Hospital-Onset Infections: A Patient Safety Issue

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Hospital-onset infections, particularly those involving the urinary tract, lung, and bloodstream, are common and costly and cause substantial morbidity. This article analyzes the case of a 78-year-old man with lung cancer who died after developing hospital-onset pneumonia and urinary catheter–related infection during hospitalization for elective removal of a cerebellar metastasis.

The field of infection control could benefit by adopting several approaches advocated by patient safety adherents, such as root-cause analysis. For example, hospital-onset infections that are implicated as attributable causes of death should perhaps be reviewed by local infection control teams regardless of the institution's overall infection rates. The patient safety movement can also learn from the traditions of infection control and hospital epidemiology. Specifically, applying infection control–based practices to safety problems may enhance safety. Such practices include establishing clear definitions of adverse events, standardizing methods for detecting and reporting events, creating appropriate rate adjustments for case-mix differences, instituting evidence-based intervention programs, and relying on skilled professionals to promote ongoing improvements in care.

**CHRONOLOGY OF EVENTS**

Tom Reilly (a pseudonym), a 78-year-old man with stage IV non–small-cell lung cancer and chronic obstructive pulmonary disease, developed several infections during hospitalization for elective surgical resection of a single cerebellar metastasis. On the day of his surgery, Mr. Reilly was brought to the operating room, where an arterial line, a standard Foley catheter, and two large-gauge peripheral intravenous lines were placed and a single intravenous dose of vancomycin was administered. At this time, the Foley catheter and the arterial catheter were removed; one peripheral intravenous catheter remained. After removal of the Foley catheter, the patient was unable to void. A straight urinary catheter was inserted, and 700 mL of clear yellow urine was removed. The patient required another straight urinary catheterization 4 hours later, and 500 mL of urine was removed. Thereafter, the patient was able to void into a urinal without difficulty. Other than the preoperative dose of vancomycin, the patient did not receive antibiotics.

**RISKS FOR INFECTIOUS COMPLICATIONS DURING HOSPITALIZATION**

This elderly patient with noncurable metastatic lung cancer underwent a palliative intracranial surgical procedure requiring postoperative intensive care. Even with flawless care, he was prone to developing serious infectious complications as a consequence of both endogenous risk factors (those that were intrinsic to his underlying health status) and exogenous risk factors (those that were attributable to the structure and processes of his complex medical care).

Data from the National Nosocomial Infections Surveillance (NNIS) System of the U.S. Centers for Disease Control and Prevention (CDC) provide an aggregate view of the frequency of common infections among hospitalized patients in the United States (Table 1, 2). Infection incidence rates are presented as device-specific incidence densities (number of infections per device-days × 1000) to adjust for the two most powerful predictors of infection risk: length of hospital stay and use of invasive devices.

Urinary tract infections are the most common hospital-onset infections; they account for approximately 40% of such infections in the United States (3, 4). More than 80% of urinary tract infections are associated with an indwelling urinary catheter, and risk increases with duration of catheterization. Mr. Reilly was at risk for urinary tract infection because he was elderly, had a history of malignancy, and had a urinary catheter in place for more

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Table. Incidence of Infection in the Intensive Care Unit from January 1995 to April 2000, according to the National Nosocomial Infections Surveillance System

<table>
<thead>
<tr>
<th>Type of Intensive Care Unit</th>
<th>Type of Infection</th>
<th>Pooled Mean Infection Incidence Density*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical</td>
<td>Ventilator-associated pneumonia</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Catheter-associated urinary tract infection</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>Vascular catheter-associated bloodstream infection</td>
<td>5.3</td>
</tr>
<tr>
<td>Surgical</td>
<td>Ventilator-associated pneumonia</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>Catheter-associated urinary tract infection</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>Vascular catheter-associated bloodstream infection</td>
<td>4.9</td>
</tr>
</tbody>
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* Pooled mean infection incidence density = number of infections per device-days × 1000.

than 24 hours (5). He was also at increased risk for catheter-related urinary tract infection because he did not receive systemic antibiotics effective against gram-negative bacilli (5–7). However, administration of prophylactic antibiotics solely to reduce the risk for catheter-related urinary tract infection is not currently recommended for most hospitalized patients (8).

