Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Nosocomial or Hospital-acquired Infections: An Overview

Robin B. McFee, DO, MPH, FACPM

Hospital-acquired Infection Rates—USA

Nosocomial or hospital-acquired infections (HAI) are a leading cause of morbidity and mortality in the USA.[1-26] Several studies have been conducted over the years to characterize and quantify this ever-growing public health problem. In a 2002 study published in 2007, the estimated number of HAI in US hospitals, adjusted to include federal facilities, was 1.7 million, with almost 99,000 deaths directly resulting from the infection.[1] The highest infection rates per 1000 patient-days occurred in intensive care units (ICU), followed by high-risk nurseries.[1,2,4,18,27] Surgical site infections accounted for a significant number of infections.[1,2,4,28-30] The most common sites of infection in this study included urinary tract infections, which accounted for 36% of HAI, surgical site infections (20%), pneumonia (11%), and bloodstream infection (11%).[1,2,4] In 1995, the Centers for Disease Control and Prevention estimated 1.9 million HAI.[1-4,6] Among the deaths associated were the following 35,967 pneumonia, 30,665 bloodstream infections, 13,088 urinary tract infections, 8205 surgical site infections, and 11,062 other infections.[1] Other national estimates are closely aligned with these data.

Within the context of HAI are selected pathogens that are or have emerged as significant public health threats—methicillin-resistant *staphylococcus aureus* (MRSA),[31,32] *Enterococcus*-resistant vancomycin, and *Clostridium difficile* (C diff).[30,33-43] The latter is especially problematic as it is highly difficult to eradicate from the health care environment and is increasing in incidence and certain strains are emerging with increased virulence.[32-35,38,42-44] C diff will be discussed in the next article. Moreover, antibiotic use is a preceding catalyst as are other commonly employed medical interventions, especially among the very young and old.[15,20,35,37,45] Given the well-recognized reality that hand hygiene rates are abysmal among health care workers, another risk factor for C diff, it is likely continued unnecessary deaths from C diff specifically and HAI

Dis Mon 2009;55:422-438
0011-5029/2009 $36.00 + 0
doi:10.1016/j.disamonth.2009.03.014

in general are likely to continue until fundamental changes occur in health care practice.[5-11,40]

HAI and the distribution of pathogens vary according to the clinical setting, patient characteristics (primary diagnosis, multiple morbidities, procedures done) and the health care setting (intensive care, burn unit, surgical care) and also by cohort (neonate, adult, region, or nation).

The most recent large-scale data and estimates available to evaluate the scope and threat of HAI resulted in the report from the 2002 National Nosocomial Infections Surveillance System (NNIS) of the Centers for Disease Control and Prevention, including the American Hospital Association Survey, and the National Hospital Discharge Survey.[2,3,13] While NNIS uses standardized data collection protocols, each organization represents different health care facility members and/or uses a variety of data sources—including hospitals over 100 beds with at least 1 infection-control officer, admission/discharge data, the use of risk component areas (ICUs and neonatal intensive care unit (NICU)) instead of hospital-wide surveillance, voluntary participation of the health care facility (HCF) in sharing data, and other variables. Nevertheless, nosocomial infections represent the eighth leading cause of death in the USA.

Regardless how HAI are estimated, the fact remains they are a persistent and in some regions growing problem causing significant suffering, extra days of hospitalization, even death. At a time when our health care system is overburdened, HAI are a preventable strain on limited resources and a burden patients as well as their families do not need. What is so disturbing is that some of the most effective preventive measures are the most basic and easily performed.

In addition to being a leading cause of morbidity and mortality, as well as increased hospital stays, HAI cause $17 to $20 billion in associated additional health care costs each year.[1-4,7,10,11] While exact data are lacking, it is estimated that approximately 2 million HAI occur in children and adults in the USA annually.[1-4,7,11,14,43,45] It is one of the most common adverse events associated with hospitalization and health care. The main challenge to deriving estimates is that no single source of representative data is available to estimate the burden of health care-associated infections in the USA.[1]

