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REVIEW

D. Chiumello
G. Chevallard
C. Gregoretti

Non-invasive ventilation in postoperative patients: a systematic review

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D. Chiumello (✉) · G. Chevallard
U.O. Anestesia e Rianimazione, Dipartimento di Anestesia, Rianimazione (Intensiva e Subintensiva) e Terapia del Dolore, Fondazione IRCCS Ca' Granda-Ospedale Maggiore Policlinico, via Francesco Sforza 35, 20122 Milan, Italy
e-mail: chiumello@libero.it
Tel.: +39-02-55033237
Fax: +39-02-55033230

C. Gregoretti
Servizio di Anestesia e Rianimazione, Azienda Ospedaliera CTO-CRF-Maria Adelaide, Turin, Italy

Abstract *Background:* Postoperative pulmonary complications, generally defined as any pulmonary abnormality occurring in the postoperative period, are still a significant issue in clinical practice increasing hospital length of stay, morbidity and mortality. Non-invasive ventilation (NIV), primarily applied in cardiogenic pulmonary edema, decompensated COPD and hypoxemic pulmonary failure, is nowadays also used in perioperative settings. *Objective:* Investigate the application and results of preventive and therapeutic NIV in postsurgical patients. *Design:* A systematic review. *Data sources:* Medical literature databases were searched for articles about "clinical trials," "randomized controlled trials" and "meta-analyses." The keywords "cardiac surgery," "thoracic surgery," "lung surgery," "abdominal surgery," "solid organ transplantation," "thoraco-abdominal surgery" and "bariatric surgery" were combined with any of these: "non-invasive positive pressure ventilation," "continuous positive airway pressure," "bilevel ventilation," "postoperative complications," "postoperative care," "respiratory care," "acute respiratory failure," "acute lung injury" and "acute respiratory distress syndrome." *Results:* Twenty-nine articles ($N = 2{,}279$ patients) met the inclusion criteria. Nine studies evaluated NIV in post-abdominal surgery, three in thoracic surgery, eight in cardiac surgery, three in thoraco-abdominal surgery, four in bariatric surgery and two in post solid organ transplantation used both for prophylactic and therapeutic purposes. NIV improved arterial blood gases in 15 of the 22 prophylactic and in 4 of the 7 therapeutic studies, respectively. NIV reduced the intubation rate in 11 of the 29 studies and improved outcome in only 1. *Conclusions:* Despite these limited data and the necessity of new randomized trials, NIV could be considered as a prophylactic and therapeutic tool to improve gas exchange in postoperative patients.

Keywords Acute respiratory failure · Non-invasive ventilation · Postoperative pneumonia · Atelectasis

Introduction

Recent data suggest that up to 234 million major surgical procedures requiring general or spinal-epidural anesthesia are performed worldwide each year [1]. Postoperative pulmonary complications (PPCs) are generally defined as any pulmonary abnormality occurring in the postoperative period. They may increase hospital length of stay, morbidity, mortality [2] and costs for the health care system [3]. PPCs can include atelectasis, postoperative pneumonia, pulmonary edema, acute respiratory failure, although incidence and clinical significance may vary among them [4]. It has been reported that 5 to 10% of all surgical patients and 9 to 40% of those undergoing abdominal surgery developed at least one PPCs [5–8]. These data show that PPCs occur at the same rate as cardiac complications in non-cardiac surgery [9].

PPCs following surgery can be related to either complications of surgery or general anesthesia (e.g., bronchospasm atelectasis, infection, pulmonary embolism up to ALI/ARDS) and/or specific complications such as those occurring during cardiac surgery such as pleural effusion, bronchopleural fistula, phrenic nerve palsy, sternal wound infection, and severe sepsis [10]. Several pulmonary pathophysiological modifications occurring during anesthesia can persist for days following the surgery, thus increasing the risk of PPCs. The induction of anesthesia, upper abdominal and thoracic surgery are usually associated with a reduction in lung gas volumes promoting lower lobe atelectasis [11, 12]. Atelectasis usually occurs in the most dependent parts of the lung near the diaphragm, which includes about 10% of the total lung tissue and may persist for 2 days after major surgery [13, 14].