Pneumonia, the second most common hospital-onset infection, is associated with high mortality rates, increased length of stay, and increased resource utilization (9–11). Pneumonia was recently found to be the leading cause of nosocomial infection in medical–surgical intensive care units, accounting for 31% of all hospital-onset infections (1). Mr. Reilly had at least five endogenous risk factors for pneumonia (chronic pulmonary disease, severe underlying illness, older age, impaired airway reflexes, and male sex) (11–14) and at least two major exogenous risk factors (mechanical ventilation and nasoenteric intubation). Nasoenteric intubation is particularly hazardous in patients with impaired airway reflexes (11–14). Several strategies to decrease pneumonia rates in such patients have been investigated. Nasoenteric intubation (that is, advancing the feeding tube into the small intestine) has no clear-cut advantage compared with nasoenteric intubation in preventing aspiration or other adverse events (15–17). Some evidence favors the use of enterostomy (gastrostomy or jejunostomy) to reduce aspiration risk, especially when neurologic recovery is unlikely, but the overall protective effect is small (18–21). Proper placement and management of the feeding tube is a more important issue in preventing aspiration. Tube misplacement, tube displacement, unrecognized ileus, gastric distension, and supine patient positioning commonly contribute to hospital-onset aspiration pneumonia (13, 14, 22).

Vascular catheter–related bloodstream infections are less common than urinary tract infections or pneumonia but greatly affect outcomes and costs of care (23, 24). Endogenous risk factors that might have increased Mr. Reilly’s risk for vascular catheter–related infection include his age and the severity of his underlying illness. Mr. Reilly had at least one intravascular catheter in place during his entire hospitalization, increasing the risk for vascular catheter–related infection. The risk was minimized, however, because he received peripheral (rather than central) venous and arterial vascular catheters (25). Other common exogenous risk factors, such as errors in intravascular catheter insertion and management and low nurse-to-patient ratio, were not documented in this case (26).

Surgical site infections are uncommon after neurosurgery (27), especially if intraoperative antimicrobial prophylaxis for staphylococcal infection is provided (28, 29). The current infection rate after craniotomy, according to the NNIS System, is approximately 1 surgical site infection per 100 surgeries for patients without special risk factors. This rate doubles for patients with risk factors, including a contaminated, dirty, or infected wound; prolonged surgery; or a preoperative risk class greater than II, according to American Society of Anesthesiologists criteria (27). Mr. Reilly had a preoperative risk class of IV, increasing his infection risk (27).

In summary, Mr. Reilly was at high risk for device-associated and procedure-associated hospital-onset infections. Implementation of evidence-based interventions aimed at prevention should have been a high priority throughout his hospitalization.

Chronology of Events, Continued

On the fourth day of hospitalization, the previously ordered Dobhoff feeding tube was inserted and enteral nutrition was provided. Mr. Reilly received nothing by mouth. He was alert and able to sit upright in a chair. The next day, he was afebrile and neurologically stable but continued to have dysphagia and dysarthria. He was transferred from the intensive care unit to a regular ward.

On the sixth day of hospitalization, Mr. Reilly developed a temperature of 38°C despite receiving 6 mg of dexamethasone intravenously every 6 hours after surgery. He was also noted to have increased upper airway secretions. Aggressive clearance of pulmonary secretions was requested because the surgical team believed that the low-grade fever was probably due to postoperative atelectasis or an acute exacerbation of chronic bronchitis. Chest radiography and urinalysis were ordered, but several hours elapsed before they were performed, and the physicians did not review the results until the next day. Urine and blood cultures were also ordered. Empirical antimicrobial treatment was not prescribed, and the patient was not evaluated for possible pulmonary embolism.