Hospital-acquired Infection Rates—Worldwide

While HAI are an important health care concern worldwide, they are especially troublesome in developing nations. Nosocomial infection rates range from 1% in Northern Europe, especially The Netherlands, which introduced extremely aggressive infection control measures, to $>$ 40% in

some parts of Asia, South America, and sub-Saharan Africa.[1-7,46-48] Sanitation is clearly a major factor for such high rates of HAI in developing nations. Lack of resources is another. Studies suggest more than 50% of injections administered at HCF in developing countries are unsafe. Often the needles and/or syringes are reused, including between patients. Some of those injections are also unnecessary such as routine injections of vitamin B-12 or antibiotics. However, when a hammer is all you have, everything looks like a nail; HCF use what they have, albeit sometimes in a well-meaning but ill-conceived attempt to heal. A major consequence of this is that an estimated 80,000-160,000 new human immunodeficiency virus (HIV) infections occur annually in sub-Saharan Africa, and even more cases of hepatitis B virus and hepatitis C virus occur worldwide each year because of unsafe injections.

Among the more industrialized and developed nations, the World Health Organization found 8.7% of all hospital patients had nosocomial infections. Annual HAI prevalence studies revealed that among 100 admissions, Greece had 9.1%, Spain had 7%, while Norway had 5.1% and Slovenia had 4.6%.[1,47,49] Not unsurprisingly, the highest prevalence of HAI occurred in ICUs and acute care surgical and orthopedic settings. Old age, multiple morbidities or disease severity, and decreased immunity increase patient susceptibility. Poor infection control measures are an overall risk factor as are certain invasive procedures including central venous or urinary catheter placements.[1,18] Antimicrobial misuse is associated with drug-resistant HAI. Other risk factors for HAI will be discussed in the following section on specific pathogens.

Leading Causes of Death

While it is true that chronic diseases such as coronary disease and diabetes have replaced acute infections as the leading cause of mortality in persons older than 65 in the USA with outbreaks of contagious infectious diseases remaining uncommon,[22,24,25,50,51] such chronic illnesses often result in hospitalizations; therein lies a risk for acquiring an infection or other adverse outcome.

This dramatic change in the top leading causes of death from infection related to chronic disease over the last century can give the false sense of "victory" that we have conquered pathogens in the USA (Table 1). We should consider this a cautionary time. "Victory" is better exchanged for the term "stalemate" with infections—possible only as long as we practice the sound infection control practices that lead to the changes in mortality from 1900 to 2000.[51] The increased inattention to these infection control practices being reported may account for the death rate

TABLE 1. Leading causes of death 1900 and 1997 USA, 1992 Peru[17,22]

Major Causes of Death (Attributable)	1900 USA	1992 Peru	1997 USA
1	Respiratory disease	Respiratory infections	Heart disease
2	Tuberculosis	Cancer	Cancer
3	Gastrointestinal disease	Gastrointestinal disease	Cerebrovascular disease
4	Heart disease	Heart disease	Pulmonary disease
5	Infectious/parasitic diseases	Tuberculosis	accidents
6	Kidney disease	Cerebrovascular disease	Pneumonia/influenza
7	Early infancy diseases	Urinary system disease	Diabetes
8	Cerebrovascular disease	Nutritional deficiencies	Suicide
9	Cancer	Early infancy	Homicide
10	Liver disease		HIV AIDS

from infectious diseases rising 58% between 1980 and 1992 (making them in the aggregate the third leading cause of death in the USA). Influenza and pneumonia remain responsible for 5.5% of the deaths of people 65 and older (95,640) in 1997, with an increase in infection-related deaths among older persons from 1980 to 1992.[51] Also, the combined death rate from influenza and pneumonia for all age-race-sex groups has increased.[51]

With almost 2 million patients acquiring nosocomial infections each year in United States hospitals, the war against infectious diseases is clearly not over.[1-7,24,51]

HAI Causes: An Overview

Key factors associated with HAI that are unlikely to change without a concerted and sustained effort[1,8,13,15,20,23,31,32,35,37,52] include the following:

- Increasingly sicker patients being admitted to HCF
- Lack of surge capacity resulting in overcrowding of patients
- Increasing number of immune impaired patients
  - HIV
  - Age
  - Immunosuppressive agents
- Autoimmune diseases
- Cancer
- Transplants

- New and/or emerging pathogens
  - *Acinetobacter*
  - *C difficile*
- Increasing antimicrobial resistance
  - MRSA
  - Vancomycin-resistant *S aureus*
  - Vancomycin-resistant *C difficile*

Failure to perform appropriate hand hygiene is a leading cause of health care associated infections and the spread of multidrug-resistant organisms and contributes to outbreaks.

