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The Epidemiology and Risk Factors for Postoperative Pneumonia

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Abstract

Postoperative pneumonia is a common complication of surgery, and is associated with marked morbidity and mortality. Despite advances in surgical and anesthetic technique, it persists as a frequent postoperative complication. Many studies have aimed to assess its burden, as well as associated risk factors. However, this complication varies among the different surgical specialties, and there is a paucity of reports that comprehensively evaluate this complication. Therefore, the purpose of this study was to review the epidemiology and risk factors of postoperative pneumonia in the setting of: 1) general surgery; 2) cardiothoracic surgery; 3) orthopedic and spine surgery; and 4) head and neck surgery.

Keywords: Postoperative pneumonia; Epidemiology; Risk factors

Introduction

Postoperative pneumonia can be defined as either hospital-acquired pneumonia (pneumonia developing 48 - 72 h after admission) or ventilator-associated pneumonia (VAP, pneumonia developing 48 - 72 h after endotracheal intubation) occurring in the post-surgical patient. Currently, postoperative pneumonia is the third most common complication for all surgical procedures and is associated with increased patient morbidity and mortality [1]. Furthermore, it prolongs length of stay (LOS) by a mean of 7 - 9 days as well as increases medical costs ranging from $12,000 to $40,000 [2-4]. In addition, since passing of the Affordable Care Act in 2010 [5-7], there will be penalization by decreasing Medicare payments for all Medicare discharges for morbidities listed under legislation section 3025, the Hospital Readmissions Reduction Program, one of which is pneumonia [8]. As a result, healthcare professionals have engaged in attempts to mitigate the burden of postoperative pneumonia, with particular focus on identifying modifiable and non-modifiable factors.

The pathogenesis of postoperative pneumonia is multifactorial, and typically starts with colonization of the aero-digestive tract, aspiration of the contaminated tract secretions, and diminished host-defenses (critical illness, comorbidities, or medications). It is usually caused by bacteria, sometimes polymicrobial, especially in patients who are at risk for aspiration [9, 10]. The majority of postoperative pneumonia cases are caused by gram-negative, aerobic bacteria including *Pseudomonas*, *Klebsiella*, and *Enterobacter* species, among others. With regard to gram-positive bacteria, methicillin-resistant *Staphyloccocus aureus* is the most common cause. Even more troubling is the growing resistance to antimicrobial medications, thereby making intervention and treatment increasingly more difficult [11].

Because of the excessive burden of postoperative pneumonia, and the incidence variation of this complication among the different surgical specialties, and a paucity of reports that comprehensively evaluate this complication, it becomes essential to review and compile this information. Therefore, the purpose of this study was to review the epidemiology and risk factors of postoperative pneumonia within different surgical specialties. More specifically, we evaluated the epidemiology and the risk factors of postoperative pneumonia in the setting of: 1) general surgery; 2) cardiothoracic surgery; 3) orthopedic and spine surgery; and 4) head and neck surgery.

Methods

A comprehensive literature search using PubMed, EBSCO Host, and SCOPUS was performed for this review. Studies that were published from January 1980 to December 2016 were reviewed. The search was performed using a combination of the following terms: "postoperative pneumonia", "post-surgical pneumonia", "hospital-acquired pneumonia", and "pneumonia". This yielded a total of 833 abstracts. Abstracts were screened for relevance by two independent authors (CG and NM). Inclusion criteria included manuscripts that were written in English, were accessible through a public domain, and in-

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cluded a fully available manuscript. Exclusion criteria included manuscripts that were not written in English, were not accessible through a public domain, and did not included a fully available manuscript. References in each manuscript were also read and assessed for relevance. After exclusion of duplicates, and manuscripts written in a language other than English, the literature review yielded 52 reports (22 for general surgery, 14 for cardiothoracic, five for orthopedic/spine, and six for head/neck surgery).

In the general surgery category, there were five studies on liver surgery, one study on endoscopic hemostasis, five studies on esophagus surgery, three studies on stomach surgery, one on pancreatic surgery, and seven abdominal surgeries. In the cardiothoracic surgery category, there were two studies on coronary artery bypass graft (CABG) surgery, seven cardiac surgery studies, and five lung surgery studies. In the orthopedic surgery category, there was one knee amputation study, one total knee arthroplasty study, one hip fracture study, and two spine surgery studies. In head and neck surgery category, there were two oral surgery studies, one transoral spine study, one head and neck cancer study, one pituitary study, and one aneurysm clipping study.

Results

General surgery

Epidemiology of postoperative pneumonia in general surgery

There were several studies that associated general surgical procedures with the development of postoperative pneumonia (Table 1 [12-33]). In a retrospective study entailing 555 patients who had a partial hepatectomy, Pessaux et al [12] reported a 13% incidence of postoperative pneumonia. Similarly, Nobili et al [13] retrospectively reviewed 555 hepatectomy patients, and found that the incidence of postoperative pneumonia was 13%. Choudhuri et al [14] identified 117 hepatic resection patients with a postoperative pneumonia incidence of 10.3%. In a study encompassing 294 hepatectomy patients, Sakamoto et al [15] reported a postoperative pneumonia incidence of 8.2%. Liver surgery patients are also susceptible to VAP. Siniscalchi et al [16] reviewed 242 orthotopic liver transplantation patients, and determined a VAP incidence of 7.4%. The mortality rate was 22% vs. 4% in those with and without VAP.