Dysfunction of the respiratory muscles, especially of the diaphragm, will occur in the first hours after surgery and may persist up to 1 or 2 weeks [15]. The surgery may impair abdominal, thoracic and diaphragmatic muscles, inducing pain and reducing the phrenic output [16]. All these factors can cause respiratory failure because of respiratory muscle impairment, with an increase in carbon dioxide and/or disorders of lung parenchyma, ventilation-perfusion mismatching and hypoxemia [16–18].

In addition, different risk factors can be simultaneously present in the same patient, thus significantly increasing the probability of developing PPCs.

Arozullah et al. [4], in a very large multicenter observational study enrolling more than 80,000 subjects undergoing major non-cardiac surgery, identified several predictors for PPCs that were then used to compute a respiratory failure index. Postoperative respiratory failure was defined as mechanical ventilation for more than 48 h after surgery or the need for reintubation and mechanical ventilation after postoperative extubation.

The respiratory failure index was analogous to the risk assessment model currently used for predicting postoperative cardiac complications. The respiratory failure risk index was developed from a simplified logistic regression model. Eleven predictors were found. Among them, abdominal aortic aneurysm repair, thoracic, abdominal and emergency surgery, an albumin level less than 30 g/l, a BUN higher than 30 mg/dl, a history of COPD and age higher than 70 years significantly increased the risk of complications. Each of these predictors has a point value, ranging from 4 to 24, so by adding the point value of each of these, it is possible to obtain the respiratory failure index.

The authors found that the higher the respiratory failure index, the higher the risk of developing a PPC.

The more commonly applied strategies to prevent postoperative pulmonary complications include good analgesia, physiotherapy, oxygen therapy and early mobilization [19–21].

Non-invasive ventilation (NIV) is a mechanical ventilation modality that does not require any artificial airway (endotracheal tube or tracheostomy) and, compared to invasive ventilation, requires lower sedation, improves the comfort and reduces the nosocomial infection rate [22, 23].

NIV has primarily been applied in patients with acute exacerbations of chronic obstructive pulmonary disease, cardiogenic pulmonary edema and hypoxemic respiratory failure [22–26]. In recent years NIV has also been used to prevent the occurrence of acute respiratory failure after surgery (prophylactic use) or to treat acute respiratory failure (therapeutic use) [27, 28]. In a phone survey of 60 intensive care units in France, 69% of physicians used NIV as first line treatment in patients with postoperative respiratory failure [29].

NIV has been applied primarily in patients both as continuous positive airway pressure (CPAP) and non-invasive intermittent positive pressure ventilation (NPPV) in different settings [22–26].

The main expected benefits from applying NIV in PPCs are an increase in gas lung volume, an improvement in gas exchange, a reduction of atelectasis and work of breathing without the need for endotracheal intubation, thus avoiding the risk of invasive mechanical ventilation [21, 24, 30–32].

We undertook a systematic review of the randomized controlled trials (RCTs) to determine the efficacy of NIV versus standard therapy to treat or to prevent PPCs in patients undergoing different types of surgery.

Methods

Search strategy

We systematically searched MEDLINE from 1996 to September 2010, EMBASE from 1950 to September 2010 and the Cochrane Central Register of controlled Trials for English articles, limiting the search to “clinical trials” and “randomized controlled trials.” The following keywords, “cardiac surgery,” “thoracic surgery,” “lung surgery,” “abdominal surgery,” “solid organ transplantation,” “thoraco-abdominal surgery” and “bariatric surgery,” were combined with any of these: “non-invasive ventilation,” “non-invasive pressure support ventilation," "continuous positive airway pressure," "bilevel ventilation," "postoperative complications," "postoperative care," "respiratory care," "acute respiratory failure," "acute lung injury" and "acute respiratory distress syndrome." Biographies of all selected articles and review article were hand searched for additional relevant articles.

Results

A total of 29 articles met the inclusion criteria and were considered in this systematic review. Nineteen of these studies used CPAP [21, 33–49], and nine used NPPV [50–58]. One study used both CPAP and NPPV [59]. Figure 1 shows the distribution of the preventive and therapeutic NIV clinical trials in a postoperative setting. Seven of the 29 articles applied NIV as a therapeutic tool to reduce PPCs. Evidence synthesis of the randomized control trials on NIV is summarized in Tables 1, 2, and 3.