Overcrowded waiting rooms and health care facilities lacking surge capacity and filled to overflowing give less time for proper sanitation.[52,53] Health care workers not adhering to good hygiene practices contributes to the rising infection problem. Overcrowding in the absence of an epidemic only portends a system-wide failure in the presence of a highly transmissible virus.[52,54-57] Recent Emergency Department closures in the face of increased patient volume and lack of affordable resources for uninsured persons contribute to diversions and overcrowding. Lack of hospital beds exacerbates the problem.

Hospital-acquired Infections: Pathogens to Watch—Overview

Health care associated infection has emerged as one of the most critical and worrisome clinical issues in contemporary society and a significant public health concern. HAI results in unnecessary human suffering and death as well as health care expenditures. Few have not read cautionary articles from the Institute of Medicine, Institute for Healthcare Improvement, and other well-respected organizations in addressing the almost runaway rates of HAI and the unacceptable risk health care facilities and professionals place on their patients in the absence of or inconsistent use of good infection control practices.

Virtually any pathogen from a long list of organisms found in hospitals is causing a nosocomial infection. However most HAI are caused by a relatively short list of pathogens, some of which target patients in selected cohorts such as those who are immune-compromised, or with specific risk factors such as antibiotic exposure, burns, surgery, or trauma.[28-30,58,59]

No discussion of HAI could begin without at least mentioning *S aureus*, especially MRSA.[31,32] Of concern, the proportion of *S aureus* isolates among ICU patients that are resistant to methicillin (MRSA) as well as oxacillin or nafcillin is on the rise at approximately 60%. Of such concern

is MRSA that the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) has recently empanelled a scientific team and issued newer guidelines.[60]

Klebsiella pneumoniae have demonstrated a 50% increase in resistance to third-generation cephalosporins. Other HAI including *Pseudomonas aeruginosa* and C diff are demonstrating increased antimicrobial resistance.

While some pathogens are the result of extraordinary circumstances—for example, *Acinetobacter baumanii* infections associated with battle field injuries as is being experienced by wounded Gulf War troops,[58,59] others should have been readily predictable—MRSA, vancomycin-resistant *Enterococcus*, and C diff, which will be discussed in greater detail in the next article.

The C diff pathogen is especially worrisome for several reasons. First, many of us were trained at a time when this bacterium was considered an unusual event associated with only a few antimicrobial medications. Second, the perception is that it can be readily treated. Third, the true epidemiology (growing) is underappreciated among health care professionals and patients.[33]

Times have changed. C diff, antibiotic-associated diarrhea, or medication-host--dependent infections such as C diff infection are a growing and significant health hazard for patients. Although it will be discussed in more depth later in this monograph, C diff is increasingly the result of common medical practices that include routine alteration of patient pH (widespread use among the elderly of proton pump inhibitors and gastric acid suppressant therapy,[61-63] inattention to the benefit of probiotic adjunct therapy when prescribing antibiotics; albeit that remains somewhat controversial, it is a low-risk possible benefit, judicious use of antimicrobial medications, and attention to infection control—especially hand washing,[64,65] cohorting infectious patients, and other methods. Putting it into perspective, although estimates of HAI are approximately 2 million annually, C diff associated diarrhea [C diff associated disease (CDAD)] is estimated to affect over 3 million inpatients a year in the USA[23,66]).

Control of emerging and existing infectious diseases can be a daunting task given the large number of disease-causing organisms, the evolution of antimicrobial resistant or increasingly virulent pathogens, the discovery of new microbes, and overpopulation—within communities and HCFs.[1,18,22,24] Changing patterns in host factors and prescribing practices, as briefly discussed earlier, also contribute.

Global travel can lead to the importation of novel pathogens uncommon in the new environment, which thus may go unsuspected or initially unidentified.[24,56]

Examples include avian flu (avian influenza, H5N1) and severe acute respiratory syndrome. HAI of avian flu were demonstrated in a retrospective study. Health care workers exposed to patients with H5N1 infection were more likely to be seropositive and this was not attributable to animal exposure.[54,55,67-70] It is reasonable to assume that the route of infection for avian influenza patients, like most influenza patients, can be from inhalation of infective respiratory secretions and/or contact with virus-laden secretions and subsequent transference contact with mucous membranes. Studies suggest that the airborne transmission of influenza explains the sometimes numerically explosive nature of flu epidemics.[54,55,67-70] It is important to recognize that seasonal influenza can be transmitted within health care and long-term facilities. The basic reproductive number for influenza (the number of secondary cases produced by 1 primary case) varies from 1.68 to 20.

