Incidence, Risk, and Prevention of Ventilator-Associated Pneumonia in Adult Cardiac Surgical Patients: A Systematic Review

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ABSTRACT Ventilator-associated pneumonia remains a major cause of morbidity and mortality in postoperative heart surgery patients. We present a systematic review of the literature on the incidence, risk factors, and prevention of this condition in a population at heightened risk. doi: 10.1111/jocs.12260 (J Card Surg 2014;29:196–203)

The incidence of ventilator-associated pneumonia (VAP) in patients undergoing heart surgery has historically been higher than in medical patient populations and other surgical patient populations.1–3 VAP has been firmly linked with longer ICU and hospital lengths of stay, increased health care costs, and increased mortality.4–7

Recent multicenter evidence shows that pneumonia is still the most common major infection in adult heart surgery patients, occurring in 2.4% of all patients and becoming more than three-and-a-half times more likely in patients on mechanical ventilation for >72 hours.8 Furthermore, there is evidence to suggest that VAP in the United States may be underreported.9

This review is designed to provide a comprehensive, systematic literature review on the incidence, risk, and prevention of VAP in adult cardiac surgical patients, a cohort that appears to be particularly at risk.

DEFINITION OF VENTILATOR-ASSOCIATED PNEUMONIA

While the term “VAP” has been used frequently in the literature, it is unfortunately not uniformly defined from study to study. The studies reviewed in this article deal with the development of pneumonia in patients on mechanical ventilation for greater than or equal to some set period of time, as defined by the authors of the individual studies.

INCIDENCE OF VAP

We included 10 studies that investigated the incidence of VAP in adult cardiac surgical patients (Table 2). Seven were prospective cohort studies, two were cross sectional studies, and one was based on surveillance
<table>
<thead>
<tr>
<th>Database</th>
<th>Date Searched</th>
<th>Parameters</th>
<th>Filters</th>
<th>Articles Retrieved</th>
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<tbody>
<tr>
<td>Embase</td>
<td>6/7/2012</td>
<td>(“Ventilator-associated pneumonia” OR VAP OR “ventilator associated pneumonia”/exp OR “ventilator associated pneumonia”/exp/dm_ep) AND (“cardiac surgery” OR “cardiac surgical patient” OR “cardiac surgical patients” OR “heart surgery” OR “cardiovascular surgery” OR CCU OR CICU OR “cardiac intensive care unit” OR “thorax surgery”/exp OR “heart surgery”/exp OR “heart muscle revascularization”/exp OR “coronary care unit”/exp) AND (postoperative OR “postoperative period”/exp OR “postoperative complication”/exp OR “postoperative care”/exp)</td>
<td>None</td>
<td>136</td>
</tr>
<tr>
<td>Scopus</td>
<td>6/13/2012</td>
<td>(“Ventilator-associated pneumonia” OR VAP OR “Pneumonia, Ventilator-Associated”) AND (“Cardiac surgery” OR “Cardiac surgical patient” OR “Cardiac surgical patients” OR “heart surgery” OR “cardiovascular surgery” OR CCU OR CICU OR “cardiac intensive care unit” OR “Thoracic Surgery” OR “Cardiac Surgical Procedures” OR “myocardial revascularization” OR “Coronary Care Units”) AND (Postoperative OR “Postoperative period” OR “Postoperative complications” OR “Postoperative care”)</td>
<td>None</td>
<td>51</td>
</tr>
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</table>

### TABLE 2

VAP Incidence and Associated Mortality in Adult Cardiac Surgical Patients (Cardiac Surgical ICU Setting): Study Characteristics