Another mechanism leading to the development of postoperative pneumonia is aspiration in endoscopic hemostasis, as outlined in a retrospective study of 504 patients by Kawanishi et al [17]. They reported a postoperative aspiration pneumonia incidence of 4.8%. Postoperative aspiration pneumonia is also a risk in esophagectomy, with oral and gastric bacteria colonizing the lower respiratory tract. A retrospective study of 105 esophagectomy patients conducted by Jimbo et al [18] demonstrated an incidence of 20% for postoperative pneumonia. Poor outcomes have also been noted in esophagectomy patients with postoperative pneumonia. A retrospective analysis by Booka et al [19] looked at 284 esophagectomy patients, with a 22.5% incidence of postoperative pneumonia.

Using spirometry to predict the normal reference value of the forced respiratory volume at 1 second (FEV1) to obtain spirometric lung age may serve as predictive indicator for postoperative pneumonia. Okamura et al [20] retrospectively studied 342 esophagectomy patients, determining each patient's spirometric lung age, and observed an incidence of 28.9% for postoperative pneumonia. Similarly, lung function tests may also play a role. A retrospective review by Wei et al [21] assessed 216 esophagectomy patients, and found a postoperative pneumonia incidence rate of 10.24%. Preoperative oral care may help prevent postoperative pneumonia. A retrospective study of 280 esophagectomy patients by Soutome et al [22] displayed an incidence of 23.2% for postoperative pneumonia, and found the incidence was significantly lower in those that had preoperative oral care (19.1% vs. 29.9%, $P = 0.037$).

Kiuchi et al [23] conducted a retrospective study of 1,415 gastrectomy patients, and found an incidence of 2.2% for the development of postoperative aspiration pneumonia. Similarly, Miki et al [24] retrospectively studied 750 gastrectomy patients, who had a postoperative pneumonia incidence of 4.3%. In a retrospective study entailing 1,205 gastrectomy patients, Ntutumu et al [25] reported a postoperative pneumonia incidence of 4.7%. In a retrospective study of 1,090 pancreaticoduodenectomy (PD) and 436 distal pancreatectomy (DP) patients, Nagle et al [26] reported a postoperative pneumonia incidence of 4.3% amongst PD patients compared to 2.5% amongst DP patients. Kim et al [27] retrospectively studied 387 abdominal surgery patients, and found those with chronic obstructive pulmonary disease (COPD) had a postoperative pneumonia incidence of 12%, compared to 15.1% for those without COPD. Pasin et al [28] conducted a systematic review and meta-analysis of 269,637 patients who had open abdominal aortic surgery, with an incidence for postoperative pulmonary complications of 10.3%, where pneumonia was the most frequently reported at 7.30%. A retrospective study by Studer et al [29] outlined 70 abdominal surgery patients who developed postoperative aspiration pneumonia, and had a mortality rate of 27%. Yang et al [30] retrospectively reviewed 165,196 patients after undergoing abdominal surgery, who had a postoperative pneumonia incidence of 3.2%. They reported that patients undergoing esophagectomy or gastrectomy had the highest rate of postoperative pneumonia. A retrospective study of 185,328 obese patients undergoing surgery by Antoniou et al [31] reported the occurrence of postoperative pneumonia was lower for laparoscopic surgery compared to open surgery (0.5% vs. 1.1%). Furthermore, laparoscopic surgery also had a lower mortality rate (0.1% vs. 0.4%). Another study proposed that intraoperative expiratory flow limitation would correlate with the incidence of postoperative pulmonary complications. Spadaro et al [32] performed a prospective observational study on 330 major abdominal surgery patients, and discovered 5% of patients had postoperative pneumonia and expiratory flow limitation. A retrospective study of 5,431 abdominal surgery patients by Chen et al [33] reported a postoperative pneumonia incidence of 1.58%.

In summary, postoperative pneumonia has been shown to be a common complication for general surgical procedures

Table 1. General Surgeries [12-33]