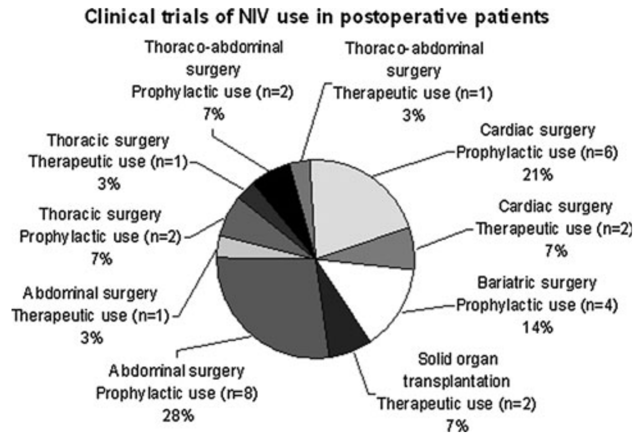

Fig. 1 Total number and percentage of the available studies of NIV in postoperative patients

Abdominal surgery

Hypoxemia complicates the recovery of 30–50% of patients after abdominal surgery; endotracheal intubation and mechanical ventilation may be required in 8–10% of cases, prolonging intensive care and hospital stay and increasing mortality [47]. In a prospective clinical evaluation over a 2-year period in 463 patients admitted to intensive care after abdominal surgery, acute respiratory failure occurred in 96 patients after extubation [60]. Seventy-two patients received NPPV. Forty-eight (67%) of these patients were non-intubated. The intubated patients compared to non-intubated patients presented significantly lower oxygenation on intensive care admission. Interestingly, oxygenation improved only in the non-intubated patients with a concomitant decrease in respiratory rate within the first hours of NPPV treatment.

Prophylactic CPAP

Compared to respiratory therapy (incentive spirometry or coughing and deep breathing), the periodic application of CPAP begun after extubation and continued in the postoperative period was associated with significantly higher arterial oxygenation [46], a quicker recovery of lung volumes [21, 42, 46] and a lower rate of atelectasis [21].

When CPAP was continuously applied for three postoperative hours both in intubated patients at the end of the abdominal surgery [33] and after extubation for at least 12 h [34], it significantly improved arterial oxygenation [33, 34], while the pulmonary complications and rate of reintubation were similar to conventional treatment. Conversely, Carlsson et al. [35], when considering only patients after cholecystectomy, did not find any beneficial effect after the application of non-invasive CPAP every 4 h in terms of arterial oxygenation or spirometry values compared to oxygen therapy. However, CPAP was not found to cause any significant difference in the length of stay [37].

A large multicenter prospective randomized clinical trial carried out by Squadrone et al. [47] cannot be considered either as prophylactic or as a curative tool. They used CPAP delivered by helmet compared with standard treatment in patients who developed acute hypoxemia after elective major abdominal surgery. Patients were extubated after surgery and underwent a 1-h screening test breathing oxygen at an inspiratory fraction of 0.3. If the PaO_2/FiO_2 remained lower than 300, the patients were randomized to receive CPAP or oxygen for a 6-h period until the acute respiratory failure resolved. Two hundred nine patients were enrolled: one patient (1%) in the CPAP group compared to ten patients (10%) in the control group required intubation. The reasons for intubation were severe hypoxemia and hemodynamic instability. The intensive care length of stay and infection rate were significantly lower in patients treated with CPAP (2.6 ± 4.2 vs. 1.4 ± 1.6 days and 3 vs. 10%, respectively). The hospital length of stay and the outcome did not differ between groups.

Therapeutic NPPV

In a matched controlled study Conti et al. evaluated the NPPV delivered by helmet or face mask to prevent endotracheal intubation in patients with acute respiratory failure after abdominal surgery [53]. Acute respiratory failure was defined by an arterial oxygenation lower than 60 mmHg and with a respiratory rate higher than 25 breaths per min. A sustained improvement in oxygenation

Table 1 Randomized controlled trials of non-invasive ventilation in abdominal/thoracic surgery