As discussed earlier, given health care in the 21st century is provided in acute care hospitals, long-term care facilities, and home health settings, emphasis on strict infection control measures cannot be directed solely toward hospital personnel; all caregivers must be taught and subsequently held accountable for adhering to infection-prevention strategies. These cannot be overemphasized or repeated too frequently: hand washing, barrier protections, vaccination (patients, caregivers, and health care workers), and other strategies to be discussed.

Most HAI are associated with urinary tract infections, surgical site infection pneumonia, bloodstream infection, and others, including gastrointestinal tract infection such as CDAD.[1] Urethral catheters are a well-known risk. Surgical site infections accounted for over 240,000 HAI in the NNIS report.[1-3] There are also seasonal variations associated with certain pathogens. The return of severely wounded troops from the Persian Gulf is becoming a risk factor for HAI—especially related to the bacteria *Acinetobacter*, most notably *Acinetobacter baumannii* at health care facilities.[58,59,71,72] Multidrug-resistant *A baumannii* is considered near epidemic among the wounded in Iraq compared to Afghanistan. A recent outbreak of *A baumannii* at Walter Reed Army Medical Center resulted in 53 HAI and 4 deaths.[58,59] Because of this, returning wounded troops are often isolated until they are cleared of this pathogen. Although typically occurring in ICU settings in US hospitals, the risk of *A baumannii* as an HAI is increasing.[72]

Although organisms causing many nosocomial infections often come from the patient's own body flora, contact in a hospital environment where pathogens often can survive on surfaces or instruments remains a significant risk. Patients also interact with staff and contaminated instruments. Because patients are highly mobile and hospital stays are becoming shorter, patients often are discharged while asymptomatic, before the infection becomes apparent. An infection control challenge resides in the fact that many nosocomial infections in hospitalized patients especially originating from ambulatory care facilities become apparent only after the patients are discharged.

Key Cohorts

While all hospitalized patients are at risk for HAI, certain subpopulations are at increased risk. These include the elderly, the immune-compromised, the very young or premature, and burn and surgical patients.

Neonates are susceptible to infection because of immature immune systems and exposure to extrinsic risk factors associated with HCF such as central venous catheters and surgical procedures, resulting in nosocomial infection rates between 15% and 20% in the NICU.[1-3,12] These rates are significantly greater than those found in the pediatric ICU population. According to the NNIS there were 33,269 HAI among newborns in high-risk nurseries, of which gram-positive organisms including MRSA, *Escherichia coli,* a gram-negative organism, and *Candida albicans* fungal infections were the most common.[1-4,12] Neonatal meningitis, a difficult diagnosis in this population, appears to be more common than previously thought. Staph, Group B *Streptococcus*, *E coli*, *Klebsiella*, *Serratia*, and *Candida* have been implicated as significant causes. MRSA, recognized in the 1970s, continues to be a major pathogen in adult, pediatric, and neonatal HAI, and *Candida* is a significant cause of mortality among neonates in the ICU. Although beyond the scope of this article, some studies support the newer strategy of using prophylactic fluconazole in high-risk neonates in the ICU such as those < 750 g to reduce the risk of fungal infections.[12,73-75]

Not unlike other patients, newborns, even those not requiring NICU care, are susceptible to HAI. According to the NNIS, there were 19,059 HAI among newborns in well-baby nurseries.[1] Among adults and children outside ICU settings, there were 1,266,851 HAI and of adults and children treated in intensive care units; 417,946 annual HAI were acquired.

