Clinical and Economic Outcomes of Postoperative Hospital-Acquired Pneumonia Patients Who Receive Invasive Diagnostic Testing or Ventilation

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**Abstract**

- **Objective:** To describe the clinical and economic impact of traditional technologies used in the diagnosis and management of intra-abdominal postoperative surgical patients who develop hospital-acquired pneumonia (HAP).
- **Methods:** We used the National Inpatient Sample (NIS) database to identify patients with intra-abdominal operations and pneumonia diagnoses for the period 1 January to 31 December 2000 using clinical classification software codes. Independent variables collected were age at time of hospitalization, race, sex, and whether the patient had bronchoalveolar lavage (BAL), closed-lung biopsy, or mechanical ventilation. A discharge weight was applied to provide a nationally representative sample; this weight was used throughout analyses. A separate discharge weight (a variable in NIS) used for cost analysis.
- **Results:** 13,292 patients had HAP following intra-abdominal surgery. Mortality rate for these patients was 10.7%. Zero of 310 HAP patients undergoing BAL died compared with 1421 (10.7%) patients not undergoing BAL. HAP–closed-lung biopsy patients had higher mortality (26%) as compared with those not undergoing biopsy (9.7%). HAP–mechanically ventilated patients had higher mortality (22%) as compared with those not ventilated (7.8%). HAP–mechanical ventilation was associated with a 1.36-fold increased risk of discharge to a nursing facility and mean increase in charges of $125,614. HAP–closed-lung biopsy resulted in 33.34-day mean increased length of stay.
- **Conclusion:** Given the high incidence and significant impact of HAP on patient outcomes, early preventive strategies and interventions to reduce HAP should be a priority.

Hospital-acquired pneumonia (HAP) is the second most common nosocomial infection and the leading cause of death among patients with hospital-acquired infections. Patients having an intra-abdominal operation are particularly vulnerable to developing HAP [1,2]. HAP in abdominal surgery patients is associated with significantly increased mortality, longer length of stay (LOS), and higher costs of care [3]. In the surgical population, mortality from postoperative HAP ranges from 19% to 45%, and increases to 65% in patients operated on for intra-abdominal sepsis [4–6]. Because rates of HAP vary widely, and interventions (eg, routine mouth care) can reduce HAP rates, HAP has been identified as a measure of quality of care for inpatient populations by the Agency for Healthcare Research and Quality (AHRQ) [7].

Patients who develop severe cases of HAP can be diagnosed and ventilated by invasive means. Bronchoalveolar lavage (BAL) may have additive diagnostic value when patients cannot expectorate sputum samples or fail to respond to antibiotic treatment [8,9]. Patients with HAP may progress to acute respiratory failure requiring mechanical ventilation. While lifesaving, mechanical ventilation increases hospital LOS [10] and may increase mortality and morbidity by reducing host defenses [11]. A clinical diagnosis of HAP is sometimes difficult and based on nonspecific findings, with a more definitive diagnostic option being biopsy by flexible bronchoscopy. This method of diagnosis, however, is not done routinely in the majority of HAP patients [12].

The purpose of this study was to describe the clinical and economic outcomes in intra-abdominal surgical patients who developed HAP and subsequently underwent invasive diagnostic testing (BAL or closed-lung biopsy) and/or mechanical ventilation, using discharge data from a nationwide data sample.

**Methods**

**Data Source**

The Nationwide Inpatient Sample (NIS) is a large inpatient care database developed as part of the Healthcare Cost and

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Utilization Project, sponsored by the AHRQ. NIS 2000 represents a sampling of 20% (two 10% subsets) of all hospital inpatient stays from 1 January 2000 to 31 December 2000 from 994 hospitals in 28 states. The database is a weighted probability sample intended to provide national estimates of all U.S. hospital admissions. The NIS captures primary and secondary diagnoses and up to 15 diagnostic-related groups or clinical classifications that use ICD-9 codes to define comorbid diseases, new onset illnesses, procedures, and costs of care.

We collected data on patient age, sex, race, admission type, hospital LOS, total hospital charges, mortality, primary diagnosis, and surgical procedure. The study was approved by the Johns Hopkins University School of Medicine institutional review board.