On the seventh day of hospitalization, Mr. Reilly’s temperature was 39.2°C. His heart rate was 120 beats/min, his blood pressure was 115/53 mm Hg, and his respiratory rate was 30 breaths/min. Arterial blood oxygen saturation was 96% on 4 L of supplemental oxygen delivered by nasal canula. The urinalysis and chest radiograph obtained the previous day...
were reviewed, and the results were found to be abnormal. The urinalysis revealed 25 to 50 leukocytes per high-power field and many bacteria. The chest radiograph showed consolidations in the right upper lobe and both lower lobes (Figure). A sputum Gram stain revealed a moderate number of polymorphonuclear leukocytes; no organisms were noted. The urine and blood cultures obtained on the previous day grew gram-negative bacilli; final identification was pending. Intravenous piperacillin and gentamicin were administered.

**Delayed Initiation of Antimicrobial Therapy**

Mr. Reilly developed clinical, microbiological, and radiographic evidence of infection on the sixth day of hospitalization but did not begin receiving antimicrobial therapy for 24 hours. Given his increased risk for pneumonia and urinary tract infection, the failure to start antimicrobial therapy when fever was first noted seems to be an error of omission (30), especially because he was receiving dexamethasone therapy (31, 32). The team caring for Mr. Reilly probably underestimated the importance of low-grade fever in a patient receiving systemic corticosteroids.

Prompt initiation of appropriate antimicrobial therapy improves survival and decreases length of stay in patients with bacteremia (33, 34). All institutions could benefit from a careful internal review of how hospital-onset infections are managed. If treatment delays are common, the institution should seek to improve the systems of care, not simply individual clinicians’ responses to suspected infection. Inquiries might be made about the sequence of events after fevers are noted, including time elapsed until patients are evaluated, when tests are ordered, when they are performed, when results become available, and when results are communicated and acted on. Communication networks could also be evaluated to ensure that no barriers obstruct the timely flow of information from one person or service to another. Factors such as inadequate staffing, competing priorities, and fatigue should also be considered.

**Chronology of Events, Continued**

On the eighth day of hospitalization, Mr. Reilly had a temperature of 39.7 °C. His heart rate was 140 beats/min, his respiratory rate was 40 breaths/min, and his blood pressure was 125/88 mm Hg. Arterial blood oxygen saturation was 85% on 4 L of supplemental oxygen delivered by nasal canula. He was transferred to the medical intensive care unit. A chest radiograph again revealed consolidations in the right upper lobe and both lower lobes consistent with pneumonia that had worsened compared with the previous radiograph. The blood culture drawn on the sixth day of hospitalization was growing Klebsiella oxytoca, and the urine culture was growing K. oxytoca and Escherichia coli. A sputum culture obtained on the seventh day of hospitalization grew two species of Pseudomonas aeruginosa. The patient’s antimicrobial therapy was changed to clindamycin, ceftriaxone, and gentamicin to cover hospital-onset urinary tract infection and pneumonia.

On the ninth day of hospitalization, Mr. Reilly was intubated to improve his oxygenation. A rapid taper of dexamethasone was initiated. One blood culture drawn on the seventh day of hospitalization grew coagulate-negative staphylococci. Because of persistent fever, vancomycin was added. Nevertheless, the patient’s fever and respiratory failure continued over the next few days. On the 14th day of hospitalization, Mr. Reilly’s family requested that he receive comfort care only. His endotracheal tube was removed, and he was discharged to home hospice. He died soon afterward.

**Are Nosocomial Infections Medical Errors?**

This patient, who had an underlying and ultimately fatal metastatic malignancy, underwent a palliative neurosurgical procedure and developed two serious infections that resulted in death. Did these infections and their outcome reflect deficiencies in the quality of health care Mr. Reilly received? Were they a consequence of medical errors (and therefore preventable), or were they unfortunate but unavoidable complications of tertiary care for this severely ill patient?

The answers to these questions are far from clear. Although some interventions may have reduced Mr. Reilly’s risk for infection, it is also possible that his course would not have been substantially altered despite the initiation of evidence-based guidelines. Nevertheless, it is important to
monitor the incidence of nosocomial infections in health care settings in an attempt to minimize their occurrence.