Author	N	Type of study	Procedure	Incidence	Risk factors/outcomes	Surgical specialty
Pessaux et al [12]	555	Prospective	Partial hepatectomy	15 (2.7%)	Risk factors: nasogastric tube, transfusion, diabetes	General
Nobili et al [13]	555	Retrospective	Hepatectomy	72 (13%)	Risk factors: blood transfusion, diabetes, atrial fibrillation	General
Choudhuri et al [14]	117	Retrospective	Hepatic resection	12 (10.3%)	Risk factors: age > 70, smoking, diabetes, surgical complications, blood transfusion	General
Sakamoto et al [15]	294	Retrospective	Hepatectomy	24 (8.2%)	Risk factors: Brinkman index ≥ 400, bacteria in sputum POD1	General
Siniscalchi et al [16]	242	Retrospective	Orthotopic liver transplantation (OLT)	18 (7.4%)	Risk factors: terlipressin use, blood transfusion, mechanical ventilation duration, preoperative hospitalization, MELD score	General
Kawanishi et al [17]	504	Retrospective	Endoscopic hemostasis	24 (4.8%)	Risk factors: age > 75, procedure duration > 30 min, hemodialysis, history of stroke	General
Jimbo et al [18]	105	Retrospective	Esophagectomy	21 (20%)	Slight association of endotracheal sputum culture + pneumonia	General
Booka et al [19]	284	Retrospective	Esophagectomy	64 (22.5%)	Pneumonia predictor for poor survival	General
Okamura et al [20]	342	Retrospective	Esophagectomy	99 (28.9%)	Risk factors: higher lung age, lower BMI	General
Wei et al [21]	216	Retrospective	Esophagectomy	17 (10.24%)	Risk factor: low peak expiratory flow	General
Soutome et al [22]	280	Retrospective	Esophageal resection	65 (23.2%)	Risk factors: diabetes, dysphagia, no pre-operative oral care	General
Kiuchi et al [23]	1415	Retrospective	Gastrectomy (gastric cancer)	31 (2.2%)	Risk factors: age > 65, albumin < 3.0, stage ≥ II, hypertension, total gastrectomy	General
Miki et al [24]	750	Retrospective	Gastrectomy (gastric cancer)	32 (4.3%)	Risk factors: age > 75, diabetes, impaired respiratory function, blood transfusion	General
Ntutumu et al [25]	1,205	Retrospective	Laparoscopic gastrectomy	56 (4.7%)	Risk factors: age, total gastrectomy, time to first diet	General
Nagle et al [26]	1,090/436	Retrospective	Pancreaticoduodenectomy/ distal pancreatectomy	47/1,090 (4.3%) 11/436 (2.5%)	Risk factors: delayed gastric emptying, O_2 on POD3, COPD	General
Kim et al [27]	387	Retrospective	Abdominal surgery w/COPD as RF	COPD + → 14/117 (12%); control → 13/86 (15.1%)	Risk factor: severe COPD Mild-to-moderate COPD not a risk factor	General
Pasin et al [28]	269,637	Systematic review and meta-analysis	Open abdominal aortic surgery	7.30%	Increased mortality, more frequent with urgent procedures	General
Studer et al [29]	70	Retrospective	Abdominal surgery	Mortality 27%	Risk factors: old age, bilateral pneumonia, blood transfusion	General
Yang et al [30]	165,196	Retrospective	Major abdominal surgery	3.20%	Risk factors: esophageal surgery, ASA class, dependent functional status, prolonged OR time, age ≥ 80, severe COPD, preoperative shock, ascites, smoking	General
Antoniou et al [31]	185/328	Retrospective	Lap vs. open surgery in obese patients	0.5% → Lap 1.1% → open	Lower incidence and mortality in lap	General
Spadaro et al [32]	330	Prospective observational	Major abdominal surgery w/ expiratory flow limitation as RF	Limited flow → 5% likely to have pneumonia	Correlation with pneumonia and expiratory flow limitation	General
Chen et al [33]	5,431	Retrospective	Abdominal surgery	86 (1.58%)	Risk factors: age ≥ 70, upper abdominal surgery, surgery > 3 h	General

POD: postoperative day; MELD: model for end-stage liver disease; BMI: body mass index; COPD: chronic obstructive pulmonary disorder; ASA: American Society of Anesthesiologists; OR: operating room; RF: risk factor.

with incidences range from 0.5% to 28%.

