancer. Ann Thorac Surg 2007;84:1098–105. discussion 1105–1096.
[37] Weller WE, Rosati C. Comparing outcomes of laparoscopic versus open bariatric surgery. Ann Surg 2008;248:10–5.
[38] Ciarrocchi A, Amicucci G. Laparoscopic versus open appendectomy in obese patients: a meta-analysis of prospective and retrospective studies. J Minim Access Surg 2014;10:4–9.
[39] Briez N, Piessen G, Torres F, et al. Effects of hybrid minimally invasive oesophagectomy on major postoperative pulmonary complications. Br J Surg 2012;99:1547–53.
[40] Tsujimoto H, Takahata R, Nomura S, et al. Video-assisted thoracoscopic surgery for esophageal cancer attenuates postoperative systemic responses and pulmonary complications. Surgery 2012;151:667–73.
[41] Boffa DJ, Dhamija A, Kosinski AS, et al. Fewer complications result from a video-assisted approach to anatomic resection of clinical stage I lung cancer. J Thorac Cardiovasc Surg 2014;148:637–43.
[42] Coccolini F, Catena F, Pisano M, et al. Open versus laparoscopic cholecystectomy in acute cholecystitis. Systematic review and meta-analysis. Int J Surg 2015;18:196–204.
[43] Deng Y, Zhang Y, Guo TK. Laparoscopy-assisted versus open distal gastrectomy for early gastric cancer: a meta-analysis based on seven randomized controlled trials. Surg Oncol 2015;24:71–7.
[44] Gajdos C, Hawn MT, Campagna EJ, et al. Adverse effects of smoking on postoperative outcomes in cancer patients. Ann Surg Oncol 2012;19:1430–8.
[45] Singh JA, Hawn M, Campagna EJ, et al. Mediation of smoking-associated postoperative mortality by perioperative complications in veterans undergoing elective surgery: data from Veterans Affairs Surgical Quality Improvement Program (VASQIP)–a cohort study. BMJ Open 2013:3.
[46] Gourgiotis S, Aloizos S, Aravosita P, et al. The effects of tobacco smoking on the incidence and risk of intraoperative and postoperative complications in adults. Surgeon 2011;9:225–32.
*[47] Wong J, Lam DP, Abrishami A, et al. Short-term preoperative smoking cessation and postoperative complications: a systematic review and meta-analysis. Can J Anaesth 2012;59:268–79.
[48] Thomsen T, Villebro N, Moller AM. Interventions for preoperative smoking cessation. Cochrane Database Syst Rev 2014; 3. CD002294.
[49] Jung KH, Kim SM, Choi MG, et al. Preoperative smoking cessation can reduce postoperative complications in gastric cancer surgery. Gastric Cancer 2015;18:683–90.
*[50] Joshi PC, Guidot DM. The alcoholic lung: epidemiology, pathophysiology, and potential therapies. Am J Physiol Lung Cell Mol Physiol 2007;292:L813–23.
[51] Tonnesen H, Rosenberg J, Nielsen HJ, et al. Effect of preoperative abstinence on poor postoperative outcome in alcohol misusers: randomised controlled trial. BMJ 1999;318:1311–6.
[52] Bernard GR, Wheeler AP, Arons MM, et al. A trial of antioxidants N-acetylcysteine and procysteine in ARDS. The Antioxidant in ARDS Study Group. Chest 1997;112:164–72.
[53] Hoogeboom TJ, Dronkers JJ, Hulzebos EH, et al. Merits of exercise therapy before and after major surgery. Curr Opin Anaesthesiol 2014;27:161–6.
[54] Patel BK, Hall JB. Perioperative physiotherapy. Curr Opin Anaesthesiol 2013;26:152–6.
[55] van Adrichem EJ, Meulenbroek RL, Plukker JT, et al. Comparison of two preoperative inspiratory muscle training programs to prevent pulmonary complications in patients undergoing esophagectomy: a randomized controlled pilot study. Ann Surg Oncol 2014;21:2353–60.
[56] Cassidy MR, Rosenkranz P, McCabe K, et al. I COUGH: reducing postoperative pulmonary complications with a multidisciplinary patient care program. JAMA Surg 2013;148:740–5.
[57] Magnusson L, Spahn DR. New concepts of atelectasis during general anaesthesia. Br J Anaesth 2003;91:61–72.
[58] Guay J, Choi P, Suresh S, et al. Neuraxial blockade for the prevention of postoperative mortality and major morbidity: an overview of cochrane systematic reviews. Cochrane Database Syst Rev 2014;1. CD010108.