Rates of hospital-onset infection have been measured for more than 30 years. The NNIS System and similar infection monitoring systems compare the observed infection rate in a given hospital with the aggregate rate observed in a cohort of similar facilities. The NNIS System currently reports “benchmark” (that is, comparison) hospital-onset infection rates based on the experience of more than 300 hospitals that use standardized and validated methods to voluntarily and confidentially report infections to the CDC. In theory, hospitals whose infection rates compare poorly with NNIS benchmarks should be motivated to identify preventable causes of infection and target interventions to prevent systematic errors, unless other explanations for the increased rate are evident. The 30% to 40% decline in infection rates reported by NNIS System hospitals in the past decade suggests that this monitoring and benchmarking approach can be effective in promoting patient safety and preventing some medical errors (2).

Data from the NNIS System have generally been used to motivate institutions with higher-than-expected infection rates to strive for the relevant national benchmark rate. With this approach, the preventability of infections acquired by individual patients has not been routinely assessed unless the institution’s overall rates are high or increasing. This monitoring and benchmarking approach is most useful when achieving a “zero rate” is not a realistic expectation or when the preventable fraction of infections (that is, the fraction due to medical errors) is unknown. The result may be both an underestimation of the preventable fraction and missed opportunities to discover new prevention strategies. Unless all institutions continuously strive to reduce their infection rates, there may be little motivation for better-than-average performers to improve, a situation that could lead to a “culture of complacency.” A continuous quality improvement model, in which institutions practice an ongoing cycle of event tracking and process improvement, is recommended for infection control activities (2) and has also been applied in some hospitals seeking to reduce serious medication errors (35, 36). A mindset that the current error rate can always be decreased almost certainly explains the fact that other complex industries routinely achieve error rates far below equivalent benchmarks in health care (37). A more aggressive approach to NNIS-type data would prompt institutions with already successful infection control programs to strive for rates even further below current benchmarks, while underperforming institutions would be encouraged to incorporate proven strategies to reach the comparison or benchmark rate. This approach may yield more robust reductions in infection rates than those achieved by our present focus on “underperforming” institutions.

The recent Institute of Medicine report (38) highlighting the relationship among medical errors, adverse events, and health care quality has encouraged new approaches to patient safety and infection prevention. Altering the premise that “many infections are inevitable, although some can be prevented” to “each infection is potentially preventable unless proven otherwise” is consistent with the expectations of patients and the Institute of Medicine. Perhaps hospital-onset infections that cause or contribute to death or other serious adverse consequences should serve as red flags that trigger close scrutiny of the safety and appropriateness of medical treatment, regardless of the institution’s overall infection rates.

In addition, although it is not practical or even useful to perform a root-cause analysis of every hospital-onset infection, the local infection control team or other appropriate hospital personnel should review infections that cause substantial harm or are implicated as an attributable cause of death. When preventable causes are suspected, a root-cause analysis to identify factors inherent in the system or processes of care that contributed to the errors should be considered. The analysis starts with an event (for example, urinary catheter–associated sepsis) and progressively moves the focus of evaluation from special causes in clinical processes (for example, use of aseptic technique during catheter insertion) to common causes in organizational processes (for example, reduced staffing ratios) to identify potential interventions for prevention.

Evaluating errors that cause serious adverse events and sentinel events requires time, skill, and tact on the part of the infection control team, quality management staff, and other health care personnel. No data as yet demonstrate that root-cause analysis improves on results attributed to traditional benchmarking and infection control methods. Nevertheless, careful evaluation of the factors contributing to fatal infections and similar adverse events may lead to important systems changes and improved patient safety.

