Infection Control for Critically Ill Trauma Patients
A Systematic Approach to Prevention, Detection, and Provider Feedback

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Critically ill patients are particularly at risk for developing hospital-acquired infections. An understanding of the predisposing factors, the epidemiology of disease, and guidelines to treat and to prevent hospital-acquired infections is necessary to incorporate infection control into the daily care of the critically ill trauma patient. Although it remains a challenge, infection control programs have moved from providing surveillance data and guidelines recommendations to implementation and engagement programs aimed at a shared responsibility for hospital-acquired infections prevention. We describe a multidisciplinary approach to infection control in the critically ill trauma patient with a special focus on ventilator-associated pneumonia at a level 1 trauma and burn center. Key words: hospital-acquired, infection control, multidisciplinary, predisposing factors, trauma

PREDISPOSING FACTORS

The surgical patient is, by definition, particularly susceptible to infection. As a result of traumatic or surgical wounds, the skin barrier is violated, facilitating a portal for both exogenous and endogenous bacterial entry and subsequent infection. During the course of hospitalization, many patients receive acid suppressive medications that neutralize the chemical barrier to infection in the stomach. Nutritional support often is interrupted because of gastrointestinal tract discontinuity or postoperative ileus. The beneficial effects of gut immunity are diminished and the patient is at increased risk for bacterial translocation through the altered intestinal mucosa. Central venous catheters, endotracheal tubes, and urinary catheters are routinely used in the care of the critical care patient, bypassing the body’s normal defenses and providing additional portals of entry for pathogenic bacteria. These devices are subject to formation of biofilms and secondary bacterial colonization that may lead to central line-associated bloodstream infections, ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infections. In addition, trauma patients often have the unique challenge of spinal clearance, which can delay elevation of the head as a method to prevent VAP. Empiric treatment with broad-spectrum antibiotics is associated with a shift from normal bacterial flora to colonization with clinically...
significant opportunistic, multidrug-resistant organisms (MDRO) such as *Acinetobacter*, *Pseudomonas aeruginosa*, and *Clostridium difficile*. Furthermore, cross-transmission of other MDRO such as methicillin-resistant *Staphylococcus aureus* (MRSA) may occur horizontally between patients by provider hand carriage or through the inoculation and transfer via contaminated environmental surfaces.

**EPIDEMIOLOGY AND IMPACT OF HOSPITAL-ACQUIRED INFECTIONS**

For 2009, the National Healthcare Safety Network (NHSN) reported data collected from 1749 hospitals on device-associated infections such as central line–associated bloodstream infections, catheter-associated urinary tract infections, and VAP.1 For the trauma surgical population, VAP continues to be one of the most challenging hospital-acquired infections (HAIs), with incidence rates highest in the burn (7.4 cases per 1000 ventilator-days), trauma (6.5 cases per 1000 ventilator-days), and neurosurgical (3.8 cases per 1000 ventilator-days) intensive care units (ICUs) compared with an overall pooled mean rate of 2.2 cases per 1000 ventilator-days.1 Late-onset VAP, usually defined as pneumonia diagnosed after 4 days of hospitalization or mechanical ventilation, is also commonly associated with MDRO such as MRSA, *Pseudomonas*, and *Acinetobacter* further complicating the management of these critically ill patients.

The cost of HAIs, both in dollars and in morbidity, remains high despite greater attention and preventive efforts. A large-scale administrative database review of 1 355 647 admissions from 2001 to 2006 in 55 US hospitals of the cardinal health system reported 58 381 HAIs. Each HAI was associated with $7007 in added variable costs (95% CI: $3256-$10 759), $12 197 in added total costs (95% CI: $4862-$19 533), and 5.4 extra days in length of stay (95% CI: 3.1-7.8).2,3 Estimates of the number of deaths due to HAI run as high as 98 000 a year,4 and in surgical patients, mortality is estimated to increase from 3.1% to 5.7% secondary to nosocomial infections.5,6

**PREVENTIVE EFFORTS: VAP AS A MODEL**

Prevention of VAP requires coordinated efforts between providers, nursing staff, and respiratory therapists to ensure implementation and compliance with the Institute for Healthcare Improvement VAP preventive bundle. The elements of this initiative include maintaining the elevation of the head of bed at more than 30°, a daily sedation awakening trial and assessment of readiness for extubation, oral care with chlorhexidine, peptic ulcer disease prophylaxis, and deep vein thrombosis prophylaxis. At our institution, each case of VAP is reviewed monthly at the unit level with the multidisciplinary team (nursing staff, providers, respiratory therapists, pharmacists, unit managers, and unit medical directors) involved in the care of the patient to review risk factors for VAP as well as compliance with the bundle elements. A facilitated review allows the team to determine whether there have been opportunities to prevent the development of VAP. These reviews engage the staff as they take ownership for the quality of care on the unit and attach a “real person” or “face” to the rates of VAP on their unit or service. As a result, our multidisciplinary team has identified several significant system-based impediments to consistent application of the bundle, leading to a number of nurse- and provider-driven initiatives, including placement of oral care kits at the bedside, tracking of head-of-bed compliance over time, and tracking of spine clearance cases. With the support of nursing and physician leadership in an effort to decrease VAP hospital wide, these grass-roots initiatives have been shared and implemented throughout all the ICUs at HMC.