<table>
<thead>
<tr>
<th>Source</th>
<th>Study Design</th>
<th>No. of Patients in Study</th>
<th>Special Considerations</th>
<th>Incidence of VAP</th>
<th>VAP Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kollef</td>
<td>Prospective cohort study</td>
<td>277</td>
<td>All patients mech. ventilated &gt;24 hours. 102 cardiothoracic ICU patients, 100 surgical ICU patients, 75 medical ICU patients</td>
<td>22/102 (21.6%)</td>
<td>37.2%</td>
</tr>
<tr>
<td>Kollef et al.</td>
<td>Prospective cohort study</td>
<td>107</td>
<td>All patients mech. ventilated &gt;48 hours</td>
<td>26/107 (24.2%)</td>
<td>8/26 (31%)</td>
</tr>
<tr>
<td>Kollef et al.</td>
<td>Prospective cohort study</td>
<td>605</td>
<td></td>
<td>59/605 (9.8%)</td>
<td>14/59 (23.7%)</td>
</tr>
<tr>
<td>Bouza et al.</td>
<td>Prospective cohort study</td>
<td>356</td>
<td></td>
<td>28/356 (7.3%)</td>
<td>16/28 (57.1%)</td>
</tr>
<tr>
<td>Bouza et al.</td>
<td>Cross sectional study</td>
<td>321</td>
<td>42 Centers, 13 countries</td>
<td>24/321 (7.5%)</td>
<td>N/A</td>
</tr>
<tr>
<td>Bouza et al.</td>
<td>Cross sectional study</td>
<td>11,915</td>
<td>17 Centers, 7 countries. Incidence reported as mean value</td>
<td>3.8%</td>
<td>N/A</td>
</tr>
<tr>
<td>Hortal et al.</td>
<td>Prospective cohort study</td>
<td>1844</td>
<td></td>
<td>106/1844 (5.7%)</td>
<td>45.7%</td>
</tr>
<tr>
<td>Hortal et al.</td>
<td>Prospective cohort study</td>
<td>986</td>
<td>25 Centers, 8 countries</td>
<td>43/986 (4.4%)</td>
<td>35%</td>
</tr>
<tr>
<td>Tamayo et al.</td>
<td>Prospective cohort study</td>
<td>1610</td>
<td>All patients status post-CPB</td>
<td>124/1610 (7.7%)</td>
<td>61/124 (49.2%)</td>
</tr>
<tr>
<td>Centers for Disease Control and Prevention</td>
<td>Surveillance report</td>
<td>(47 Cardiopulmonary ICU's in the United States)</td>
<td>6.3 cases per 1000 ventilator days (median)</td>
<td></td>
<td>N/A</td>
</tr>
</tbody>
</table>
data from the Centers for Disease Control and Prevention. Associated mortality from VAP was included in Table 2 where possible. Incidence of VAP in adult cardiac surgical patients ranged from 2.1% to 24.2%, though the highest incidence reported in the past 10 years was 7.9%. Confusion may arise because many of the studies here report incidence as a percentage of patients on mechanical ventilation who develop pneumonia rather than the incidence of VAP as it is currently reported: as cases per 1000 ventilator-days. We report each study’s incidence in its original form.

Three prospective studies from the United States were included. In 1993 Kollef reported a study of 102 patients in the CSICU of an academic tertiary care center in the United States, all of whom had received mechanical ventilation for at least 24 hours. Although the proportions of cardiac and thoracic surgical patients were not reported, he found a VAP incidence of 21.6% and an associated mortality of 37.2%. Multivariate analysis showed the incidence of VAP in adult cardiovascular surgical patients was more than double that of VAP in medical ICU patients who were also ventilated for at least 24 hours (p = 0.03). Two years later in 1995, Kollef et al. reported on 107 CSICU patients in the same center, all of whom had received mechanical ventilation for at least 48 hours, and found a similar incidence of VAP and its associated mortality, 24% and 31%, respectively. Of note, these first two series reported by Kollef et al. dealt exclusively with patients who were mechanically ventilated for a prolonged period of time, which is known to be associated with development of VAP. By contrast, a third study by Kollef et al. reported on 605 CSICU patients in the same center, this time without focusing only on patients receiving prolonged ventilation. Average postoperative ventilation time was six days in patients who eventually developed a nosocomial infection (VAP, wound infection, blood stream infection, or urinary tract infection) and 1.4 days in patients who did not. The VAP incidence in this study was 9.8% with an associated mortality of 23.7%. Although it would have been of interest to better relate ventilator time as a continuous variable to risk of VAP, this was not done.