As one element in such a review, it is reasonable to ask whether an anti-infective urinary catheter would have made a difference in preventing Mr. Reilly’s sepsis. Several types of anti-infective catheters are available; the best studied are urinary catheters coated with silver alloy, although catheters coated with minocycline–rifampin are also available (39). A meta-analysis of eight trials found a significant reduction in bacteriuria rates in patients given silver alloy catheters compared with standard catheters (40), and this finding has been duplicated in more recent studies (41, 42). The effect of the catheters on reducing more important outcomes, such as septicemia and death, is unclear. However, recent studies suggest that patients such as Mr. Reilly, who have indwelling urinary catheters for 2 to 10 days, are likely to derive both clinical and economic benefits from the silver alloy catheter (40, 43, 44).

**WHAT CAN PATIENT SAFETY AND INFECTION CONTROL EFFORTS DRAW FROM EACH OTHER?**

Modern patient safety practices, such as root-cause analyses and continuous quality improvement, can en-
hance the field of infection control. The patient safety movement can also learn much from the traditions of infection control and hospital epidemiology. Precise and valid definitions of infection-related adverse events, standardized methods for detecting and reporting events, confidentiality protections, appropriate rate adjustments for institutional and case-mix differences, and evidence-based intervention programs come to mind. Perhaps most important, reliance on skilled professionals to promote ongoing improvements in care has contributed to the 30-year track record of success in infection prevention and control.

Analogously, in approaching patient safety, standard definitions should be used as much as possible when discussing adverse events and preventability. Health care organizations should be encouraged to pool data on adverse events in a central repository to permit benchmarking, and such data should be appropriately adjusted and reported. Finally, institutions should consider hiring dedicated, trained patient safety officers (comparable to infection control practitioners), as has been done in many Veterans Affairs hospitals (45).

**The Institutional Response**

The institution’s infection control committee implemented several strategies to prevent catheter-associated urinary tract infections. First, after reviewing data showing that catheters are inappropriately used in approximately one third of patients (46, 47), that approximately 50% of catheter days are not medically necessary (47), and that attending physicians are unaware of catheter use in approximately 40% of cases (48), the hospital instituted a pilot program of urinary catheter stop orders. In addition, silver alloy urinary catheters are being used in targeted high-risk areas and patients. Although silver alloy catheters cost approximately $5 more per unit, they may be cost-effective in patients who are at high risk for urinary tract infection and require catheterization for at least 2 days (43). Use of these catheters will at first be limited to patients in the intensive care units and on the hematology–oncology wards. The hospital will perform a before-and-after evaluation to assess effectiveness.

The hospital’s infection control committee began an intensive educational program highlighting prevention of nosocomial pneumonia, especially in ventilated patients. On the basis of the evidence (49), directives included elevation of the head of the bed, strict adherence to hand washing before and after contact with patients, aseptic management of endotracheal tubes, and extubation as soon as possible.

**Conclusions**

The institution should be commended for taking action. Systematic examination of events, relevant processes of care, and prevention options is an excellent contemporary model for preventing infections and promoting patient safety. Nevertheless, a before-and-after evaluation in a single hospital will not usually have adequate statistical power to detect a meaningful difference. When a difference is detected, secular changes may be contributory. We need large, multicenter studies to assess novel strategies for patient safety enhancement.

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Excerpts of the question-and-answer session and excerpts of an interview with the chair of the institution’s infection control committee are available at www.annals.org.

**References**


www.annals.org


Questions and Answers from the Conference

An Audience Member: What is the experience with computerized systems to improve or decrease the rate of hospital-onset infections?

Dr. Gerberding: In theory, computerized provider order entry with on-line decision support should be a major prevention strategy. Hospitals that have adequate systems, such as LDS Hospital in Salt Lake City, Utah, have shown important improvements in antimicrobial utilization and patient outcomes (50). Unfortunately, only a few hospitals have them. Our role at CDC is to identify the best ways to support improved decisions and then to work with vendors to make these systems more widely available.

Dr. Robert M. Wachter (Moderator): At the practical level, a hospital may say that it can introduce a more effective urinary catheter but that it will cost $5 more per catheter. There’s a humanitarian case to do that, but is there a business case to do it?