[59] Savas JF, Litwack R, Davis K, et al. Regional anesthesia as an alternative to general anesthesia for abdominal surgery in patients with severe pulmonary impairment. Am J Surg 2004;188:603–5.
[60] Tzovaras G, Fafoulakis F, Pratsas K, et al. Spinal vs general anesthesia for laparoscopic cholecystectomy: interim analysis of a controlled randomized trial. Arch Surg 2008;143:497–501.
[61] Takasaki M, Takahashi T. Respiratory function during cervical and thoracic extradural analgesia in patients with normal lungs. Br J Anaesth 1980;52:1271–6.
[62] Groeben H, Schafer B, Pavlakovic G, et al. Lung function under high thoracic segmental epidural anesthesia with ropivacaine or bupivacaine in patients with severe obstructive pulmonary disease undergoing breast surgery. Anesthesiology 2002;96:536–41.
[63] Murphy GS, Brull SJ. Residual neuromuscular block: lessons unlearned. part I: definitions, incidence, and adverse physiologic effects of residual neuromuscular block. Anesth Analg 2010;111:120–8.

[64] Cammu G, De Witte J, De Veylder J, et al. Postoperative residual paralysis in outpatients versus inpatients. Anesth Analg 2006;102:426–9.
[65] Murphy GS, Szokol JW, Marymont JH, et al. Intraoperative acceleromyographic monitoring reduces the risk of residual neuromuscular blockade and adverse respiratory events in the postanesthesia care unit. Anesthesiology 2008;109: 389–98.
*[66] Grosse-Sundrup M, Henneman JP, Sandberg WS, et al. Intermediate acting non-depolarizing neuromuscular blocking agents and risk of postoperative respiratory complications: prospective propensity score matched cohort study. BMJ 2012;345:e6329.
[67] Sasaki N, Meyer MJ, Malviya SA, et al. Effects of neostigmine reversal of nondepolarizing neuromuscular blocking agents on postoperative respiratory outcomes: a prospective study. Anesthesiology 2014;121:959–68.
[68] Reid JE, Breslin DS, Mirakhur RK, et al. Neostigmine antagonism of rocuronium block during anesthesia with sevoflurane, isoflurane or propofol. Can J Anaesth 2001;48:351–5.
[69] Della Rocca G, Pompei L, Pagan DEPC, et al. Reversal of rocuronium induced neuromuscular block with sugammadex or neostigmine: a large observational study. Acta Anaesthesiol Scand 2013;57:1138–45.
[70] Kotake Y, Ochiai R, Suzuki T, et al. Reversal with sugammadex in the absence of monitoring did not preclude residual neuromuscular block. Anesth Analg 2013;117:345–51.
[71] Landoni G, Biondi-Zoccai GG, Zangrillo A, et al. Desflurane and sevoflurane in cardiac surgery: a meta-analysis of randomized clinical trials. J Cardiothorac Vasc Anesth 2007;21:502–11.
[72] Faller S, Strosing KM, Ryter SW, et al. The volatile anesthetic isoflurane prevents ventilator-induced lung injury via phosphoinositide 3-kinase/Akt signaling in mice. Anesth Analg 2012;114:747–56.
[73] Fortis S, Spieth PM, Lu WY, et al. Effects of anesthetic regimes on inflammatory responses in a rat model of acute lung injury. Intensive Care Med 2012;38:1548–55.
[74] De Conno E, Steurer MP, Wittlinger M, et al. Anesthetic-induced improvement of the inflammatory response to one-lung ventilation. Anesthesiology 2009;110:1316–26.
[75] Schilling T, Kozian A, Senturk M, et al. Effects of volatile and intravenous anesthesia on the alveolar and systemic inflammatory response in thoracic surgical patients. Anesthesiology 2011;115:65–74.
[76] Modolo NS, Modolo MP, Marton MA, et al. Intravenous versus inhalation anaesthesia for one-lung ventilation. Cochrane Database Syst Rev 2013;7. CD006313.
[77] Warner DO. Preventing postoperative pulmonary complications: the role of the anesthesiologist. Anesthesiology 2000; 92:1467–72.
[78] Nishimori M, Low JH, Zheng H, et al. Epidural pain relief versus systemic opioid-based pain relief for abdominal aortic surgery. Cochrane Database Syst Rev 2012;7. CD005059.
[79] Popping DM, Elia N, Marret E, et al. Protective effects of epidural analgesia on pulmonary complications after abdominal and thoracic surgery: a meta-analysis. Arch Surg 2008;143:990–9. discussion 1000.