Six studies from Europe have reported on the incidence of VAP in adult cardiac surgical patients. In 2003, Bouza et al. reported a VAP incidence of 7.9% in a Spanish CSICU; mortality from VAP was 57.1%. Three studies reported the incidence of VAP in adult cardiac surgical patients in multiple countries throughout Europe. One found a VAP incidence of 7.5%; another reported 3.8%; the third reported 4.4%. In a study of 1844 adult patients undergoing heart surgery over a period of three years at a large academic center in Spain, the incidence of VAP was found to be 5.7% and the associated mortality was 45.7%. Another prospective study from Spain looked at 1610 adult cardiac surgical patients, all of whom had undergone surgery on cardiopulmonary bypass (CPB). In this population, the incidence of VAP was 7.7% and the mortality associated with VAP was 49.2%. None of these studies related duration of ventilation and the development of VAP.

Finally, the Centers for Disease Control and Prevention published results from the National Nosocomial Infections Surveillance System (NNIS) on the incidence of VAP in patients from 47 different cardiothoracic surgical intensive care units in the United States between 2002 and 2004. Although the report did not differentiate between cardiac surgical patients and thoracic surgical patients, the NNIS data showed an incidence of 6.3 cases of VAP per 1000 ventilator days.

RISK FACTORS FOR DEVELOPING VAP

We reviewed seven studies that examined independent risk factors for development of VAP in adult cardiac surgical patients. Four were prospective cohort studies, one was a retrospective cohort study, and two were randomized clinical trials. Those risk factors found to be independently associated with the development of VAP (p < 0.05) by logistic regression modeling are listed in Table 3.

In the 1993 Kollef study, the authors used stepwise logistic regression analysis to identify four risk factors independently associated with VAP: an organ system failure index of three or greater (adjusted odds ratio [OR] = 10.2; 95% confidence interval [95% CI] = 4.5 to 23), had the greatest predictive value. This index assigns one point for each of seven organ systems found to be dysfunctional, as defined by specific criteria outlined in a prior study by the same author. Along with this association, the other three that were remarkable were age 60 or older (adjusted OR = 5.1; 95% CI = 1.9 to 14.1), prior administration of antibiotics (defined as administration of IV antibiotics for at least 24 hours during any part of the hospital course, including while on mechanical ventilation) (adjusted OR = 3.1; 95% CI = 1.4 to 6.9), and supine head position during the first 24 hours of mechanical ventilation (defined in this study as head of bed elevation < 30°) (adjusted OR = 2.9; 95% CI = 1.3 to 6.8). Additional regression analysis reported in this study showed that supine head position during the first 24 hours of mechanical ventilation was independently associated with mortality. The finding that supine head position can have dramatic consequences is especially noteworthy because maintaining hospital beds at the proper elevation (above 30°) is perhaps the single most cost-effective way to reduce VAP and its associated mortality. The association between supine head position and the development of VAP has been well-documented in other studies. Interestingly, in 2003 Bouza et al. examined 374 consecutive postoperative heart surgery patients and identified five risk factors independently associated with VAP, all different from the ones identified by Kollef. They were a prior central nervous system disorder (not specifically defined) (adjusted relative risk [RR] = 4.7; 95% CI = 2.3–15.4), ulcer disease (adjusted RR = 3.6; 95% CI = 2.7–10.9), need for mechanical circulatory support (intra-aortic balloon support or ventricular assistance) (adjusted RR = 6.8; 95% CI = 3.2–20.1), mechanical ventilation time > 96 hours (adjusted RR = 12.3; 95% CI = 9.3–26.4), and reintubation (adjusted RR = 63.7; 95% CI = 20.2–104.3). They also
compared seven different cardiac surgical procedures (valve surgery, coronary artery bypass grafting [CABG], valve/CABG surgery, heart transplantation, aortic surgery, congenital heart surgery, and pericardiectomy) and found no association between type of procedure and development of VAP. In 2009, Hortal et al. studied 1844 adult heart surgery patients and found seven independent risk factors for VAP. In common with other studies mentioned in this review, they found the following to be significant determinants of VAP: age >70 (RR = 4.0; 95% CI = 2.1–7.7), duration of mechanical ventilation (RR = 1.1 per day; 95% CI = 1.1–1.2), and reintubation (RR = 14.3; 95% CI = 7.9–25.8). In addition they revealed an association between VAP and emergent surgery (RR = 2.5; 95% CI = 1.1–5.5), intraoperative inotropic support (RR = 2.1; 95% CI = 1.1–4.5) and number of packed red blood cell units transfused perioperatively (RR = 1.1 per unit; 95% CI = 1.04–1.1).18 Armed with this knowledge, the authors attempted to create a “day 0” risk score that could predict development of VAP in cardiac surgical patients based only on preoperative data. The score was found to have a sensitivity of 93% but a specificity of only 40%. A similar “day 3” risk score was developed in an attempt to predict development of VAP in those patients who remained on mechanical ventilation on postoperative day 3. The authors again used logistic regression modeling, this time with data collected from all patients ventilated on day 3. The only independent risk factor identified in this case, however, was age >70. Thus the “day 3 score” involved only one risk factor (age greater than 70). It had a sensitivity of 69.5% and a specificity of 56%.18 In a separate 2009 study, Hortal et al.17 reported on 986 adult cardiac surgical patients in 25 centers and eight countries in Europe. They found an association between ascending aorta surgery and development of VAP (OR = 6.22; 95% CI = 1.69–22.89), the only significant association between a specific procedure and development VAP found in the literature we reviewed. It is possible that circulatory arrest may have been the culprit but this was not a variable in the article. Other risk factors determined by the study were number of blood units transfused (OR = 1.08 per unit; 95% CI = 1.03–1.13) and need for early reoperation (OR = 6.65; 95% CI = 2.10–21.01).