Dr. Gerberding: The available data suggest that use of silver alloy–impregnated catheters is cost-effective in certain high-risk patient populations, but additional research is needed to determine the true economic impact for hospitals, health care purchasers, and society. Ultimately, prevention requires that all components of the care system be optimized, including indications for device use, product selection, insertion and care protocols, and prompt removal of devices.

In this specific case, it is unclear whether any of these interventions would have influenced the ultimate outcome. For example, we do not know if this patient would have definitely benefited from the use of a silver alloy catheter as he received a catheter for about 2 days, the minimum amount of time when silver alloy catheters have been shown to provide clinical and economic benefits. Similarly, although the urinary catheter stop order is an interesting idea, it probably would not have influenced his outcome because of the short duration of catheterization.

Interview Excerpts

On 6 September 2000, Quality Grand Rounds managing editor Amy J. Markowitz, JD, conducted an interview with Dr. D., medical director of infection control and chair of the hospital’s infection control committee. Following are excerpts of that interview.

Ms. Markowitz: What is your committee’s philosophy of infection control?

Dr. D.: We’re designed to do a number of different things. We do targeted surveillance and collect information about infections occurring in our hospital. We target high-risk procedures and patient populations. We look primarily at the intensive care unit, where most of our hospital-acquired infection occurs.

Ms. Markowitz: What typically triggers an investigation?

Dr. D.: There are several ways that we can institute an investigation. Sometimes we get a call from a practitioner who notices an unusual cluster or number of infections; the other is through our active surveillance. We have data on normally occurring rates, and if we see a change in types of organisms we would institute an investigation.

Ms. Markowitz: How do you determine when to institute an intervention based on the data that you are collecting?

Dr. D.: We analyze our rates of infection and we compare them to benchmarks from the NNIS System provided by the CDC. We pick a threshold that we think we should be able to achieve. The NNIS System provides a pooled mean for all the hospitals that are reporting but also gives you a percentile ranking as to how many hospitals have infection rates at which benchmarks. We generally use the 50th percentile, but our hospital now has made the very aggressive decision to work for the 25th percentile for bloodstream infections.

Ms. Markowitz: What measures has the hospital taken to decrease the risk of hospital-acquired resistant infection?

Dr. D.: We have a number of different programs in place. Let’s start with antibiotic restrictions. Through the pharmacy and therapeutics committee, we have an antibiotic subcommittee that monitors and sets guidelines for use of antibiotics. The pharmacy has dedicated pharmacists who are directed to watch the use of all our restricted agents and make sure that antimicrobial use is appropriate. They have the authority to discontinue antibiotics if it’s felt that the antibiotic was unnecessary.

Ms. Markowitz: How is that protocol carried out?

Dr. D.: The pharmacist leaves a note in the chart that says the physician has 24 hours to either discontinue the antibiotic or get approval from the infectious disease consult service. So there is always another physician group to monitor the decision, and physicians are given that 24-hour period, during which time they usually resolve the situation. We find that the pharmacists almost never have to write an order to discontinue the antibiotic.

Ms. Markowitz: How has your compliance been, and how are you measuring your success?

Dr. D.: We measure our success in two different ways. Number one, by tracking the use of restricted antimicrobials. We saw it go down significantly in the first year of the program. There are still improvements to be made. The second way is to follow antibiotic resistance patterns and monitor key indicator organisms. If the microbiology lab identifies an antibiotic-resistant organism that we are concerned about, we will initiate special precautions, similar to contact precautions. We call them our antibiotic-resistant precautions.

Ms. Markowitz: What does this include and who is notified?

Dr. D.: The microbiology laboratory contacts the physicians taking care of the patients. The patient is placed into a private room, and anybody entering the room to care for the patient puts on a mask, gown, and gloves, and...
any device or equipment that goes between patients has to be disinfected. The final thing that has been instituted is a patient transfer policy, which is designed to try to decrease the number of transfers around the hospital of patients with resistant organisms.

Ms. Markowitz: How do you measure your progress with that intervention?

Dr. D.: We’re following incidence of vancomycin-resistant enterococcus infection.