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 Staphylococcus 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-
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 include 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 esophageal 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 prostatectomy 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 Kawaniashi 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, Ntutum 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 | Pancreatoduodenectomy/ distal pancreatetomy | 47/1,090 (4.3%)/11/436 (2.5%) | Risk factors: delayed gastric emptying, O₂ 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 bacterium 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. Kawashishi 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 (OR: 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
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 7,349 cardiac surgery patients, and reported a ventilator-associated postoperative pneumonia incidence of 3.5\%. Similarly, Poelaert et al [39] retrospectively studied 123 patients undergoing cardiovascular surgery, and found an incidence of 9.8\% for postoperative aspiration pneumonia.

### 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 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   | 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.
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 lumbar 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 smoking (OR: 2.6;
Similarly, in a retrospective observational study by Damian et al., an incidence rate for all pulmonary complications to be 18%. Underwent major oral and maxillofacial surgery, and found a postoperative pneumonia incidence of 5.6%. Loeffelbein et al. [55] retrospectively assessed 648 patients who underwent transoral odontoidectomy and posterior fixation, showing 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, and revealed a postoperative pneumonia incidence rate of 19.7%. Li et al. [53] determined independent risk factors to be male, age > 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 = 0.012), 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).

### Head and neck surgical procedures

#### 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.

#### 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 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 | Lumbar fusion (NSQUIP)     | 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.
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 pre-vention 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.

### References

1. Kazaure HS, Martin M, Yoon JK, Wren SM. Long-term results of a postoperative pneumonia prevention program for the inpatient surgical ward. JAMA Surg. 2014;149(9):914-918.
2. Chastre J, Fagon JY. Ventilator-associated pneumonia. Am J Respir Crit Care Med. 2002;165(7):867-903.
3. Rello J, Ollendorf DA, Oster G, Vera-Llonch M, Bellm L, Redman R, Kollef MH. Epidemiology and outcomes of ventilator-associated pneumonia in a large US database. Chest. 2002;122(6):2115-2121.
4. Warren DK, Shukla SJ, Olsen MA, Kollef MH, Hollenbeak CS, Cox MJ, Cohen MM, et al. Outcome and attributable cost of ventilator-associated pneumonia among intensive care unit patients in a suburban medical center.
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J Clin Med Res. 2017;9(6):466-475

1. Mistry JB, Chughtai M, Elmallah RK, Die-drich AM, Bonutti PM, Delanois R, et al. What Influences How Patients Rate Their Hospital After Total Knee Arthroplasty? Surg Technol Int. 2016;28:261-265.

2. Chughtai M, Patet NK, Gwam CU, Kholopas A, Bonutti PM, Delanois RE, Mont MA. Do Press Ganey Scores Correlate With Total Knee Arthroplasty-Specific Outcome Questionnaires in Postsurgical Patients? J Arthroplasty. 2017.

3. Li M, Pan P, Hu C. [Pathogen distribution and antibiotic resistance for hospital acquired pneumonia in respiratory medicine intensive care unit]. Zhong Nan Da Xue Xue Bao Yi Xue Ban. 2013;38(3):251-257.

4. Choudhuri AH, Chandra S, Aggarwal G, Uppal R. Predictors of postoperative pulmonary complications after liver resection: Results from a tertiary care intensive care unit. Indian J Crit Care Med. 2014;18(6):358-362.

5. Sakamoto K, Tamesa T, Tokumitsu Y, Matsu-kuma S, Tokumitsu Y, Maeda Y, Takeda S, et al. Perioperative Microbiologic Monitoring of Sputum on Postoperative Day One as a Predictor of Pneumonia After Hepatectomy. J Gastrointest Surg. 2015;19(9):1662-1667.

6. Siniscalchi A, Aurini L, Benini B, Gamberini L, Nava S, Viale P, Faenza S. Ventilator associated pneumonia following liver transplantation: Etiology, risk factors and outcome. World J Transplant. 2016;6(2):389-395.