A retrospective study reported in 2010 attempted to match 23 cardiac surgical patients who developed VAP with 23 patients who did not.23 Regression analysis found four independent risk factors associated with developing VAP: EuroSCORE, intraoperative and postoperative blood transfusion, and postoperative ventilator time. Because this study has only been published as an abstract, additional details are unavailable; it was not included in Table 3.

In 2008, a study of 714 heart surgery patients performed by Bouza et al.24 confirmed that reintubation was an independent risk factor for development of VAP, with a relative risk very much in line with prior studies (RR = 6.07; 95% CI = 2.20–16.60). Interestingly, the authors’ regression model did not identify prolonged mechanical ventilation as an independent risk factor for developing VAP, as they defined their at-risk group as those patients ventilated for >48 hours. It was within this group that their analysis was done.

A 2008 study by Poelaert et al. looked at 134 heart surgery patients randomized to one of two types of endotracheal tubes. Looking at the population as a whole, they confirmed perioperative transfusion of packed red blood cells as a risk factor (OR = 1.50 per unit; 95% CI = 1.08–3.37) but also noted that elevated preoperative serum creatinine (OR = 1.85; 95% CI = 1.02–3.37) played a significant role.25 While the regression analysis did not determine that duration of mechanical ventilation was a factor, the authors noted that the average duration of mechanical ventilation was short, <35 hours in the control group and <18 hours in the study group.

### Table 3

VAP Risk Factors in Adult Cardiac Surgical Patients (Cardiac Surgical ICU Setting)