*[80] Popping DM, Elia N, Van Aken HK, et al. Impact of epidural analgesia on mortality and morbidity after surgery: systematic review and meta-analysis of randomized controlled trials. Ann Surg 2014;259:1056–67.
[81] Hughes MJ, Ventham NT, McNally S, et al. Analgesia after open abdominal surgery in the setting of enhanced recovery surgery: a systematic review and meta-analysis. JAMA Surg 2014;149:1224–30.
[82] Rosero EB, Cheng GS, Khatri KP, et al. Evaluation of epidural analgesia for open major liver resection surgery from a US inpatient sample. Proc (Bayl Univ Med Cent 2014;27:305–12.
[83] Sanford DE, Hawkins WG, Fields RC. Improved peri-operative outcomes with epidural analgesia in patients undergoing a pancreatectomy: a nationwide analysis. HPB Oxf 2015;17:551–8.
[84] Davies RG, Myles PS, Graham JM. A comparison of the analgesic efficacy and side-effects of paravertebral vs epidural blockade for thoracotomy—a systematic review and meta-analysis of randomized trials. Br J Anaesth 2006;96:418–26.
[85] Wu Y, Liu F, Tang H, et al. The analgesic efficacy of subcostal transversus abdominis plane block compared with thoracic epidural analgesia and intravenous opioid analgesia after radical gastrectomy. Anesth Analg 2013;117:507–13.
[86] Fortier S, Hanna HA, Bernard A, et al. Comparison between systemic analgesia, continuous wound catheter analgesia and continuous thoracic paravertebral block: a randomised, controlled trial of postthoracotomy pain management. Eur J Anaesthesiol 2012;29:524–30.
[87] Ventham NT, Hughes M, O'Neill S, et al. Systematic review and meta-analysis of continuous local anaesthetic wound infiltration versus epidural analgesia for postoperative pain following abdominal surgery. Br J Surg 2013;100:1280–9.
[88] Holte K, Klarskov B, Christensen DS, et al. Liberal versus restrictive fluid administration to improve recovery after laparoscopic cholecystectomy: a randomized, double-blind study. Ann Surg 2004;240:892–9.
[89] Licker M, Fauconnet P, Villiger Y, et al. Acute lung injury and outcomes after thoracic surgery. Curr Opin Anaesthesiol 2009;22:61–7.
[90] Evans RG, Naidu B. Does a conservative fluid management strategy in the perioperative management of lung resection patients reduce the risk of acute lung injury? Interact Cardiovasc Thorac Surg 2012;15:498–504.
*[91] Arslantas MK, Kara HV, Tuncer BB, et al. Effect of the amount of intraoperative fluid administration on postoperative pulmonary complications following anatomic lung resections. J Thorac Cardiovasc Surg 2015;149:314–20. 321 e311.
[92] Futier E, Constantin JM, Petit A, et al. Conservative vs restrictive individualized goal-directed fluid replacement strategy in major abdominal surgery: a prospective randomized trial. Arch Surg 2010;145:1193–200.
[93] Grocott MP, Dushianthan A, Hamilton MA, et al. Perioperative increase in global blood flow to explicit defined goals and outcomes after surgery: a cochrane systematic review. Br J Anaesth 2013;111:535–48.
[94] Della Rocca G, Vetrugno L, Tripi G, et al. Liberal or restricted fluid administration: are we ready for a proposal of a restricted intraoperative approach? BMC Anesthesiol 2014;14:62.
[95] Verma R, Nelson RL. Prophylactic nasogastric decompression after abdominal surgery (review). Cochrane Database Syst Rev 2010:1–47.
[96] Rao W, Zhang X, Zhang J, et al. The role of nasogastric tube in decompression after elective colon and rectum surgery: a meta-analysis. Int J Colorectal Dis 2011;26:423–9.

[97] Wei ZW, Li JL, Li ZS, et al. Systematic review of nasogastric or nasojejunal decompression after gastrectomy for gastric cancer. Eur J Surg Oncol 2014;40:1763–70.
[98] Zhao T, Huang L, Tian Y, et al. Is it necessary to insert nasogastric tube routinely after radical cystectomy with urinary diversion? A meta-analysis. Int J Clin Exp Med 2014;7:4627–34.
[99] Kerger KH, Mascha E, Steinbrecher B, et al. Routine use of nasogastric tubes does not reduce postoperative nausea and vomiting. Anesth Analg 2009;109:768–73.
[100] Li C, Mei JW, Yan M, et al. Nasogastric decompression for radical gastrectomy for gastric cancer: a prospective randomized controlled study. Dig Surg 2011;28:167–72.