Source	Surgery	Intervention	Enrolled patients	Type of non-invasive ventilation	Control	Interface	Rate of atelectasis	Spirometric data	Arterial blood gas	Intubation rate	Outcome
Stock et al. [21]	Elective abdominal surgery	P	65	CPAP	CPT	FM	Favour CPAP	Favour CPAP	ND	ND	ND
Anderes et al. [33]	Elective abdominal surgery	P	30	CPAP	O_2	ET	ND	ND	Favour CPAP	ND	ND
Böhner et al. [34]	Elective abdominal surgery	P	204	CPAP	O_2	NM	ND	ND	Favour CPAP	Favour CPAP	ND
Carlsson et al. [35]	Cholecystectomy	P	24	CPAP	O_2	FM	No difference	No difference	No difference	ND	ND
Denehy et al. [37]	Elective abdominal surgery	P	58	CPAP	CPT	NM	ND	No difference	No difference	ND	No difference
Linder et al. [42]	Elective abdominal surgery	P	34	CPAP	CPT	MP	ND	Favour CPAP	ND	ND	ND
Ricksten et al. [46]	Elective abdominal surgery	P	50	CPAP	CPT	FM	Favour CPAP	Favour CPAP	Favour CPAP	ND	ND
Squadrone et al. [47]	Elective abdominal surgery	P	209	CPAP	O_2	H	ND	ND	Favour CPAP	Favour CPAP	No difference
Conti et al. [38]	Abdominal surgery	T	25	NPPV	NPPV	H-FM	ND	ND	No difference	Favour NPPV	No difference
Aguilò et al. [50]	Elective lung resection	P	19	NPPV	O_2	NM	ND	ND	Favour NPPV	ND	ND
Auriant et al. [52]	Lung resection	T	48	NPPV	O_2	NM	ND	ND	Favour NPPV	Favour NPPV	Favour NPPV
Perrin et al. [57]	Elective lobectomy	P	39	NPPV	O_2	FM	No difference	Favour NPPV	Favour NPPV	ND	ND

Outcome intensive care or hospital discharge, *P* prophylactic, *T* therapeutic, *CPAP* continue positive airway pressure, *NPPV* noninvasive positive pressure ventilation, *H* helmet, *MP* mouthpiece, *FM* face mask, *NM* nasal mask, *CPT* chest physiotherapy, O_2 oxygen therapy, *ND* no data

Table 2 Randomized control trials of noninvasive ventilation in thoracoabdominal and cardiac surgery

Source	Surgery	Intervention	Enrolled patients	Type of noninvasive ventilation	Control	Interface	Rate of atelectasis	Spirometric data	Arterial blood gas	Intubation rate	Outcome
Fagevik et al. [38]	Thoracoabdominal surgery	P	70	CPAP	O_2-CPT	FM	ND	No difference	Favour CPAP	Favour CPAP	No difference
Kindgen-Milles et al. [41]	Elective thoracoabdominal aneurysms	P	56	CPAP	O_2-CPT	FM	Favour CPAP	ND	Favour CPAP	Favour CPAP	ND
Michelet et al. [56]	Transthoracic esophagectomy	T	243	NPPV	O_2-CPT	FM	ND	ND	ND	Favour NPPV	ND
Stock et al. [21]	Cardiac surgery	P	38	CPAP	CPT	FM	No difference	No difference	No difference	ND	ND
De Morais Coimbra et al. [36]	Cardiac surgery	T	57	CPAP	NPPV	FM	ND	ND	Favour NPPV	Favour NIV	ND
Jousela et al. [40]	Cardiac surgery	P	30	CPAP	O_2-CPT	FM	No difference	ND	No difference	ND	ND
Pasquina et al. [44]	Cardiac surgery	T	150	CPAP	NPPV	FM	Favour NPPV	No difference	No difference	ND	No difference
Pinilla et al. [45]	Cardiac surgery	P	58	CPAP	O_2-CPT	FM	No difference	No difference	Favour CPAP	ND	ND
Thomas et al. [48]	Cardiac surgery	P	28	CPAP	CPT	NM	ND	ND	Favour CPAP	ND	ND
Zarbock et al. [49]	Cardiac surgery	P	468	CPAP	O_2-CPT	FM	ND	ND	Favour CPAP	Favour CPAP	ND
Matte et al. [59]	Cardiac surgery	P	96	CPAP NPPV	CPT	FM	No difference	Favour CPAP NPPV	Favour CPAP	ND	ND