TABLE 2. Readily applied strategies to reduce HAI[12,35,40]

- Hand hygiene
  - Use soap and water after patient contact, especially if hands become contaminated
- Skin cleaning
  - Avoid scrubbing skin with brushes or harsh soaps
- Gowns/gloves
  - Use best barrier practices when doing procedures, especially inserting catheters, central lines, or changing dressings
- Antimicrobial stewardship protocols
  - Promote the use of the simplest and most targeted antimicrobials. Whenever possible avoid broad-spectrum antibiotics
- Avoid drugs associated with increased HAI risk
  - H2 blocking agents can alter the pH of the GI tract and affect the balance between normal/beneficial flora and pathogenic flora
  - Systemic steroids can alter immune status and increase the risk of HAI
- Minimize practices that disrupt skin barrier
  - Venipunctures or heel sticks
  - Catheters. NB attempt to minimize the duration of central catheter and other invasive instruments
- Patient spacing
  - Isolate or cohort infectious patients
  - Attempt to maximize space between patients
  - Attempt to avoid overcrowding
  - Use alcohol bases antiseptic before patient contact

Hospital-acquired Infections—Prevention: An Overview

So how can HAI happen amid the world's leading health care facilities? Why is an admission to a HCF now a risk factor for contracting a potentially deadly infection, often unrelated to the admission diagnosis? What can be done to reduce HAI?

Sometimes the best interventions are also the lowest technologically (Table 2). In the 1800s a young obstetrician, Philipp Semmelweis, recommended disinfecting the hands of health care professionals before examining pregnant women or assisting in their childbirth as a way of preventing puerperal or "childbed fever," which Dr Louis Pasteur in 1879 subsequently identified as hemolytic streptococcal infection.[12,49] Dr Semmelweis noted that women giving birth on the street had less likelihood of becoming infected with "childbed fever" or dying, compared to those who were attended by health care professionals![49] What would seem so basic now, especially knowing germ theory, in the 21st century, in a nation blessed with and abundance of clean water coast to coast, is the need for hand washing. It would seem almost embarrassingly obvious to any health care professional the need for cleanliness before

touching a patient, let alone after using the bathroom, yet such is not so apparent nor practiced.[5-8,11,40,60,64,65]

While we increasingly rely on high-technology measures to improve health outcomes, such low-technology preventive measures cannot and should not be abandoned. In an era of advanced medications, evidence-based medicine protocols, mass media coverage of adverse health outcomes, and computer technology, it is both amazing and appalling that patients still are harmed through acquiring HAI during the course of their care.

It should therefore be no surprise that evidence supports hand hygiene to reduce health care associated infection rates—whether using soap and water or other waterless interventions including alcohol-based hand rubs, although CDAD is more amenable to prevention using soap and water. In a nation blessed with clean water and an abundance of soap and disinfectants, it is incredible that health care professionals need to be reminded to wash their hands—accepted as one of the most effective infection-control procedures.

With estimates suggesting 1 patient in 20 will fall victim to a HAI, the Joint Commission on the Accreditation of Healthcare Organizations has issued new guidelines to address MRSA and is becoming more aggressive in penalties for nonadherence to good infection-control practices among its member organizations.[32,60] In addition to hand washing, other key recommendations from JCAHO and the Ministry of Health and Long Term Care–Canada guidelines emphasize a broad as well as focused view on C diff/infection control covering the facility/environment, the patient, health care workers, and medication selection (Table 3).[40]

Of interest, in 2006, 7 states in the USA have implemented mandatory reporting of HAI by hospitals.[1,8] Such legislative mandates are an important step in what must be a comprehensive approach to a strategy of reducing nosocomial infections. Consistent training, greater emphasis on sanitation, investment in single-use equipment when necessary, greater communication, and coordination of care across disciplines, including directed guidance by infection control professionals, are needed. Amazingly, blood pressure cuffs and other equipment continue to be shared between patients with C diff or other HAI and those uninfected! Solutions include single-use sphygmomanometers that can then be billed to the patient (they are low cost as anyone who has purchased one at a chain pharmacy can attest, especially in the grand scheme of hospital expenses), cuff barriers, which are increasingly available and low cost, or disposable cuffs—all significantly less expensive than a hospital-wide outbreak.