To monitor compliance with individual bundle elements, as well as to assess the effectiveness of our new initiatives, we have collaborated in the development of a real-time
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Electronic Quality and Safety Dashboard. This module, accessible through our electronic medical record and on monitors mounted throughout the ICUs, provides reminders for those elements not currently in compliance with the bundle. In addition, monthly electronic audits of the individual bundle elements identify opportunities for improvement as well as opportunities to enhance documentation within the electronic medical record. For instance, a drop in compliance with sedation awakening was noted after a change in the electronic medical record nursing documentation process because it was removed from the medication administration record section. The monthly audits of bundle compliance are reviewed with the individual units. Being able to highlight specific areas of the bundle that are done well or need improvement has allowed for specific feedback and celebration when 100% compliance is achieved. Weekly monitoring has also allowed for more immediate feedback rather than waiting for a month-end review.

Increased focus on readiness for extubation through the ICU daily plan has led to levels of ventilator utilization in our trauma ICU later the NHSN mean (0.39 vs 0.51). Documenting readiness for extubation has improved substantially over the last 2 years as each VAP is reviewed and the need for adequate documentation was noted.

Also included in the monthly reviews are the hand hygiene compliance rates that are the foundation of preventing any HAI. The HMC monitors hand hygiene compliance in 3 ways: monthly observations, monthly calculation of gel and soap usage through the Washington State Hospital Association, and as a part of the discharge survey from patients and their families. Compliance is reported by discipline, location, and service. Enhanced transparency and access to this data for all staff has improved compliance and has been a key component in reducing transmission of MDRO such as MRSA.

A particular area of challenge to bundle compliance in our trauma patients was the need to clear spine precautions to ensure safe mobility prior to head-of-bed elevation. Our goal was that 95% of our trauma patients have their spine cleared within 48 hours allowing elevation of the head of bed, but we encountered challenges to implementation. To facilitate this effort, we developed an automated electronic query to identify all patients in the hospital on spine precautions and monitored the time to head of bed at 30° or more for each patient. This daily list is distributed electronically to our trauma care coordinators who can review patients who have not yet had their spine cleared to determine and potentially resolve the reason for delay.

In addition to a focus on hand hygiene, isolation practices, and compliance with the ventilator bundle, we introduced daily chlorhexidine baths into the trauma ICU in May 2007. This not only led to a reduction in MRSA transmission and catheter-associated bloodstream infections, but also was associated with a reduction in MRSA VAP, which had not previously been reported (5.7 vs 1.6 per 1000 ventilator-days, \( P = .03 \).)

These preventive measures, combined with fewer device days have led to a sustained reduction in the number of VAP cases from 266 in 2007 to 98 in 2010, reflecting a 63% reduction in the absolute number of VAP cases during this 4-year time period. The incidence of VAP has also decreased during this time from 20 cases per 1000 ventilator-days to consistently less than 10 per 1000 ventilator-days, despite our high-risk patient trauma and burn population (the Figure).

**DIAGNOSIS AND MANAGEMENT OF VAP**

In 2004, we implemented a guideline for the management of VAP emphasizing quantitative bronchoscopy for diagnosis and empiric therapy on the basis of local microbiology and antimicrobial resistance patterns. Given the variation in published diagnostic criteria for VAP, we wished to standardize
our practice across ICU providers. We instituted a protocol recommending bronchoscopic alveolar lavage (BAL) to obtain quantitative lower respiratory tract cultures for all patients who were suspected to have VAP on the basis of abnormal radiographic results consistent with pneumonia (ie, new or persistent focal infiltrate(s) or diffuse lung injury pattern), who had not received any new antimicrobial therapy for 72 hours or more, and who met one or more of the following criteria: fever (temperature of 38.5°C or higher), purulent endotracheal secretions, or leukocytosis (defined as a white blood cell count of 10,000/mm³ or greater). As bronchoscopy was not readily available at night, the use of mini-BAL was introduced in January 2005. Mini-BAL was performed by trained respiratory therapists who introduced a catheter blindly into the bronchial tree allowing lavage of the lower respiratory tract. The diagnosis of VAP was considered confirmed if quantitative cultures of bronchoalveolar lavage fluid samples yielded $10^4$ or more colony-forming units (cfu) per mL or if cultures of protected specimen brush samples yielded $10^3$ or more cfu/mL consistent with the NHSN Pneumonia with Common Bacterial or Filamentous Fungal Pathogens and Specific Laboratory Findings (PNU2) criteria.