Risk factors for postoperative pneumonia in general surgery

Pesseaux et al [12] identified three risk factors for postoperative pneumonia, which included: use of a nasogastric tube (odds ratio (OR): 1.8; 95% confidence interval (CI): 1.1 - 2.9; P = 0.01); blood transfusion (OR: 1.9; 95% CI: 1.1 - 3.8; P = 0.04); and diabetes (OR: 2.4; 95% CI: 1.3 - 4.5; P = 0.05). Patients who developed postoperative pneumonia were significantly more likely to have used a nasogastric tube (55.5% vs. 36.4%; P = 0.001). Nobili et al [13] reported risk factors to be intraoperative blood transfusion (OR: 1.9; 95% CI: 1 - 3.6; P = 0.03), diabetes mellitus (OR: 2.2; 95% CI: 1.1 - 4.5; P = 0.01), and atrial fibrillation (OR: 3; 95% CI: 1.2 - 7.4; P = 0.01). The risk factors that Choudhuri et al [14] identified in this study were age > 70 years (OR: 2.13; 95% CI: 1.04 - 1.06; P = 0.01), history of smoking (OR: 3.97; 95% CI: 0.9 - 1.67; P = 0.002), presence of diabetes (OR: 1.17; 95% CI: 0.87 - 1.04; P = 0.04), occurrence of surgical complications (leak, dehiscence, etc.) (OR: 1.62; 95% CI: 1.05 - 1.18; P = 0.03), and blood transfusion (OR: 2.76; 95% CI: 0.96 - 1.27; P = 0.008). Sakamoto et al identified the presence of bacteria in sputum as an independent risk factor for postoperative pneumonia after hepatectomy [15]. Additionally, their analysis demonstrated a Brinkman index (the number of cigarettes smoked/day multiplied by the number of years) was over 400 (OR: 4.29; 95% CI: 1.44 - 12.8; P < 0.01) and bacteria in sputum on postoperative day 1 (OR: 9.43; 95% CI: 2.11 - 42.0; P < 0.01) independently predicted postoperative pneumonia. Siniscalchi et al [16] found risk factors to be terlipressin use (OR: 31.49; 95% CI: 4.7 - 49.2; P < 0.001), red cell transfusion (OR: 1.1; 95% CI: 1.04 - 1.1; P < 0.001), duration of mechanical ventilation (OR: 1.10; 95% CI: 1.03 - 1.15; P < 0.001) and preoperative hospitalization (OR: 1.8; 95% CI: 1 - 1.9; P < 0.05). Additionally, the model for end-stage liver disease (MELD) score was higher in VAP patients on univariate analysis. Kawanishi et al [17] identified age >75 years (OR: 4.4; 95% CI: 1.5 - 13.6; P = 0.0073), procedural duration > 30 min (OR: 5.6; 95% CI: 1.9 - 18.2; P = 0.0023), hemodialysis (OR: 3.6; 95% CI: 1.2 - 11; P = 0.024), and a history of stroke (OR: 3.8; 95% CI: 1 - 14; P = 0.041) as independent risk factors for developing postoperative pneumonia. Okamura et al [20] identified higher lung age (OR: 1.02; 95% CI: 1.00 - 1.03; P = 0.010) and lower body mass index (OR: 0.89; 95% CI: 0.82 - 0.96; P = 0.006) as independent risk factors. Wei et al [21] found that low peak expiratory flow was an independent risk factor for postoperative pneumonia (HR: 0.97; 95% CI: 0.94 - 0.99; P = 0.009). Several independent risk factors identified by Soutome et al [22] included: diabetes mellitus (OR: 2.961; 95% CI: 1.159 - 7.565; P = 0.023), postoperative dysphagia (OR: 8.879; 95% CI: 4.295 - 18.352; P ≤ 0.001), and absence of preoperative oral care (OR: 0.422; 95% CI, 0.209 - 0.851; P = 0.016). Age greater than 65 years (OR: 3.59; 95% CI: 1.45 - 10.81; P = 0.010), low nutritional status (albumin < 3.0; OR: 4.51; 95% CI: 0.96 - 15.72; P = 0.029), advanced stage cancer (pStage ≥ II; OR: 2.35; 95% CI: 1.05 - 5.67; P = 0.045), concurrent hypertension (OR: 2.21; 95% CI: 1.00 - 4.70; P = 0.042), and total gastrectomy (P = 0.026; OR: 2.42) were risk factors for postoperative pneumonia identified by Kiuchi et al [23]. Miki et al [24] identified age over 75 years (OR: 2.37; 95% CI: 1.10 - 5.13; P = 0.028), diabetes mellitus (OR: 2.46; 95% CI: 1.02 - 5.59; P = 0.046), impaired respiratory function (OR: 2.72; 95% CI: .27 - 5.95; P = 0.010), and blood transfusion (OR: 3.88; 95% CI: 1.34 - 4.39; P = 0.015) as risk factors for postoperative pneumonia. Ntutumu et al [25] found advanced age (OR: 1.036; 95% CI: 1.010 - 1.063; P = 0.010), total gastrectomy (OR: 3.420; 95% CI: 1.960 - 5.969; P < 0.001), and time to first diet (OR: 1.207; 95% CI: 1.703 - 1.358; P = 0.002) were risk factors for postoperative pneumonia. Nagle et al [26] identified predictors for developing postoperative pneumonia as delayed gastric emptying (OR: 8.2; 95% CI: 3.61 - 18.62; P < 0.001), oxygen requirement on postoperative day 3 (OR: 3.2; 95% CI: 1.41 - 7.12; P = 0.005), and COPD (OR: 3.1; 95% CI: 1.01 - 9.79; P = 0.049). Kim et al [27] found severe COPD was a risk factor for postoperative pneumonia (OR: 3.47; 95% CI: 1.16 - 10.42; P = 0.027), as well as a history of hospitalization for respiratory problems (OR: 4.20; 95% CI: 1.52 - 11.59; P = 0.006), emergency surgery (OR: 3.93; 95% CI: 1.75 - 8.82; P = 0.001), amount of RBC transfusion (OR: 1.09; 95% CI: 1.05 - 1.14; P < 0.001 for one pack increase of red blood cell (RBC) transfusion), and laparoscopic surgery (OR: 0.41; 95% CI: 0.18 - 0.93; P = 0.033). The risk factors for mortality from postoperative pneumonia identified by Studer et al [29] were older age (OR: 7.41; 95% CI: 1.29 - 42.62), bilateral aspiration pneumonia (OR: 7.39; 95% CI: 1.86 - 29.29), and intraoperative blood transfusion (OR: 5.09; 95% CI: 1.34 - 19.38). Yang et al [30] found the strongest risk factors for developing pulmonary complications were esophageal operations and American Society of Anesthesiology (ASA) class. Spadaro et al [32] discovered patients with intraoperative expiratory flow limitation had an increased likelihood of developing pulmonary complications (P < 0.001). Chen et al [33] also reported that an age of 70 years and older (OR: 1.93; 95% CI: 1.16 - 3.22; P = 0.01), upper abdominal surgery (OR: 2.07; 95% CI: 1.18 - 3.64; P = 0.01), and surgeries lasting more than 3 h (OR: 2.48; 95% CI: 1.49 - 4.15; P = 0.00) were also risk factors for developing postoperative pneumonia.