7. Kawani-shi K, Kato J, Toda N, Yamagami M, Yamada T, Kojima K, Ohki T, et al. Risk Factors for Aspiration Pneumonia After Endoscopic Hemostasis. Dig Dis Sci. 2016;61(3):835-840.

8. Jimbo K, Mori K, Aikou S, Okazaki M, Sato T, Moriya K, et al. Detection and identification of pathogenic bacteria responsible for postoperative pneumonia after esophagectomy. Esophagus. 2016.

9. Spadaro S, Caramori G, Rizzuto C, Mogli J, Zani G, Ragazzi R, Valpiani G, et al. Expiratory Flow Limitation as a Predictor of Pneumonia After Hepatectomy. J Cardiothorac Vasc Anesth. 2016;30(6):1729-1734.
a Risk Factor for Pulmonary Complications After Major Abdominal Surgery. Anesth Analg. 2017;124(2):524-530.

33. Chen P, A Y, Hu Z, Cun D, Liu F, Li W, Hu M. Risk factors and bacterial spectrum for pneumonia after abdominal surgery in elderly Chinese patients. Arch Gerontol Geriatr. 2014;59(1):186-189.

34. Strobel RJ, Liang Q, Zhang M, Wu X, Rogers MA, Theurer PF, Fishstrom AB, et al. A Preoperative Risk Model for Postoperative Pneumonia After Coronary Artery Bypass Grafting. Ann Thorac Surg. 2016;102(4):1213-1219.

35. Likosky DS, Paone G, Zhang M, Rogers MA, Harrington SD, Theurer PF, DeLucia A, 3rd, et al. Red Blood Cell Transfusions Impact Pneumonia Rates After Coronary Artery Bypass Grafting. Ann Thorac Surg. 2015;100(3):794-800; discussion 801.

36. Vera Urquiza R, Bucio Reta ER, Berrios Barcenas EA, Choreno Machain T. Risk factors for the development of postoperative pneumonia after cardiac surgery. Arch Cardiol Mex. 2016;86(3):203-207.

37. Kilic A, Okhuma R, Grimm JC, Magruder JT, Sussman M, Schneider EB, Whitman GJ. A novel score to estimate the risk of pneumonia after cardiac surgery. J Thorac Cardiovasc Surg. 2016;151(5):1415-1420.

38. Allou N, Allyn J, Snaauwaert A, Welsch C, Lucet JC, Kortbaoui R, Desmard M, et al. Postoperative pneumonia following cardiac surgery in non-ventilated patients versus mechanically ventilated patients: is there any difference? Crit Care. 2015;19:116.

39. Poelaert J, Haentjens P, Blot S. Association among duration of mechanical ventilation, cuff material of endotracheal tube, and postoperative nosocomial pneumonia in cardiac surgical patients: a prospective study. J Thorac Cardiovasc Surg. 2014;148(4):1622-1627.

40. Miyata E, Tanaka A, Emori H, Taruya A, Miyai S, Sakagoshi N. Incidence and risk factors for aspiration pneumonia after cardiovascular surgery in elderly patients. Gen Thorac Cardiovasc Surg. 2017;65(2):96-101.

41. Stephan F, Zarrouki Y, Mougeot C, Imbert A, Kortchinsky T, Pilorge C, Rezaiguia-Delclaux S. Non-Ventilator ICU-Acquired Pneumonia After Cardiothoracic Surgery: Accuracy of Diagnostic Tools and Outcomes. Respir Care. 2016;61(3):324-332.

42. O’Keefe S, Williams K, Legare JF. Hospital-Acquired Infections After Cardiac Surgery and Current Physician Practices: A Retrospective Cohort Study. J Clin Med Res. 2017;9(1):10-16.

43. Lugg ST, Agostini PJ, Tikka T, Kerr A, Adams K, Bishay E, Kalkat MS, et al. Long-term impact of developing a postoperative pulmonary complication after lung surgery. Thorax. 2016;71(2):171-176.

44. Simonson DF, Sogaard M, Bozi I, Horsburgh CR, Thomsen RW. Risk factors for postoperative pneumonia after lung cancer surgery and impact of pneumonia on survival. Respir Med. 2015;109(10):1340-1346.