TABLE 3. Overview of infection control measures[12,35,40]

I. Patient
   a. Antibiotic selection
   b. Risk factors for infection
   c. Multidisciplinary team involved in infection control
   d. Patient care guidelines
      i. Catheters
      ii. Antimicrobial use
      iii. Surgical wound care
      iv. Postoperative care
      v. GI care

II. Accommodation
   a. General consideration to limit the spread throughout the facilities
      i. Cohorting
      ii. Isolation precautions
      iii. Patients suspected of having C diff should be placed in rooms with the following
         1. Signage as to risk, required personal protective equipment (PPE)
         2. Available barrier PPE with laundry hamper or dedicated waste disposal for PPE
         3. Placement in a single room with dedicated toileting facilities
         4. If the number of cases exceeds single room capacity then
   a. Prioritize cohorting
   b. Dedicated commode wherever possible

III. Contact precautions
   a. Signage with precautions on doors of cohort and isolation patients
   b. PPE readily available with instruction placards
   c. Procedures on specific handling with regard to infected patients should be provided to all employees coming in contact—housekeeping to senior attending
   d. Dedicated equipment and/or barrier covers
      i. Wheelchairs
      ii. Commodes
         1. SPECIAL handling precautions to prevent spore spread
      iii. BP cuffs
      iv. Lifts
      v. Thermometers (avoid rectal temperatures)
      vi. Other

IV. Hand hygiene
   a. Soap and water as well as other hand rubs—time and attention to complete washing
      i. Remove gloves
      ii. Alcohol based if dedicated hand washing sink not available (avoid patient sink)
      iii. Wash hands with soap and water at nonpatient sink

V. Environmental cleaning
   a. All surfaces in the room and items within reach of patients with suspected C diff or other aggressive HAI should be cleaned twice daily with hospital-grade disinfectant
   b. Special attention to patient-specific items and “high touch” surfaces (phone, bedside rails, call and light activators, door handles, faucets, commodes, etc)
   c. Work from clean to dirty
   d. Change cloths and mop heads frequently
   e. Disposable toilet brushes should be used in ALL patients with C diff/HAI
   f. Discharge/transfer level cleaning must occur when patient is cleared
   g. Educational and auditing materials should be developed for environmental/housekeeping and communicated throughout the chain of care

TABLE 3. Continued

VI. Visitors
  a. Should receive instruction especially concerning
    i. Hand hygiene
    ii. PPE
    iii. Safe visitation procedures
VII. Patient transfer
  a. Transportation services and all downstream services/departments should be alerted to and trained in the care of C diff and HAI patients
  b. Educational and audit materials should be made available
  c. Availability of PPE with instruction on proper usage
  d. Coordination with environmental/housekeeping on proper cleaning of transport equipment
VIII. Patient discharge
  a. Precautions and educational material should be provided for patients and their family members/caregivers.

For more complete information, refer to *Best Practices Document for the Management of Clostridium difficile in all health care settings*. PIDAC. Ministry of Health and Long Term Care. Published December 2004, Revised November 2007.

Outcome measures need to be "owned" by every member of the facility team. Updating the staff where positive- and negative-infection control outcomes are occurring in a "no blame" environment can promote greater awareness, problem-solving, and effort. A recent unpublished survey of health care professionals revealed most were not aware C diff was a leading HAI or was readily transmitted by shared stethoscopes or blood pressure cuffs. Some thought it was an ICU problem. In 2008, C diff and HAI should be top concerns at HCF. Too many patients and no support staff are not viable excuses in the short term to not wash hands or attend to infection-control measures. However, they are viable problems that must be addressed for the long term. Local HCF trends in infection-control successes and failures need to be shared across departments and not just the purview of the medicine or infection-control departments. Departmental compartmentalization or annual in-service updates are inadequate to address the daily threat of HAI.

Educational programs, with posted outcomes measures and communications about progress or areas needing improvement, not in a blameful manner but with the goal of continuous quality improvement, should be implemented. Everyone who works at or is a patient/visitor in a health care facility is a stakeholder, *and* a potential problem or solution. Everyone needs to be engaged from the top to the most entry level worker. Infection Control is a team sport.

Cost remains a driver in HCF policies and infection control measures. However, balanced against human suffering, preventable death, and the

billions of dollars in added health care costs associated with HAI, clearly greater investment in infection control must be expended. Given the number of deaths associated with HAI exceeds that associated with many of the top 10 causes of death in the USA, reinforcement is needed to address this problem. In the coming years increasingly sicker and older patients will be admitted to HCF, and their likelihood of acquiring an HAI will increase as will their untimely death unless dramatic change occurs.