Many risk factors contribute to the development of postoperative pneumonia in general surgery. The most common were older age reported in nine studies, transfusion reported in six studies, diabetes reported in five studies, and poor lung function/COPD reported in five studies.

Cardiothoracic surgery

Epidemiology of postoperative pneumonia in cardiothoracic surgery

There were several studies that associated cardiothoracic surgical procedures with the development of postoperative pneumonia (Table 2 [34-47]). In an observational study by Strobel et al [34], 16,084 patients underwent CABG, and 3.3% of patients developed postoperative pneumonia. RBC transfusions have been shown to increase the risk of developing postoperative pneumonia. Likosky et al [35] retrospectively reported on

Table 2. Cardiothoracic surgeries [34-47]

Author	N	Type of study	Procedure	Incidence	Risk factors/outcomes	Surgical specialty
Strobel et al [34]	16,084	Observational	CABG	531 (3.30%)	Developed a model of 17 pre-operative factors that may predict postoperative pneumonia	CT
Likosky et al [35]	16,182	Retrospective	CABG	576 (3.6%)	RBC transfusion increase risk	CT
Vera Urquiza R et al [36]	211	Prospective	Cardiac surgery	31 (14.6%)	Risk factors: hypertension, CRF, re-intubation, extubation after 6 h	CT
Kilic et al [37]	6,222	Retrospective	Cardiac surgery	282 (4.5%)	Created 33-point risk score Risk factors: age, chronic lung disease, peripheral vascular disease, cardiopulmonary bypass time, intraoperative red blood cell transfusion, and pre- or intraoperative intra-aortic balloon pump	CT
Allou et al [38]	7,349	Retrospective	Cardiac surgery	257 (3.5%)	Risk factors: CHF, age, diabetes, time to pneumonia onset	CT
Poelaert et al [39]	136	Retrospective	Cardiac surgery	43 (32%)	Risk Factors: mechanical ventilation > 16.6 h, PVC endotracheal tube cuff	CT
Miyata et al [40]	123	Prospective	Cardiovascular surgery	12 (9.8%)	Risk factors: cerebrovascular disorder, new neurologic deficit postoperatively	CT
Stephan et al [41]	105	Prospective observational	Cardiothoracic surgery	57 (54.3%)	Fiberoptic bronchoscopic bronchoalveolar lavage has most sensitive culture	CT
O'Keefe et al [42]	185	Retrospective	Cardiac surgery	39 (7%)	Antibiotics are being given even when cultures are negative	CT
Lugg et al [43]	670 regional thoracic center	Prospective observational	Lung resection	86 (13%)	Independent risk factors for development of pneumonia: COPD and smoking. Pneumonia patients had longer LOS and higher rates of ICU admissions.	CT
Simonsen et al [44]	7,479	Retrospective	Lung cancer surgery	268 (3.6%)	Risk factors: age ≥ 80 years, previous pneumonia, obesity, chronic pulmonary disease, alcoholism, atrial fibrillation	CT
Wang et al [45]	511	Retrospective	Lung cancer resection	15 (2.9%)	Risk factor: age > 60 years, squamous cell carcinoma	CT
Kobayashi et al [46]	941	Retrospective	Lung cancer resection	137 (14.6%)	Postoperative pyothorax leads to acute exacerbation of pneumonia, majority male	CT
Lai et al [47]	421	Retrospective	Lobectomy in stage I NSCLC	37 (8.8%)	Risk factors: COPD, low WBC count	CT

CABG: coronary artery bypass graft; RBC: red blood cell; CT: cardiothoracic; CRF: chronic renal failure; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; PVC: polyvinyl chloride; LOS: length of stay; ICU: intensive care unit; NSCLC: non-small cell lung cancer; WBC: white blood cell.

16,182 patients who underwent CABG and out of the 39.9% of patients who were transfused RBCs, 3.6% developed postoperative pneumonia. A prospective study by Vera Urquiza et al [36] followed 211 cardiac surgery patients, and postoperative pneumonia developed with an incidence of 14.6%. Kilic et al [37] described a retrospective study of 6,222 cardiac surgery patients with a postoperative pneumonia incidence of 4.5%. The use of a ventilator can be a risk factor for postoperative pneumonia, as a retrospective study by Allou et al [38] followed 7,439 cardiac surgery patients, and reported a ventilator-associated postoperative pneumonia incidence of 3.5%. Similarly, Poelaert et al [39] retrospectively studied 136 cardiac surgery patients, and reported a postoperative pneumonia incidence of 32%. Miyata et al [40] retrospectively studied 123 patients undergoing cardiovascular surgery, and found an incidence of 9.8% for postoperative aspiration pneumonia. A prospective observational study of 105 cardiothoracic surgery patients by Stephan et al [41] diagnosed 54.3% with non-ven-

tilator intensive care unit (ICU)-acquired postoperative pneumonia. A retrospective cohort study of 185 cardiac surgery patients by O'Keefe et al [42] had a postoperative pneumonia incidence of 7%. Lugg et al [43] described a prospective observational study of 670 patients receiving pulmonary resections that had a postoperative pneumonia incidence of 13%. A retrospective study by Simonsen et al [44] looked at 7479 lung cancer surgery patients, finding 3.6% of them developed pneumonia postoperatively. Similarly, a retrospective study by Wang et al [45] studied 511 patients who underwent lung resection for cancer. They found 2.9% of patients developed postoperative pneumonia. In a retrospective study of 941 patients who received a lung resection by Kobayashi et al [46], 14.6% of them had idiopathic postoperative pneumonia.