Outcome intensive care or hospital discharge, *P* prophylactic, *T* therapeutic, *CPAP* continue positive airway pressure, *NPPV* noninvasive positive pressure ventilation, *H* helmet, *FM* face mask, *NM* nasal mask, *CPT* chest physiotherapy, O_2 oxygen therapy, *ND* no data

Table 3 Randomized controlled trials of noninvasive ventilation in bariatric surgery and after solid organ transplantation

Source	Surgery	Intervention	Enrolled patients	Type of noninvasive ventilation	Control	Interface	Rate of atelectasis	Spirometric data	Arterial blood gas	Intubation rate	Outcome
Gaszynski et al. [39]	Elective bariatric surgery	P	19	CPAP	O_2	FM	ND	ND	Favour CPAP	ND	ND
Neligan et al. [43]	Laparoscopic bariatric surgery	P	40	CPAP	O_2	FM	ND	Favour CPAP	ND	ND	ND
Ebeo et al. [54]	Elective bariatric surgery	P	27	NPPV	O_2	NM	ND	Favour NPPV	Favour NPPV	ND	ND
Joris et al. [55]	Elective bariatric surgery	P	33	NPPV	O_2	FM	ND	Favour NPPV	Favour NPPV	ND	ND
Antonelli et al. [51]	Solid organ transplantation	T	40	NPPV	O_2	FM	ND	ND	Favour NPPV	Favour NPPV	No difference
Rocco et al. [58]	Bilateral lung transplantation	T	21	NPPV	O_2	FM	ND	ND	Favour NPPV	Favour NPPV	ND

Outcome intensive care or hospital discharge, *P* prophylactic, *T* therapeutic, *CPAP* continue positive airway pressure, *NPPV* noninvasive positive pressure ventilation, *FM* face mask, *NM* nasal mask, *CPT* chest physiotherapy, O_2 oxygen therapy, *ND* no data was similarly obtained in both groups. The helmet group was associated with a significantly lower number (16 vs. 76%) of general complications (NPPV intolerance, air leaks, nosocomial pneumonia) and with a lower incidence of endotracheal intubations (20 vs. 48%); however, the intensive care mortality did not change between the groups.

Thoracic surgery

Although postoperative mortality and morbidity after lung resection has decreased over the years, its rate still remains high [52]. The overall mortality ranges between 6.2 and 24% after pneumonectomy [61, 62] and between 2.2 and 4.6% after lobectomy [61–63]. Pulmonary complications remain the leading cause of death [64], occurring in between 60 and 80% of the patients [5]. During a 6-year period, Kutlu et al. [65] investigated the frequency of acute lung injury (ALI)/acute respiratory distress syndrome (ARDS) and related mortality after pulmonary resection in more than 1,000 patients. Among the overall lung resections, 625 (55%) were carried out for lung cancer with a combined frequency of ALI/ARDS of 3.9%. Considering the age of the patients, the frequency of ALI/ARDS was 2.8% in patients under 60 years and 4.9% in patients over 60; among patients who developed ALI/ARDS, the overall mortality was 64%. Recently, Sen et al. [66] in an observational study reported that ARDS developed in 7.5% of patients requiring mechanical ventilation after lung resection.

Prophylactic NPPV

In a physiologic study, Aguilo et al. [50] investigated the short-term effects of bilevel ventilation in patients extubated after lung surgery and able to maintain spontaneous breathing compared to conventional treatment. The NPPV was maintained for 60 min. NPPV significantly increased the arterial oxygenation, and this effect was still present 1 h after removing the ventilator support. NPPV did not affect the carbon dioxide level and the physiological dead space. NPPV tolerance was quite good, and only one patient had a significant pleural air leak.

It has also been suggested that an increased risk of postoperative pulmonary complications is associated with lower levels of forced expiratory lung volume and forced vital capacity [65]. Perrin et al. [57] tested the hypothesis of whether a perioperative prophylactic use of NPPV (pre- and postoperatively) produced a better gas exchange and pulmonary function after lung resection compared to oxygen therapy in patients presenting a forced expiratory volume lower than 70% of the predicted. NPPV was initiated 7 days before surgery and was continued postoperatively for 3 days. NPPV was applied for at least five 1-h periods per day. Gas exchange and the spirometric values were significantly better in the NPPV group compared to the control group from day 1 to day 3. The hospital length of stay was significantly lower in the NPPV group (12 ± 1 days) than in the control group (19 ± 3 days).