Conclusions

The purpose of this monograph is to increase awareness about HAI, especially C diff, as largely preventable causes of death and suffering, to share best practices in infection control, to introduce emerging pathogens yet to be fully appreciated, and to discuss one of the most dangerous HAI, which is at epidemic proportions, C diff.

Without question, C diff has become an infection-control challenge of enormous proportions affecting hospital patients, as well as long-term care residents, even outpatients. Of additional concern is its increase in virulence as well as antimicrobial resistance. Moreover, antibiotics heretofore considered low risk as contributory to clostridial overgrowth or development of symptomatic illness are now becoming associated with CDAD. Unless infection control measures improve facility-wide and until health care professionals, especially physicians and nurses, adhere to basic tenets of hygiene, not the least of which should be hand washing before and after every patient encounter, HAI will continue to harm our patients.

As a profession we have contributed to the increase in HAI, including C diff; with little additional effort, together we can significantly reduce this major public health problem and with it increase the likelihood of protecting our patients.[76]

REFERENCES

1. Klevens RM, Edwards JR, Richards CL, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Pub Health Rep 2007 March–April;122:160-6.
2. National nosocomial infections surveillance (NNIS) system report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Cont 2004;32:470-85.
3. CDC. NNIS system. National nosocomial infections surveillance (NNIS) system report, data summary from January 1992-June 2003. Issued August 2003. Am J Infect Cont 2003;31:481-98.
4. Edwards JR, Peterson KD, Andrus ML, et al. National Healthcare Safety Network (NHSN) Report. Data summary for 2006, issued 2007. Am J Infect Cont 2007;35:290-301.

5. Centers for Disease Control and Prevention (CDC). Outline for health care-associated infection surveillance. Available at: http://www.cdc.gov/ncidod/dhqp/nhsn+documents.html.
6. Centers for Disease Control and Prevention (CDC). Reduction in central line associated bloodstream infection among patients in intensive care units—Pennsylvania. April 2001-March 2005. MMWR Morb Wkly Rep 2005;54:1013-6.
7. Institute for healthcare improvement. Saving 100,000 lives campaign. http://www.ihi.org.
8. Association for Professionals in Infection Control and epidemiology (APIC). Government advocacy. Available from: http://www.apic.org/content/navigationmenu/governmentadvocacy/mandatoryreporting/abouttheissue/about_the_issue.htm.
9. Tokars JI, Richards C, Andrus M, et al. The changing face of surveillance for health care associated infections. Clin Infect Dis 2004;39:1347-52.
10. American Hospital Association, Hospital Statistics 2004. Chicago Health Forum LLC, 2005.
11. Burke JP. Infection control—A problem for patient safety. N Engl J Med 2004;348:651-6.
12. Carey AJ, Saiman L, Polin RA. Hospital Acquired Infections in the NICU: Epidemiology for the new millennium. Clin Perinatol 2008;35:223-49.
13. National nosocomial infections surveillance (NNIS) system report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Cont 2004;32:470-85.
14. Nguyen QV. Hospital Acquired Infections. 2007; August http://www.emedicine.com/ped/fulltopic/topic1619.htm.
15. Jarvis WR. Infection control and changing health care delivery systems. Emerg Infect Dis 2001;7(2):170-3.
16. Fauci AS. Infectious diseases: Considerations for the 21st century. Clin Infect Dis 2001;32:675-85.
17. Trends in causes of death among the elderly. Aging Trends 1(March) 2001. Publication of the Centers for Disease Control and Prevention. Atlanta, Georgia. National Center for Health Statistics.
18. Wenzel RP. Edmond, MB. Team based prevention of catheter related infections. N Engl J Med 2006;355:2781-3.
19. Kyne L. Health care associated costs and mortality associated with nosocomial diarrhea due to Clostridium difficile. Clin Infect Dis 2002;34:346-53.
20. Goldmann DA. Epidemiology and prevention of pediatric viral respiratory infections in health care institutions. Emerg Infect Dis 2001;7:249-53.
21. Summary of notifiable diseases—United States, 2002. MMWR Morb Mortal Wkly Rep 2004;51:1-84.
22. Deaths: Leading causes for 2001. Natl Vital Stat Rep 2003;52:Table E.
23. Scheurer DB, Hicks LS, Cook EF, et al. Short report—Accuracy of ICD-9 coding for Clostridium difficile infections: A retrospective cohort. Epidemiol Infect 2007;135:1010-3.
24. McFee RB. Avian influenza: The next pandemic? Dis Mon 2007;53:337-88.
25. 2001. Population Reference Bureau, editor. United States Government. NCHS-FASTATS-Leading Causes of Death Deaths–Leading Causes. (Data are for US for year indicated). Number of deaths for leading causes of death. http://www.cdc.gov/nchs/fastats/lcod.htm.