<table>
<thead>
<tr>
<th>Independent Risk Factor (P &lt; 0.05)</th>
<th>Effect Size</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perioperative transfusion of blood products</td>
<td>1.08–1.50 per unit</td>
<td>Hortal et al.17, Hortal et al.18, Poelaert et al.25</td>
</tr>
<tr>
<td>Days of mechanical ventilation</td>
<td>1.1 per day</td>
<td>Hortal et al.18</td>
</tr>
<tr>
<td>Reintubation</td>
<td>6.07–63.7</td>
<td>Hortal et al.18, Bouza et al.14, Bouza et al.24</td>
</tr>
<tr>
<td>Mechanical ventilation &gt;96 hours</td>
<td>12.3</td>
<td>Bouza et al.14</td>
</tr>
<tr>
<td>Organ system failure index &gt;3</td>
<td>10.2</td>
<td>Bouza et al.14</td>
</tr>
<tr>
<td>Mechanical circulatory support (intra-aortic balloon support or ventricular assistance)</td>
<td>6.9</td>
<td>Bouza et al.14</td>
</tr>
<tr>
<td>Reintervention</td>
<td>6.65</td>
<td>Hortal et al.17</td>
</tr>
<tr>
<td>Ascending aorta surgery</td>
<td>6.22</td>
<td>Hortal et al.17</td>
</tr>
<tr>
<td>Age &gt;60 years</td>
<td>5.1</td>
<td>Kollef2</td>
</tr>
<tr>
<td>Prior central nervous system disorder</td>
<td>4.7</td>
<td>Bouza et al.14</td>
</tr>
<tr>
<td>Age &gt;70 years</td>
<td>4.0</td>
<td>Hortal et al.18</td>
</tr>
<tr>
<td>Ulcer disease</td>
<td>3.6</td>
<td>Hortal et al.18</td>
</tr>
<tr>
<td>Prior administration of antibiotics</td>
<td>3.1</td>
<td>Kollef2</td>
</tr>
<tr>
<td>Supine head position</td>
<td>2.9</td>
<td>Kollef2</td>
</tr>
<tr>
<td>Emergent surgery</td>
<td>2.5</td>
<td>Hortal et al.18</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>2.2</td>
<td>Hortal et al.18</td>
</tr>
<tr>
<td>Intraoperative inotropic support</td>
<td>2.1</td>
<td>Hortal et al.18</td>
</tr>
<tr>
<td>Serum creatinine</td>
<td>1.85</td>
<td>Poelaert et al.25</td>
</tr>
</tbody>
</table>

*Reported as range of odds ratios or relative risks from cited studies. Details of studies described in the text.
PREVENTION OF VAP IN ADULT CARDIAC SURGICAL PATIENTS

We examined a total of eight RCTs (Table 4) that focused not on risk factors for VAP, but rather on the prevention of VAP in cardiac surgical patients.

Two trials, investigated the use of continuous aspiration of subglottic secretions (CASS), a possibly important therapy as it had demonstrated a significant reduction in the incidence of VAP in the combined medical-surgical ICU setting. Both studies employed Hi-Lo Evac Endotracheal Tubes (Mallinckrodt Inc.; Athlone, Ireland) for ventilated patients randomized to CASS and conventional endotracheal tubes in the control group. The first, a 1999 Kollef et al. study, compared 160 cardiac surgical patients receiving CASS to 183 not receiving CASS. The incidence of VAP in each group was not significantly different, but the CASS patients who developed VAP did so later, by an average of 2.7 days (p = 0.006). In the second trial, a 2008 study by Bouza et al., 359 patients were assigned to receive CASS and 331 were assigned to the control group. Again, overall VAP incidence was not significantly different between groups, but when the data were analyzed by duration of ventilation, among patients on mechanical ventilation for >48 hours, CASS patients experienced a significantly lower incidence of VAP compared to the control group (26.7% vs. 47.5%, p = 0.04). For all patients randomized, CASS patients experienced significantly shorter CSICU lengths of stay and significantly less antibiotic usage. Although Hi-Lo Evac Endotracheal Tubes were more expensive than conventional tubes, the authors estimated savings from decreased use of antibiotics of close to $100 per patient, which more than offset the cost of the Hi-Lo Evac Endotracheal Tube, which was approximately $10 more expensive than the conventional endotracheal tube.

A 2008 trial by Poelaert et al. compared endotracheal tube cuff materials. One hundred thirty-seven patients scheduled for heart surgery were randomized to be intubated using either polyurethane-cuffed endotracheal tubes (67 patients) or polyvinyl chloride-cuffed endotracheal tubes (67 patients). Because polyurethane is a polymer less prone to bending and folding than the thinner polyvinyl chloride, the authors hypothesized that polyurethane-cuffed endotracheal tubes would create a tighter tracheal seal that would prevent subclinical aspiration of glottic content, and thus decrease the incidence of pneumonia. In fact, they confirmed their hypothesis, finding that the incidence of early postoperative pneumonia as well as the use of antibiotic therapy was significantly lower in the polyurethane group than in the polyvinyl chloride group (23% vs. 42%, p < 0.03).