Study Population
The study population included adults 18 years and older admitted electively for an intra-abdominal operation without a primary diagnosis of pneumonia. To identify patients who underwent an intra-abdominal operation, we used the clinical classification software codes 71–75, 78, 84, 89, and 104–105. This coding process was developed by AHRQ for researchers to aid in the analysis of large numbers of ICD-9 codes by truncating them from 12,000 diagnosis codes into clinically similar codes for statistical analyses (www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp). We focused on patients having an intra-abdominal operation because these patients are particularly vulnerable to developing HAP [1,2]. We used the clinical classification software code 122 to identify patients with pneumonia. Patients who underwent a BAL or closed-lung biopsy or required mechanical ventilation were then identified using the ICD-9 codes that identify bronchoscopy (3321–23), mechanical ventilation (9390, 9362, 9604, 9605, and 9670–72), and tissue biopsy (3324–29).

After the sample was selected, the discharge weight was applied to provide a national representative sample. The discharge weight was used for all analyses from this point forward. A second weight was used for total analysis charges that was provided as a variable in the NIS data set.

Outcome Variables
The primary outcome variables were in-hospital mortality, hospital LOS, total hospital charges, and patient discharge disposition. Mortality in the data set indicated in-hospital death or death during the same admission as the surgical procedure. LOS was defined as the total number of hospital days from the date of admission to the date of discharge or death. Total hospital charges are expressed in Year 2000 dollars. Patient disposition or discharge status for patients who survived was classified as sent home with or without home care or discharge to a skilled nursing facility.

Independent Variables
Patient demographics identified included age at the time of hospital admission, sex, and race, defined as white, black, Hispanic, Asian or Pacific Islander, Native American, or other. We also identified surgical procedure performed, specifically, whether or not patients underwent BAL, closed-lung biopsy, and/or mechanical ventilation.

Statistical Analysis
We performed descriptive analyses of patient characteristics and associated each separately with our primary outcome variables for patients who had BAL, biopsy, or mechanical ventilation. The chi-square statistic was used to compare in-hospital mortality and discharge to a skilled nursing facility between groups that did and did not receive BAL, closed-lung biopsy, or mechanical ventilation. We used t tests to compare hospital LOS and total hospital charges between groups that did and did not receive BAL, closed-lung biopsy, or mechanical ventilation.

Logistic regression was performed to evaluate the univariate and multivariate association between the independent variables and the outcome variables, in-hospital mortality, and patient discharge disposition. Only patients who survived and were discharged were included in the discharge disposition analysis. We used linear regression to evaluate the univariate and multivariate association between the independent variables, LOS, and hospital charges. We used a forward stepwise logistic regression to determine which variables \( P = 0.05 \) were included in the models. Results are presented as crude risk with 95% confidence intervals (CIs). The results were reviewed to determine if assumptions of logistic regression were met. The Hosmer-Lemeshow goodness-of-fit statistic and a chi-square distribution were done to determine how much of the variance resulted from the effect of the independent variables on in-hospital mortality and discharge to a skilled nursing facility.

Prior to performing logistic regression analysis, data screening was completed to identify missing data and outliers. Approximately 25% of patients’ race data was missing in our sample. The data were left in their original form and no imputation of data was performed. We used SPSS version 13.0 software (Chicago, IL) to perform all calculations.

Results
Of 13,292 intra-abdominal surgical patients with HAP, 310 (2%) received diagnostic BAL, 529 (4%) had a closed-lung biopsy, and 1759 (13%) required mechanical ventilation (Table 1).

In-hospital Mortality
The mortality rate for all patients with HAP was 10.7%. Of 310 HAP-BAL patients, zero deaths occurred compared with 1421 deaths (10.7%) in patients not undergoing BAL.
In bivariate analysis, BAL did not increase in-hospital mortality and may have even been protective (Table 2). After adjusting for patient characteristics using forward logistic regression, BAL was not associated with an increase in hospital mortality.

Of 529 HAP–closed-lung biopsy patients, 136 (26%) deaths occurred compared with 1284 deaths (97%) in patients not undergoing closed-lung biopsy. In bivariate analysis, closed-lung biopsy was associated with a threefold (95% CI, 2.4–3.6) increased risk for in-hospital mortality. After adjusting for patient characteristics, closed-lung biopsy was independently associated with a 2.6-fold (95% CI, 2.0–3.2) increased risk for in-hospital mortality.

Of 1759 HAP–mechanically ventilated patients, 389 deaths (22%) occurred compared with 1031 deaths (78%) in patients who were not ventilated. In bivariate analysis, mechanical ventilation was associated with a threefold (95% CI, 2.5–3.6) increased risk for in-hospital mortality. After adjusting for patient characteristics, mechanical ventilation was independently associated with a 1.27-fold (95% CI, 0.96–1.67) increased risk of discharge to a skilled nursing facility.