Therapeutic NPPV

In a randomized trial, Auriant et al. [52] compared the efficacy of bilevel ventilation with standard therapy in patients with acute hypoxemic respiratory insufficiency after lung resection. Patients were enrolled if they presented at least three of the following criteria: respiratory rate higher than 25 breaths per min, active contraction of the accessory respiratory muscles, arterial oxygen ratio lower than 200 mmHg and chest radiographic abnormalities. Two hours after the initiation of treatment, NPPV treatment significantly improved the arterial oxygenation and respiratory rate. Twelve of the 24 patients (50%) in the standard treatment group required invasive mechanical ventilation versus only 5 (20.8%) in the NPPV group. Nine patients in the standard treatment group (37.5%) died versus only three (12.5%) in the bilevel ventilation group ($p = 0.045$). The mean duration of NPPV was 2.1 ± 2.4 days.

Compared to clinical studies, in a "real life" study over a 4-year period, Lefebvre et al. [67] reported that among 690 patients admitted to intensive care following lung resection, 89 (12.9%) received NPPV. NPPV was applied for hypoxemic acute respiratory failure in 59 patients (66%) and for hypercapnic acute respiratory failure in 30 patients (34%). Initial positive response to NPPV was observed in up to 80% of patients, while NPPV failure occurred in 13 patients (14%) without any difference between hypoxemic or hypercapnic respiratory failure. The average duration of NPPV was 3.4 ± 1.9 days. The mortality rate in the patients who required invasive mechanical ventilation was 46%. The two independent factors significantly associated with NPPV failure were the presence of cardiac comorbidities and the absence of any initial beneficial response.

Thoraco-abdominal vascular surgery

The repair of a thoraco-abdominal aortic aneurysm is a high-risk surgical procedure complicated by intraoperative large high blood losses, incision of the thorax and abdomen, need for elevated blood transfusions and hemodynamic instability.

In a retrospective review of thoraco-abdominal aortic aneurysm repairs, Money et al. [68] reported that 53% of the patients were extubated within 48 h after surgery. Of these patients, 21% developed acute respiratory failure presenting an almost three-fold longer hospital stay (46 days) than patients without acute respiratory failure (16 days).

Svensson et al. [69] reported respiratory problems in up to 60% of the patients that underwent thoraco-abdominal surgery. Postoperative invasive mechanical ventilation was required in about 8% of these patients. The most common reported respiratory complications were atelectasis (37%), pleural effusions (21%) and pneumonia (8%).

Etz et al. [70], in a population of more than 219 patients after aortic aneurysm repair, clearly showed that the need for prolonged respiratory therapy after surgery was associated with a higher mortality rate. Of the 60 patients (27%) who required ventilator support for more than 48 h, 12% died.

Prophylactic CPAP

In a randomized controlled study, Kindgen-Milles et al. [41] evaluated the effects of nasal CPAP continuously delivered for the first 24 h compared to intermittent CPAP plus oxygen therapy in patients following thoraco-abdominal aortic aneurysm repair. When CPAP was applied continuously, it significantly increased the arterial oxygenation. After removing CPAP the oxygenation level was similar in the two groups. The pulmonary complications and the total length of hospital stay were significantly reduced in the group continuously receiving CPAP.

Thoraco-abdominal surgery

Thoraco-abdominal resection for a carcinoma of the esophagus or cardia may present similar respiratory problems to aortic aneurysm repairs. Respiratory efficiency may be further worsened because of the transposition of the stomach into the chest [71]. The rate of respiratory complications after esophago-gastric resection varies between studies, ranging from 8 to 45% [71–73].

Prophylactic CPAP

Seventy patients undergoing thoraco-abdominal resection for carcinoma of the esophagus or cardia were randomized to receive CPAP or an inspiratory resistance-positive expiratory pressure [38]. The two treatments were applied during the first 3 days for 30 min every 2 h. The need for reintubation and prolonged mechanical ventilation was significantly lower in patients treated with CPAP while the gas exchange, lung volumes and clinical outcome were similar between the two groups.