Three RCTs investigated the effectiveness of oral care with 0.12% chlorhexidine gluconate (CHX). In 1996 DeRiso et al. randomized 173 patients undergoing heart surgery (excluding heart or lung transplant surgery) to receive 0.12% CHX to diminish colonization of the oropharynx; 180 comparable patients were randomized to the control group. They reported a 69% lower incidence of respiratory tract infections in patients receiving CHX treatment twice daily (p < 0.05) with no difference in antibiotic resistance between groups. In 2002, Houston et al. randomized 561 cardiac surgical patients, comparing the use of twice daily CHX to twice daily Listerine (phenolic mixture) for oropharyngeal decontamination. They found that the incidence of nosocomial pneumonia was lower in the CHX group but not to a statistically significant degree. However, among patients on mechanical ventilation for >24 hours who also had significant microbial culture growth (determined by routine sputum cultures as part of the study protocol) patients in the CHX group had a 71% lower incidence of nosocomial pneumonia than
those in the Listerine group (p = 0.02). Segers et al.30 in 2006 performed a randomized, double-blind, placebo-controlled trial of 991 cardiac surgery patients. Five hundred patients in the experimental group received both 0.12% CHX mouthwash for oropharyngeal decontamination four times daily in conjunction with a 0.12% CHX topical gel for nasopharyngeal decontamination; 491 patients assigned to the control group received mechanical oral care with a placebo solution and no nasopharyngeal antimicrobial or placebo. Patients in the CHX group experienced an absolute risk reduction for lower respiratory infection of 6.5% (p = 0.002) as well as lower risk of deep surgical site infection and overall nosocomial infection.

A trial reported by Hulzebos et al.31 in 2009 examined the effectiveness of preoperative inspiratory muscle training (IMT) in preventing postoperative pneumonia in patients undergoing CABG. Patients in the treatment group underwent seven sessions of IMT per week for at least two weeks prior to surgery. Pneumonia occurred in nine (6.5%) of 139 patients randomized to the IMT group and 22 (16.1%) of 137 patients in the control group (OR = 0.40, 95% CI = 0.19-0.84).

In 2001, Tepaske et al.32 randomized 25 preoperative CABG patients to receive oral immune-enhancing nutritional supplement containing L-arginine, omega-3 polyunsaturated fatty acids, and yeast RNA for at least five days prior to surgery; another 25 preoperative CABG patients were assigned to the control group. The treatment group experienced 70% fewer postoperative pneumonias (three cases of pneumonia vs. nine, p = 0.047). In our judgment, however, this specific study should be placed in a broader context. A systematic review of the literature on immune-enhancing nutritional supplements found that studies evaluating the beneficial effect of specific nutritional supplementation produced results that were too heterogeneous to justify drawing any conclusions.33 That review article found that so-called “immunonutrition” did not affect overall mortality in either critically ill patients or in patients undergoing elective surgery. In patients categorized as critically ill there was no reduction in infectious complications with use of immunonutrition.33

**PERSPECTIVES ON VAP RISK, PREVENTION, AND TREATMENT**

Good data exist on the general detection, prevention, and treatment of VAP. As a result, “bundled” processes aimed at diminishing VAP have been developed and recommended for routine use by the Institute for Healthcare Improvement and others,34 though only to a limited extent in cardiac surgical patients.35 A 2009 editorial by Segers and de Mol argued that we should aggressively apply the knowledge we already have about VAP to patients who have had heart surgery.36 They argue in favor of implementing many of the elements of VAP bundles in the cardiac surgical setting: minimizing mechanical ventilation time via standardized weaning protocols, the routine interruption of sedation, keeping head-of-bed angles above 30° in the CSICU setting, avoiding reintubation by such measures as non-invasive ventilation, minimizing pathogen cross-contamination by enforcing optimal hand hygiene, and applying proven methods such as CASS and CHX. This is undoubtedly the approach we currently should be taking while more studies are performed to better understand effective prophylactic therapies in preventing VAP in cardiac surgical patients.