Cardiopulmonary complications, such as postoperative pneumonia, are common in lung cancer patients. Lai et al [47] retrospectively analyzed 421 patients who underwent lobectomy, and found 15.2% of the stage 1 non-small cell lung cancer patients had cardiopulmonary complications, with 8.8% having pneumonia as the primary postoperative complication.

In summary, cardiothoracic surgical procedures are commonly associated with postoperative pneumonia. The incidence of it ranges from 2% to 54%.

Risk factors for postoperative pneumonia in cardiothoracic surgery

Strobel et al [34] identified 17 preoperative risk factors associated with postoperative pneumonia: demographics (OR: 1.66; P < 0.001); hematocrit (OR: 0.98; P = 0.01); white blood cell count (OR: 1.03; P < 0.001); dyslipidemia (OR: 0.73; P = 0.03); peripheral vascular disease (OR: 1.48; P < 0.001); cerebrovascular disease (OR: 1.44; P < 0.001); diabetes mellitus (OR: 1.26; P = 0.02); liver disease (OR: 1.82; P = 0.004); home oxygen therapy (OR: 1.74; P = 0.02); history of pneumonia (OR: 1.55; P = 0.001); current cigarette smoking (OR: 2.06; P < 0.001); mild chronic lung disease (OR: 1.27; P = 0.04); moderate/severe chronic lung disease (OR: 1.91; P < 0.001); preoperative intra-aortic balloon pump (OR: 1.59; P = 0.002); recent history of arrhythmia (OR: 1.48; P = 0.002); ejection fraction (OR: 0.99; P = 0.002). Likosky et al [35] reported RBC transfusion to increase the risk of developing postoperative pneumonia (OR: 3.8; 95% CI: 3.2 - 4.6; P < 0.001). Furthermore, the odds of postoperative pneumonia increased with increasing RBC units transfused (P < 0.001). Vera Urquiza et al [36] determined independent risk factors for postoperative pneumonia were hypertension (OR: 3.94; 95% CI: 1.3 - 11.9; P = 0.01), chronic renal failure (OR: 13.67; 95% CI: 1.5 - 124.3; P = 0.02), re-intubation (OR: 22.29; 95% CI, 3.5 - 139.8; P = 0.001), and extubation after 6 h (OR: 15.81; 95% CI: 2.2 - 110.7; P = 0.005). The risk factors that Allou et al [38] identified were congestive heart failure (OR: 2.28; 95% CI: 1.17 - 4.46; P = 0.016), age (OR: 1.03; 95% CI: 1.01 - 1.06; P = 0.02), diabetes mellitus (OR: 2.26; 95% CI: 1.19 - 4.30; P = 0.01), and time to onset of postoperative pneumonia (OR: 1.18; 95% CI: 1.01 - 1.39, P = 0.04). Miyata et al [40] found the independent risk factors for postoperative pneumonia to be a history of cerebral vascular disorder (OR: 7.480; 95% CI: 1.037 - 53.935; P = 0.045), and new neurological deficits after surgery (OR: 40.867; 95% CI: 4.831 - 345.665; P = 0.007). Lugg et al [43] described COPD (OR: 1.81; 95% CI: 1.11 - 2.95; P = 0.017) and smoking (OR: 5.42; 95% CI: 1.99 - 14.76; P < 0.001) as risk factors. The important risk factors found by Simonsen et al [44] were age ≥ 80 years (adjusted OR (aOR): 3.64; 95% CI: 2.17 - 6.12), previous pneumonia (aOR: 2.68; 95% CI: 2.02 - 3.56), obesity (aOR: 1.91; 95% CI: 0.99 - 3.69), chronic pulmonary disease (aOR: 1.90; 95% CI: 1.40 - 2.57), alcoholism (aOR: 1.56; 95% CI: 0.81 - 3.01), and atrial fibrillation (aOR: 1.42; 95% CI: 0.82 - 2.45). Patients who underwent open thoracotomy had the highest risk of postoperative pneumonia (aOR: 1.79; 95% CI: 1.02 - 3.17). Wang et al [45] found age > 60 years was a significant independent risk factor (OR: 5.813; P = 0.018), as was squamous cell carcinoma histopathology (OR: 5.831; P < 0.001). Preoperative COPD (OR: 0.031; 95% CI: 0.012 - 0.078; P < 0.001) and WBC count (OR: 1.451; 95% CI: 1.212 - 1.736; P < 0.001) were identified as independent risk factors by Lai et al [47].

There were multiple risk factors associated with postoperative pneumonia in cardiothoracic surgery, but the most common risks were older age reported in five studies, poor lung function/COPD reported in five studies, cerebrovascular disease in one study, peripheral vascular disease in one study, and chronic renal failure in one study.