Therapeutic NPPV

In a case control study Michelet et al. [56] compared the efficacy of NPPV with conventional treatment in patients who developed postoperative acute respiratory failure after esophagectomy. Over a 3-year period, 243 patients were admitted to the intensive care unit after surgery, and 84 patients presented acute respiratory failure. Thirty-six of these received NPPV for a mean 6 ± 2 days. NPPV use was associated with a significant reduction in reintubation rate, septic shock and intensive care unit length of stay. No complications, such as major gastric distension or anastomotic leakage, were observed. There was no difference between groups in overall hospital stay or hospital mortality.

Cardiac surgery

Pinilla et al. [45] reported that 40 to 90% of patients undergoing cardiac surgery have pulmonary complications. Possible damage of the phrenic nerve, chest opening, the use of bypass and the use of mammary arteries may further promote postoperative pulmonary impairment [59].

Prophylactic CPAP NPPV

In small series of randomized trials the application of CPAP or NPPV compared to standard treatment with oxygen therapy and chest physiotherapy for a period of 1–12 h significantly improved the gas exchange [45, 48, 49, 59] without any significant difference in the rate of atelectasis [40, 45, 74] or spirometry [45, 74].

Conversely, in a large randomized trial enrolling 468 patients, CPAP significantly reduced the incidence of pulmonary complications (hypoxemia, pneumonia, reintubation rate) compared to oxygen therapy; however, the lengths of stay in the intensive care unit and hospital were similar between groups [49].

Therapeutic CPAP NPPV

One hundred fifty patients who presented a radiological atelectasis score >2 were randomized to receive either CPAP or NPPV four times a day for 30-min sessions [44]. Compared to CPAP, NPPV caused a significantly higher reduction in the radiological atelectasis score with no significant difference in arterial blood gases. The hospital length of stay and the mortality rate were not different between the two groups.

De Morais Coimbra et al. [36] randomized 57 patients presenting acute respiratory failure to receive CPAP or bilevel ventilation. They did not find any statistically significant difference in terms of gas exchange or reduction in the intubation rate among them.

Bariatric surgery

In the largest prospective worldwide database on bariatric surgery, enrolling more than 13,000 patients, acute respiratory failure represented the fourth cause of mortality (11%) [75]. Morbidly obese compared to non-obese patients are characterized by a restrictive syndrome, an increase in chest wall elastance and intra-abdominal pressure, which may promote lung atelectasis [76–79]. Obese patients may also present several respiratory complications such as sleep apnea syndrome [80] and obesity hypoventilation syndrome. These co-morbidities may increase the sensitivity to the anesthetics and opioids, enhancing the risk of acute respiratory failure [81].

Prophylactic CPAP

Neligan et al. [43] evaluated, in 40 morbidly obese patients undergoing laparoscopic gastric bypass surgery, CPAP applied immediately after extubation in the operating room or after 30 min in the post-surgical care unit. In both groups CPAP was applied for a minimum of 8 h. The CPAP significantly preserved lung volume after 1 h and at day 1 after surgery.

A further study showed that CPAP applied after surgery in the post-surgical care unit for 8 h significantly improved arterial oxygenation without any influence on carbon dioxide elimination [39].

Similarly to previous studies, the application of bilevel ventilation during the first 24 h after gastroplasty significantly improved forced vital capacity, forced expiratory volume and arterial saturation compared to oxygen therapy alone [54, 55]. This improvement was maintained after the interruption of the NPPV, leading to a faster recovery of the preoperative spirometric lung volumes.

Some concerns had arisen regarding the use of NIV in postoperative patients because of the possible increase in the intra-luminal pressure of the stomach and intestine, which could promote anastomotic disruptions. A specific study was designated to examine the incidence of anastomotic disruption and respiratory complications [82]. The authors found that only 15 cases of major anastomotic leaks in more than 1,000 postoperative patients; out of these anastomotic leaks, only two of these leaks occurred in patients receiving CPAP. However, these results could not be applied in malnourished patients or in cancer patients undergoing surgery who may present difficulties in wound healing.

Solid organ transplantation

The indications, the number of transplantations and the rate of survival after lung transplantation have improved over the years. However, acute respiratory failure still represents the most frequent cause of postoperative mortality [83, 84].