Of 529 HAP–closed-lung biopsy patients, 106 (34%) were discharged to a skilled nursing facility compared with 4355 (33%) who did not have BAL. In bivariate analysis, BAL was associated with a 0.64-fold (95% CI, 0.50–0.81) reduced risk of discharge to a skilled nursing facility. After adjusting for patient characteristics, BAL was independently associated with a 0.59-fold (95% CI, 0.45–0.77) reduced risk of discharge to a skilled nursing facility.

Discharge Disposition
Of the 11,871 postoperative patients with HAP that survived, 7410 (62%) were discharged to home and 4461 (38%) to a skilled facility (Table 2). Of the patients discharged home, 1763 (15%) required home health care.

Of 310 HAP–BAL patients, 106 (34%) were discharged to a skilled nursing facility compared with 4355 (33%) who did not have BAL. In bivariate analysis, BAL was associated with a 9% decrease in LOS compared with those not undergoing BAL (Table 3). In bivariate analysis, BAL was associated with a 0.84-fold (95% CI, 0.65–1.09) reduced risk of discharge to a skilled nursing facility. After adjusting for patient characteristics, BAL was independently associated with a 1.27-fold (95% CI, 0.96–1.67) increased risk of discharge to a skilled nursing facility.

Of 529 HAP–closed-lung biopsy patients, 98 (19%) were discharged to a skilled nursing facility compared with 4362 (33%) who did not have BAL. In bivariate analysis, BAL was associated with a mean increase LOS of 33.34 days (95% CI, 31.96–34.72). After adjusting for patient characteristics, mechanical ventilation was independently associated with a 1.36-fold (95% CI, 1.06–1.75) increased risk of discharge to a skilled nursing facility.

Length of Stay
Mean hospital LOS for HAP–BAL patients was 15.74 days (SD ± 5.41) compared with 171 days (SD ± 18.86) for those not undergoing BAL (Table 3). In bivariate analysis, BAL was associated with a 9% decrease in LOS compared with HAP patients not undergoing BAL, with a mean LOS of 15.7 days (95% CI, 13.67–17.82 days). After adjusting for patient characteristics, BAL was independently associated with a mean LOS of 16.21 days (95% CI, 14.4–18.03).

Mean hospital LOS for HAP–mechanically ventilated patients was 31.8 days (SD ± 33.43) compared with 16.56 days (SD ± 17.66) in those not undergoing a closed-lung biopsy. In bivariate analysis, closed-lung biopsy was associated with an unadjusted mean increased LOS of 30.01 days (95% CI, 28.44–31.58). After adjusting for patient characteristics, closed-lung biopsy was independently associated with a mean increase LOS of 33.34 days (95% CI, 31.96–34.72).

Table 1. Frequencies and Percentages for Sample Population (n = 13,292)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Bronchoalveolar Lavage, n (%)</th>
<th>Biopsy, n (%)</th>
<th>Mechanical Ventilation, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>259 (84)</td>
<td>481 (91)</td>
<td>1241 (71)</td>
</tr>
<tr>
<td>Black</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>47 (3)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>51 (16)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Native American</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>46 (3)</td>
</tr>
<tr>
<td><strong>Age, yr</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–29</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>30–39</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>40–49</td>
<td>53 (17)</td>
<td>97 (18)</td>
<td>0</td>
</tr>
<tr>
<td>50–59</td>
<td>50 (16)</td>
<td>53 (10)</td>
<td>114 (7)</td>
</tr>
<tr>
<td>60–69</td>
<td>53 (17)</td>
<td>139 (26)</td>
<td>395 (22)</td>
</tr>
<tr>
<td>70–79</td>
<td>95 (31)</td>
<td>45 (9)</td>
<td>843 (48)</td>
</tr>
<tr>
<td>80–89</td>
<td>58 (19)</td>
<td>149 (28)</td>
<td>407 (23)</td>
</tr>
<tr>
<td>≥ 90</td>
<td>0 (0)</td>
<td>46 (9)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0 (0)</td>
<td>153 (29)</td>
<td>537 (31)</td>
</tr>
<tr>
<td>Male</td>
<td>310 (100)</td>
<td>376 (71)</td>
<td>1222 (69)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>310</td>
<td>529</td>
<td>1759</td>
</tr>
</tbody>
</table>

*Race was not documented in 3375 of the 13,292 cases of HAP identified.
The mean hospital LOS for HAP–mechanically ventilated patients was 21.55 days (SD ± 16.79) compared with 16.24 days (SD ± 18.61) in those not ventilated. In bivariate analysis, mechanical ventilation was associated with an unadjusted mean increased LOS of 22.73 days (95% CI, 21.87–23.68). After adjusting for patient characteristics, mechanical ventilation was independently associated with a mean increased LOS of 25.36 days (95% CI, 24.26–26.46).