Orthopedic and spine surgery

Epidemiology of postoperative pneumonia in orthopedic and spine surgery

There were several studies that associated orthopedic and spine procedures with the development of postoperative pneumonia (Table 3 [48-52]). Karam et al [48] conducted a retrospective study of 6,839 patients who underwent knee amputation, and found an incidence of postoperative pneumonia of 4%. Similarly, Song et al [49] performed a prospective study on 111 TKA patients who had a postoperative pneumonia incidence of 14.4%. Lv et al [50] performed a retrospective study that included 1,429 patients who underwent hip fracture surgery, and had a 4.9% of incidence of postoperative pneumonia. Bohl et al [51] retrospectively reviewed 11,353 patients who underwent anterior cervical decompression and fusion, and found postoperative pneumonia had an incidence rate of 0.45%. Another retrospective study by Bohl et al [52] looked at 12,428 posterior lumber fusion patients who had a postoperative pneumonia incidence of 0.59%.

Orthopedic/spine surgical procedures have a postoperative pneumonia incidence ranging from 0.45% to 14%.

Risk factors for postoperative pneumonia in orthopedic and spine surgery

Song et al [49] discovered acute hypoxemia to be a risk factor for postoperative pneumonia (OR: 6.0; 95% CI: 1.4 - 25.5; P = 0.007), as well as lower body mass index (BMI) (OR: 0.9; 95% CI: 0.776 - 0.995; P = 0.042) and transfusion (OR: 2.6;

Table 3. Orthopedic and Spine Surgeries [48-52]

Author	N	Type of study	Procedure	Incidence	Risk factors/outcomes	Surgical specialty
Karam et al [48]	6,839	Retrospective	BKA or AKA	274 (4%)	Mortality: 87 (32%)	Orthopedic
Song et al [49]	111	Prospective	TKA	16 (14.4%)	Risk factors: acute hypoxemia, lower BMI, transfusion	Orthopedic
Lv et al [50]	1,429	Retrospective	Hip fracture surgery	70 (4.9%)	Risk factors: advanced age, anemia, diabetes, prior stroke, number of comorbidities, ASA score ≥ III, and some laboratory biomarkers	Orthopedic
Bohl et al [51]	11,353	Retrospective	Anterior cervical decompression and fusion	0.45%	Risk factors: age, dependent functional status, COPD, longer operation	Spine
Bohl et al [52]	12,428	Retrospective (NSQUIP)	Lumbar fusion	0.59%	Risk factors: COPD, diabetes, more operative levels Also higher rate of sepsis and mortality	Spine

BKA: below knee amputation; AKA: above knee amputation; TKA: total knee arthroplasty.

95% CI: 1.134 - 6.038; P = 0.024). Bohl et al [51] identified independent risk factors as greater age (relative risk (RR) for age 50 - 59 years: 2.6; 95% CI: 1.0 - 7.2; RR for age 60 - 69 years: 4.3; 95% CI: 1.6 - 11.7; RR for age ≥ 70 years: 9.5; 95% CI: 3.5 - 25.6; P < 0.001), dependent functional status (RR: 5.3; P < 0.001), COPD (RR: 4.4; 95% CI: 2.3 - 8.6; P < 0.001), and greater operative duration (RR for 100 - 149 min: 1.4; 95% CI: 0.7 - 3.0; RR for 150 - 199 min: 2.2; 95% CI: 1.0 - 4.9; RR for ≥ 200 min: 3.0; 95% CI: 1.5 - 6.4; P = 0.020). Another retrospective study by Bohl et al [52] identified COPD (RR: 2.7; P = 0.006), steroid use (RR: 2.6; P = 0.017), non-insulin-dependent diabetes mellitus (DM) (RR: 2.4; P = 0.003), insulin-dependent DM (RR: 2.9; P = 0.005), and greater number of operative procedure levels (two level: RR: 1.7, P = 0.033; three level: RR: 2.7, P = 0.007).

The most common risk factors for postoperative pneumonia in orthopedic and spinal surgeries were poor lung function/COPD reported in three studies, older age reported in two studies, and diabetes in one study.

Head and neck surgery

Epidemiology of postoperative pneumonia in head and neck surgery

There were several studies that associated head and neck procedures with the development of postoperative pneumonia (Table 4 [53-58]). Li et al [53] retrospectively studied 482 oral surgery patients who received a tracheotomy, and revealed a postoperative pneumonia incidence rate of 19.7%. Marda et al [54] conducted a retrospective study of 178 patients who underwent transoral odontoidectomy and posterior fixation, showing a postoperative pneumonia incidence of 5.6%. Loeffelbein et al [55] retrospectively assessed 648 patients who underwent major oral and maxillofacial surgery, and found an incidence rate for all pulmonary complications to be 18%. Similarly, in a retrospective observational study by Damian et al [56], 110 head and neck surgery cases were reviewed, yielding a postoperative pneumonia incidence of 9.1%.