In a before and after study, implementation of this protocol improved antimicrobial utilization with more frequent de-escalation of antimicrobial therapy based on quantitative culture results (69.4% vs 61.3%, $P = .0342$), increased appropriate definitive therapy (89.0% vs 80.4%, $P = .0004$), and decreased duration of therapy (10.7 vs 12.0 days, $P = .0014$). During the 12 months after guideline implementation, there were 2417 antibiotic-days among the 459 patients with suspected VAP, a decrease in the mean number of antibiotic-days per patient (6.2 antibiotic-days per patient before implementation vs 5.3 antibiotic-days

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**Table.** Microbiology of Late-Onset VAP at Harborview Medical Center

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>July 2003-June 2004 (N = 138), n (%)</th>
<th>July 2008-June 2009 (N = 114), n (%)</th>
<th>July 2009-June 2010 (N = 83), n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acinetobacter</em> spp.*</td>
<td>44 (32)</td>
<td>4 (4) ↓</td>
<td>4 (5) ↓</td>
</tr>
<tr>
<td>MRSA*</td>
<td>32 (23)</td>
<td>8 (7) ↓</td>
<td>2 (2) ↓</td>
</tr>
<tr>
<td>MSSA**</td>
<td>21 (15)</td>
<td>30 (26) ↑</td>
<td>23 (28) ↑</td>
</tr>
<tr>
<td><em>Haemophilus</em> spp.</td>
<td>20 (14)</td>
<td>24 (21)</td>
<td>13 (16)</td>
</tr>
<tr>
<td><em>Pseudomonas</em> spp.</td>
<td>13 (9)</td>
<td>14 (12)</td>
<td>15 (18)</td>
</tr>
<tr>
<td><em>Enterobacter</em> spp.</td>
<td>4 (3)</td>
<td>12 (11)</td>
<td>4 (5)</td>
</tr>
<tr>
<td>Klebsiella spp.</td>
<td>7 (5)</td>
<td>7 (6)</td>
<td>5 (6)</td>
</tr>
<tr>
<td>Serratia spp.</td>
<td>5 (3)</td>
<td>7 (6)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>6 (4)</td>
<td>6 (5)</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-sensitive *Staphylococcus aureus*; VAP, ventilator-associated pneumonia.

*More than 4 days of mechanical ventilation or length of hospitalization. *P = .0001; **P = .01.

per patient after implementation; *P = .020). This reduction was most prominent among patients treated for suspected early-onset VAP (6.9 antibiotic-days per patient before implementation vs 4.7 antibiotic-days per patient after implementation; *P = .011), and it included a decrease in the total duration of imipenem use, from 61 to 45 days, and a decrease in the total duration of piperacillin-tazobactam use from 66 to 23 days, in patients with suspected early-onset VAP.8

Improved antimicrobial usage with decreased selective pressure along with infection control initiatives such as hand hygiene, active surveillance cultures of all patients admitted to the ICU for MRSA and carbapenem-resistant *Acinetobacter* on admission every 7 days and at discharge from the ICU, the use of contact precautions, minimizing shared equipment, and improved terminal cleaning by environmental services with monthly cleaning audits has led to dramatic reductions in VAP due to MRSA and *Acinetobacter* (the Table). These changes in local microbiology have led to modification of empiric antimicrobial therapy and reduced use of imipenem for late-onset VAP resulting in an estimated savings in excess of $130 000 per year.

**SUMMARY**

Critically ill trauma patients are at high risk for HAI and acquisition of MDRO requiring an integrated approach to infection control. We have described a comprehensive multidisciplinary approach for VAP focused on prevention, diagnosis, and appropriate management with detailed surveillance of VAP cases and rates, microbiology, and antimicrobial resistance, which can be used as a model for other HAI preventive efforts. This had led to a 63% reduction in the number of VAP cases over the past 4 years although improving our management of those cases that do occur through appropriate antimicrobial therapy based on local microbiology. The hallmark has been an iterative process of surveillance, feedback, and partnership with the front-line critical care clinicians and staff to develop novel approaches to keep our patients safe and improve the quality of their care.
REFERENCES