Therapeutic NPPV

Antonelli et al. [51] randomized 40 recipients of solid organ transplants (i.e., lung, liver and kidney) with hypoxemic acute respiratory failure to NPPV delivered by face mask or to conventional medical treatment. Within the first hour, NPPV significantly improved the oxygenation in 14 patients (70%) versus 5 patients (25%) receiving conventional treatment (25%). This improvement was also observed over time in the patients managed with NPPV. Only 4 patients (20%) of the NPPV group versus 14 patients (70%) of the conventional group required invasive mechanical ventilation. Four patients (20%) compared to ten patients (50%) died in the intensive care unit. In addition, severe sepsis and septic shock developed less frequently in the NPPV group. The 16 survivors in the NPPV group had a shorter length of stay in the intensive care unit than the 10 survivors in the conventional group; however, the hospital mortality rate was not different between groups.

Rocco et al. [58], in an observational study on 21 patients who presented acute respiratory failure after bilateral lung transplantation, reported that NPPV prevented endotracheal intubation in 18 out of 21 treated patients (85%). Fifteen patients showed a sustained improvement, and 19 out of 21 patients (90%) were discharged from the intensive care unit.

Discussion

The objective of this review was to identify the best clinical evidence available on the use of NIV in the perioperative setting. NIV significantly improved arterial blood gas in 19 of the considered studies [33, 34, 36, 38, 39, 41, 45–52, 54, 55, 57–59] and the intubation rate compared to standard medical therapy in 11 of them [34, 36, 38, 41, 47, 49, 51–53, 56, 58]. NIV improved the outcome in only one study [52].

The rationale for using NIV in the postoperative patients depends mainly on the cause of the respiratory failure and whether NIV has to be used therapeutically or just as a preventive tool to avoid respiratory distress. We clearly separated the preventive and therapeutic application of NIV as well as CPAP versus NPPV in order to avoid any misunderstandings in NIV use. Although NIV is defined as any form of ventilatory support applied without ETI [52], NPPV and CPAP are different modes of delivering positive pressure. CPAP delivers a constant airway pressure during all the respiratory cycle while NPPV delivers intermittent inspiratory pressure. CPAP is a spontaneous breathing modality where the pressure applied to the respiratory system is only generated by the respiratory muscles, whereas during NPPV the pressure applied to the respiratory system is generated only by the ventilator (controlled modes) or by the ventilator and the respiratory muscles (assisted modes). NPPV may be delivered as pressure support ventilation with or without positive pressure during the expiration (PEEP) or bilevel ventilation [52].

We considered a therapeutic study, that is, a study that usually includes patients with overt acute respiratory failure, which means the presence of hypoxemia or hypercapnia coupled with signs of respiratory muscle fatigue such as tachypnea. In Squadrone's study [47], hypoxemia was the only inclusion criteria. For this reason we consider this study neither a study were NIV was used as prophylactic nor a therapeutic tool.

The present review has some limitations. (1) The review process identified data sets on the efficacy of NIV treatment separated by 21 years. Consequently, it would be possible that over this period of time the clinical scenario has changed because of better technology and more accurate diagnostic procedures. (2) The evaluated studies may differ slightly with regard to eligibility criteria and in the methods for delivering CPAP or NPPV. However, we clearly divided the studies that applied CPAP or NPPV. (3) We decided not to perform any meta-analysis evaluating the association of NIV and patient outcomes in abdominal surgery, because of the absence of any new studies since the meta-analysis carried out by Ferreyra et al. [85]. Regarding the other surgical setting (thoracic, thoraco-abdominal, bariatric surgery and solid organ transplantation), only a few studies are available and present great heterogeneity (prophylactic-therapeutic use). This makes data pooling not clinically acceptable.

In conclusion, anesthesia and surgery can profoundly impair respiratory function for several days resulting in PPCs leading to respiratory failure. Despite the limited data and the need for more randomized trials, early administration of NIV should be considered both as a prophylactic and as a therapeutic tool in postoperative patients for improving gas exchange. However, a careful search for any possible surgical complications and the selection of the correct interface (helmet vs. face mask) and type of NIV (CPAP vs. NPPV) together with the individual characteristics of the patients is fundamental for increasing NIV success.

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