Cranial surgeries were also subject to postoperative pneumonia. Desai et al [57] retrospectively assessed 15,317 patients that received pituitary surgery with postoperative pneumonia developing in 0.6% of patients. A prospective study by Savardekar et al [58] followed 103 patients undergoing microsurgical aneurysm clipping, and 27.2% of them developed postoperative pneumonia, with an associated 9.7% mortality rate.

Head and neck surgical procedures have been variably associated postoperative pneumonia. The reported incidences range from 0.6% to 27%.

Risk factors for postoperative pneumonia in head and neck surgery

Li et al [53] determined independent risk factors to be male gender (OR: 1.945; P = 0.018) and long duration of tracheotomy (OR: 1.694; P = 0.0001). Marda et al [54] reported the only significant factor for developing postoperative pneumonia for patients who underwent transoral odontoidectomy and posterior fixation was blood transfusion (P < 0.001). Loeffelbein et al [55] identified several risk factors, including male gender (OR: 1.75; 95% CI: 1.13 - 2.71; P = 0.012), advanced age (60 - 69 years OR: 2.02; 95% CI: 1.05 - 3.91; P = 0.036; > 70 years OR: 2.28; 95% CI: 1.15 - 4.52; P = 0.019), and BMI > 30 (OR: 3.24; 95% CI: 1.80 - 5.82; P = 0.001). Significant risk factors identified by Desai et al [57] were male sex (P = 0.044) and older age (P < 0.001). The predictive variables for postoperative pneumonia from Savardekar et al [58] were duration of postoperative endotracheal intubation > 48 h (aOR: 6.638; 95% CI: 1.08 - 40.8; P = 0.041), tracheostomy (aOR: 8.97; 95% CI: 0.97 - 80.8; P = 0.049), and ICU stay > 5 days (aOR: 9.8; 95% CI: 1.15 - 84.8; P = 0.036).

In head and neck surgical procedures, the most common risk factors for postoperative pneumonia were being male in two studies, longer intubation duration in two studies, longer

Table 4. Head and Neck Surgeries [53-58]

Author	N	Type of study	Procedure	Incidence	Risk factors/outcomes	Surgical specialty
Li et al [53]	482	Retrospective	Oral cancer surgery	95 (19.7%)	Risk factors: male, long duration of tracheostomy	Head and neck
Marda et al [54]	178	Retrospective	TOO and PF	10 (5.6)	Risk factor: blood transfusion	Head and neck
Loeffelbein et al [55]	648	Retrospective	Major oral and maxillofacial surgery	18.8% PPCs (pneumonia, atelectasis, pleural effusions, pulmonary embolism, pulmonary edema, pneumothorax or respiratory failure)	Risk factors: male, advanced age, BMI	Head and neck
Damian et al [56]	110	Retrospective	Head and neck cancer surgery	10 (9.1%)	Patients required longer ventilation support and frequent ICU admissions	Head and neck
Desai et al [57]	15,317	Retrospective	Pituitary surgery	98 (0.6%)	Transfrontal has higher incidence than transsphenoidal	Head and neck
Savardekar et al [58]	103	Prospective	Microsurgical clipping of aneurysm	28 (27.2%)	Mortality: 10 (9.7%) Risk factors: postoperative intubation > 48 h, tracheostomy, ICU stay > 5 days	Head and neck

TOO: transoral odontoidectomy; PF: posterior fixation; PPC: postoperative pulmonary complication.

duration of having a tracheostomy in two studies, and being admitted to the ICU in one study.

There were a wide range of incidences reported for postoperative pneumonia in the different surgical sub-specialties: general surgery (0.5-28%), cardiothoracic surgery (2-54%), orthopedic and spine surgery (0.45-14%), and head and neck surgery (0.6-27%). This wide variance may be due to heterogeneity in terms of the surgical procedures included in the studies, with some being associated with a higher incidence of postoperative pneumonia compared to other surgeries within the same surgical sub-specialty. Additionally, there may be differences between hospitals in pneumonia prevention protocols, such as frequency of incentive spirometry use, or variance in utilization of methods such as oral cleansing and suctioning (pre-operatively vs. postoperatively vs. both pre- and postoperatively).

Conclusion

While there have been many advances in surgery and anesthesia techniques, postoperative pneumonia continues to be a major complication following surgery. Furthermore, its association with increased patient morbidity and mortality, in addition to increased healthcare costs and hospital readmissions, underscores the need to identify and mitigate its associated risk factors. While this study found that the majority of risk factors such as age, sex, and preoperative functional status are often not modifiable, surgical-specific modifiable factors such as oral bacterial load, and smoking status may be avenues in which intervention may prove effective. With regard to modifiable factors, considerable focus has been placed on ICU prevention bundles with techniques such as head of bed elevation, comprehensive oral care, early mobility, and incentive spirometry; however, less effort has been focused on preoperative interventions as well as bundles for the postoperative patient on surgical units. For example, methods to decrease oral bacterial load, such as oral cleansing and suctioning systems paired with an oral antiseptic pre- and postoperatively, may help to reduce the incidence of postoperative pneumonia, and need to be investigated. Both the surgery and anesthesia communities should focus on implementing such interventions aimed at reducing the incidence of postoperative pneumonia in light of the wide range of reported incidences of postoperative pneumonia across studies and specialties. Future studies should assess the burden of postoperative pneumonia using national databases.

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