45. Wang Z, Cai XJ, Shi L, Li FY, Lin NM. Risk factors of postoperative nosocomial pneumonia in stage I-IIa lung cancer patients. Asian Pac J Cancer Prev. 2014;15(7):3071-3074.

46. Kobayashi S, Karube Y, Nishihiro M, Inoue T, Araki O, Maeda S, Sado T, et al. Postoperative pyothorax as a risk factor for acute exacerbation of idiopathic interstitial pneumonia following lung cancer resection. Gen Thorac Cardiovasc Surg. 2016;64(8):476-480.

47. Lai Y, Su J, Wang M, Zhou K, Du H, Huang J, Che G. [Classification and Risk-factor Analysis of Postoperative Cardio-pulmonary Complications after Lobectomy in Patients with Stage I Non-small Cell Lung Cancer]. Zhongguo Fei Ai Za Zhi. 2016;19(5):286-292.

48. Karam J, Shepard A, Rubinfeld I. Predictors of operative mortality following major lower extremity amputations using the National Surgical Quality Improvement Program public use data. J Vasc Surg. 2013;58(5):1276-1282.

49. Song K, Rong Z, Yang X, Yao Y, Shen Y, Shi D, Xu Z, et al. Early Pulmonary Complications following Total Knee Arthroplasty under General Anesthesia: A Prospective Cohort Study Using CT Scan. Biomed Res Int. 2016;2016:4062043.

50. Lv H, Yin P, Long A, Gao Y, Zhao Z, Li J, Zhang L, et al. Clinical characteristics and risk factors of postoperative pneumonia after hip fracture surgery: a prospective cohort study. Osteoporos Int. 2016;27(10):3001-3009.

51. Bohl DD, Ahn J, Rossi VJ, Tabaraeae E, Grauer JN, Singh K. Incidence and risk factors for pneumonia following anterior cervical decompression and fusion procedures: an ACS-NSQIP study. Spine J. 2016;16(3):335-342.

52. Bohl DD, Mayo BC, Massel DH, Iantorno SE, Ahn J, Basques BA, Grauer JN, et al. Incidence and Risk Factors for Pneumonia After Posterior Lumbar Fusion Procedures: An ACS-NSQIP Study. Spine (Phila Pa 1976). 2016;41(12):1058-1063.

53. Li L, Yuan W, Zhang S, Wang K, Ruan H. Analysis of Risk Factors for Pneumonia in 482 Patients Undergoing Oral Cancer Surgery With Tracheotomy. J Oral Maxillofac Surg. 2016;74(2):415-419.

54. Marda M, Pandia MP, Rath GP, Bithal PK, Dash HH. Post-operative pulmonary complications in patients undergoing transoral odontoidectomy and posterior fixation for craniovertebral junction anomalies. J Anaesthesiol Clin Pharmacol. 2013;29(2):200-204.

55. Loeffelbein DJ, Julinek A, Wolff KD, Kochs E, Haller B, Haseneder R. Perioperative risk factors for postoperative pulmonary complications after major oral and maxillofacial surgery with microvascular reconstruction: A retrospective analysis of 648 cases. J Craniofac Surg. 2016;24(8):952-957.

56. Damian D, Esquenazi J, Duvvuri U, Haller B, Haseneder R. Perioperative risk factors for postoperative pulmonary complications in head and neck cancer surgery patients with free flap reconstructions. J Clin Anesth. 2016;28:12-18.

57. Desai SV, Fang CH, Raikundalia MD, Baredes S, Liu JK, Eloy JA. Impact of postoperative pneumonia following pituitary surgery. Laryngoscope. 2015;125(8):1792-1797.

58. Savareskoder A, Gyurmey T, Agarwal R, Podder S, Mohindra S, Gupta SK, Chhabra R. Incidence, risk factors, and outcome of postoperative pneumonia after microsurgical clipping of ruptured intracranial aneurysms. Surg Neurol Int. 2013;4:24.