Total Hospital Charges
The mean total hospital charges for intra-abdominal surgery patients who developed HAP were $52,100 (SD ± $61,780) (Table 3). The mean total hospital costs for HAP-BAL patients were $52,122 (SD ± $21,857) compared with $51,903 (SD ± $62,518) for patients who did not have a BAL. In bivariate analyses, BAL was associated with an unadjusted mean increase of $59,191 (95% CI, $52,805–$65,577) in total hospital charges. After adjusting for patient characteristics, BAL was independently associated with a $59,087 (95% CI, $53,334–$64,840) mean increase in total hospital charges.

<table>
<thead>
<tr>
<th>Outcome in</th>
<th>Outcome with Procedure, n (%)</th>
<th>Outcome Without Procedure, n (%)</th>
<th>Crude Odds Ratio (95% CI)†</th>
<th>Adjusted Odds Ratio (95% CI)‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample (n = 13,292), n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAL (n = 310)</td>
<td>0</td>
<td>1421 (10.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed-lung biopsy (n = 529)</td>
<td>136 (26)</td>
<td>1284 (9.7)</td>
<td>3.0 (2.4–3.6)</td>
<td>2.6 (2.0–3.2)</td>
</tr>
<tr>
<td>Mechanical ventilation (n = 1759)</td>
<td>389 (22)</td>
<td>1031 (7.8)</td>
<td>2.9 (2.5–3.6)</td>
<td>3.9 (3.1–4.8)</td>
</tr>
<tr>
<td>Discharged to extended care</td>
<td>4461 (34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAL (n = 310)</td>
<td>106 (34.2)</td>
<td>4355 (32.8)</td>
<td>0.64 (0.50–0.81)</td>
<td>0.59 (0.45–0.77)</td>
</tr>
<tr>
<td>Closed-lung biopsy (n = 529)</td>
<td>98 (19)</td>
<td>4362 (32.8)</td>
<td>0.84 (0.65–1.09)</td>
<td>1.27 (0.96–1.67)</td>
</tr>
<tr>
<td>Mechanical ventilation (n = 1759)</td>
<td>597 (33.9)</td>
<td>3863 (29.1)</td>
<td>1.5 (1.3–1.70)</td>
<td>1.36 (1.06–1.75)</td>
</tr>
</tbody>
</table>

BAL = bronchoalveolar lavage; CI = confidence interval.
*Chi-square.
†Logistic regression.
‡Forward logistic regression, adjusted for age, race, and sex.

Discussion
To our knowledge, this is the first study to evaluate the outcome of invasive diagnostic testing and mechanical ventilation in a large national sample of HAP patients. Our study identified some important findings and indications for future research.

First, we found that BAL was associated with reduced mortality risk in intra-abdominal surgical patients with HAP. Indeed, there were no deaths among the 310 HAP patients who underwent BAL. Although we cannot establish a causal relationship between BAL and mortality in this study, there may be biologic plausibility for this association since HAP is sometimes difficult to diagnose clinically [13]. BAL has been previously suggested as a method to accurately confirm or rule out pneumonia when a clinical definition is uncertain [14,15]. For over a decade, BAL has been used successfully to guide therapy in HAP patients by identifying pathologic organisms and altering antibiotic regimens with little to no complications [16,17]. This has important implications since inappropriate or inadequate antibiotics are associated with an increased risk for mortality [18].

Future research should aim to identify the optimum time to perform BAL, including a protocol to enhance antibiotic therapy, and to determine if use of BAL is associated with reduced mortality. Patients who underwent BAL were also less likely than non-BAL patients to be discharged to a skilled nursing facility. Total charges for HAP-BAL patients
were slightly higher. Given the potential for reduced mortality, we must understand the role of BAL in HAP and weigh the costs and benefits.