While not specific to cardiac surgery, the American Thoracic Society and the Infectious Disease Society of America have published guidelines for antibiotic prophylaxis and treatment for VAP.37 According to those guidelines, empiric therapy is indicated when there is a high clinical suspicion of VAP. If a patient is at risk of multidrug-resistant infection due to factors such as antimicrobial use in the past 90 days, current hospital stay of five days or more, or transfer from another healthcare facility, then combination therapy is indicated as below:

1. One of the following: cefepime, ceftazidime, imipenem, meropenem, or piperacillin-tazobactam.
2. Plus one of the following: ciprofloxacin, levofloxacin, amikacin, gentamicin, or tobramycin.
3. Add linezolid or vancomycin if there is a high risk of meticillin-resistant *Staphylococcus aureus*.

If a patient has no risk factors for multidrug-resistance, monotherapy recommendations include ceftriaxone, levofloxacin, moxifloxacin, ciprofloxacin, ampicillin/sulbactam, ertapenem; alternatively, combination therapy may be indicated in cases of VAP until cultures confirm an appropriate single agent. Clinical response should be assessed after 48–72 hours of antibiotic therapy, with subsequent treatment tailored to the case at hand.

We know of no studies that have looked at the relationship between perioperative antibiotic usage and VAP in heart surgery patients.

To our knowledge, few studies exist on the relationship between VAP and on- versus off-bypass CABG patients, though there is limited evidence that the use of CPB during CABG makes no difference in pneumonia incidence.38 There is evidence from at least one large study39 that cigarette smoke is associated with adverse pulmonary outcomes, including pneumonia, after major surgery. The same study showed that smoking cessation at least one year prior to major surgery decreases the risk of adverse postoperative pulmonary outcomes.

Finally, further study is needed on long-term outcomes after VAP. One study showed an estimated five-year mortality rate of 45% among VAP patients who survived initial hospitalization40 but it is uncertain how much mortality risk is attributable directly to VAP and how much is attributable to one or more risk factors associated with VAP.

**CONCLUSIONS AND FUTURE DIRECTIONS**

The incidence of VAP in adult cardiac surgical patients tends to range between 4% and 10% with one notable
exception: In patients who receive prolonged mechanical ventilation, VAP incidence rises dramatically. Studies reviewed here found several independent risk factors for developing VAP after heart surgery but two surfaced repeatedly: reintubation (with relative risk ranging from 6.07 to 63.7) and perioperative transfusion of blood products (with odds ratios ranging from 1.08 to 1.50 per unit transfused). There is strong evidence for interventions designed to prevent VAP in the adult heart surgery patient population, including:

1. Minimization of perioperative transfusion of blood products.17,18,25
2. Preoperative IMT performed seven days a week for two weeks.31
3. Use of endotracheal tubes made from polyurethane instead of polyvinyl chloride.25
4. Decontamination of the oro and nasopharynx two to four times daily with 0.12% chlorhexidine gluconate.28–30
5. CASS with endotracheal tubes designed for that purpose.24

This review should serve as a basis for expanding research on VAP after heart surgery. More investigation into the unique aspects of heart surgery patient and what puts him at particular risk for VAP could significantly impact the prevalence of this life-threatening complication in this high-risk population. Clearly, a better understanding of risk factors and effective preventive measures could immensely improve our care of these patients. In the meantime, application of current, evidence-based risk stratification models, targeting those patients at risk for prolonged ventilation with the application of already-determined effective strategies to prevent VAP should be the standard of care in all cardiac intensive care units. This review provides sound evidence that VAP is a complication we can measurably reduce. Its incidence and the implementation of strategies to prevent its occurrence should be metrics followed by all surgeons and intensivists involved in providing care for these patients.

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REFERENCES


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