Intra-abdominal surgical patients with HAP who underwent closed-lung biopsy had a threefold increase in mortality compared with patients not receiving the biopsy. Only 35% of closed-lung biopsy patients were discharged home without skilled assistance. The mean hospital LOS was highest in the closed-lung biopsy group and on average 16 days greater than for those not having a closed-lung biopsy. Hospital charges were highest among the 3 groups until adjusting for patient demographics.

This study cannot establish a causal relationship between a closed-lung biopsy and outcomes. However, the need for a closed-lung biopsy is likely a marker for severity of illness. In general, closed-lung biopsy by flexible bronchoscopy is considered a safe procedure with few associated complications [19,20]. It was not possible to determine if this sample of patients had complications, which could account for the high mortality rate and extended LOS. However, the majority of patients in this sample were older than 60 years and likely had significant comorbid diseases that may account for mortality and LOS findings.

We can safely assume that mechanically ventilated patients were cared for in the intensive care unit (ICU) since mechanical ventilation is a core technology in the ICU, and its use is growing [10]. Perhaps not surprisingly, we hypothesized that intra-abdominal surgical patients with HAP who required mechanical ventilation would have a higher mortality rate than patients not requiring ventilation. Use of mechanical ventilation is also a likely marker for severity of illness. In fact, the majority of mechanically ventilated patients in this sample were 60 to 89 years of age, which is consistent with other studies showing an increase in mortality among older patients [21–24]. Additional literature reports mortality rates between 24% and 50% for HAP patients in the United States, in rare circumstances reaching 76% when certain high-risk pathogens are involved [25,26].

Of mechanically ventilated patients, 34% required discharge to an extended care facility and were 1.5 times more likely to require extended care than the general HAP population. Another 14% of mechanically ventilated patients required home care. As such, almost half of all mechanically ventilated patients required additional care beyond their initial hospitalization. Total hospital charges were 45% higher than HAP patients not requiring mechanical ventilation.

**Study Limitations**

There are several limitations to this study. First, the validity of the HAP diagnosis in discharge data is based on hospital discharge records and not on pre-set clinical criteria. However, we selected patients who had an elective intra-abdominal operation and were then diagnosed with pneumonia. It is unlikely that patients in our sample were admitted with pneumonia, since this diagnosis is a contraindication to proceed with an elective operation. Thus, the diagnosis of HAP is assessed to represent a postoperative complication. Second, our results were seen in a national representative sample but are only generalizable to patients who underwent an elective intra-abdominal operation. Third, this study was a secondary data analysis and limited by the variables collected by the NIS. As such, we have limited clinical data regarding factors that may have contributed to HAP and cannot establish causal relationships between patient characteristics and the development of
HAP. However, it would be exceedingly expensive to conduct a prospective cohort study in this large a sample of hospitals and patients. Fourth, we could not differentiate between HAP and other types of pneumonias, such as aspiration pneumonia or ventilator-associated pneumonia. Some of the patients labeled as HAP may have also had aspiration or ventilator-associated pneumonia. This would likely increase the mortality and costs associated with HAP. Fifth, the hospital characteristics only provided demographic data for the hospitals and did not indicate when patients were transferred to an ICU or ICU physician and nursing staffing patterns that impact LOS, mortality, and costs of care [27,28].

Despite these limitations, the data sample was a national probability sample and representative of all patients in the United States. It has statistical power to identify patients with HAP who had an invasive diagnostic technique, monitoring, or ventilation and a large enough sample size to approximate the true incidence of these diagnostic or therapeutic techniques while providing clinical and economic outcomes for each group. This finding and the clinical impact of invasive diagnostic techniques, monitoring, and ventilation in HAP patients may serve as an impetus for future research.

Conclusion

HAP has associated negative clinical and economic outcomes for all stakeholders. HAP patients undergoing invasive diagnostic testing, mechanical ventilation, or monitoring had increased LOS, higher total hospital charges, and were more often discharged to a skilled nursing facility. This is probably a proxy for higher acuity within the intra-abdominal HAP population. The need for long-term care has important implications in terms of patients’ quality of life, functional status for hospital discharge planning, and costs of care. Independent of the postdischarge costs, our estimates of the total charges for HAP underestimate the total costs to insurers and the federal government, who are often responsible for these costs. Strategies to reduce these costs should be a priority for health care insurers. In addition, BAL appears to be effective in aiding diagnosis and reducing otherwise significant mortality, which warrants further investigation. Our findings regarding the incidence and impact of HAP are important given that therapies are available to prevent HAP and ventilator-associated pneumonia [29–33] and should be a clinical and research priority.

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References