26. O'Connor JC. diff—Rise in UK deaths. 72% increase between 2005 and 2006. FEBS Lett 2008;28. http://patient-health-education.suite101.com/article.cfm/c_difficile_rise_in_uk_deaths Last accessed 6/24/08.
27. Christensen M, Jepsen OB. Reduced rates of hospital acquired UTI in medical patients. Prevalence surveys indicated effect of active infection control programmes. J Hosp Infect 2001;47:36-40.
28. Sands K, Vineyard G, Platt R. Surgical site infections occurring after hospital discharge. J Infect Dis 1996;173:963-70.
29. Manian F, Meyer L. Adjunctive use of monthly physician questionnaires for surveillance of surgical site infections after hospital discharge and in ambulatory surgical patients: Report of a seven year experience. Am J Infect Cont 1997;25: 390-4.
30. Zerey M, Paton BL, Lincourt AE, et al. The burden of Clostridium difficile in surgical patients in the United States. Surg Infect (Larchmt) 2007;8(6):557-66.
31. Deaths involving MRSA and Clostridium difficile continue to rise. Health statistics. Quarterly Spring 2007;22. Issued by the Office on National Statistics: Lond SW;1V:2QQ. http://www.statistics.gov.uk/releases.
32. Griffin FA. Reducing methicillin-resistant Staphylococcus aureus (MRSA) infections. Jt Comm J Qual Patient Safety/JCAHO 2007;33(12):726-31.
33. Fordtran JS. Colitis due to Clostridium difficile toxins: Underdiagnosed, highly virulent, and nosocomial. Proc Bayl Univ Med Cent 2006;19:3-12.
34. Dramatic rise in C diff deaths. BBC News February 28 2008;34 http://news.bbc.co.uk/1/hi/health/7268578.stm. Last accessed 8/12/08.
35. Sunenshine RH, McDonald LC. Clostridium difficile-associated disease: New challenges from an established pathogen. Cleve Clin J Med 2006; 73(2):187-97.
36. Friedenberg FK. Clostridium difficile associated disease: Changing epidemiology and treatment options. Medscape gastroenterology 36. http://www.medscape.com/viewarticle/563386_print. Last accessed 6/25/08.
37. Ashu NJ, Tompkins D, Wilcox MH. Comparative analysis of prevalence, risk factors and molecular epidemiology of antibiotic associated diarrhea due to Clostridium difficile, Clostridium perfringens, and Staphylococcus aureus. J Clin Microbiol 2006;44:2785-91.
38. Kuijper EJ, Coignard TP. Emergence of Clostridium difficile associated disease in North America and Europe. Clin Microbiol Infect 2006;12(Suppl 6):2-18.
39. McDonald LC, Kilgore GE, Thomson A, et al. An epidemic, toxin gene-variant strain of Clostridium difficile. N Engl J Med 2005;353:2433-41.
40. Best practices document for the management of Clostridium difficile in all health care settings. Provincial Infectious Diseases Advisory Committee (PIDAC). Ministry of Health and Long Term Care. Published December 2004, Revised, November 2007.
41. Clostridium difficile. In: Isada CM, Kasten BL, eds. Infectious Diseases Handbook, 5th ed. Hudson, OH: Lexi-Comp, 2003. p. 83-6.
42. Johal SS, Hammond J, Solomon K, et al. Clostridium difficile associated diarrhea in hospitalized patients: Onset in the community and hospital and role of flexible sigmoidoscopy. Gut 2004;53:673-7.
43. Halsey J. Current and future treatment modalities for Clostridium difficile associated disease. Am J Health Syst Pharm 2008;65:705-15.

44. Drudy D, Harnedy N, Fanning S, et al. Emergence and control of fluoroquinolone resistant, toxin A negative, toxin B positive Clostridium difficile. Infect Cont Hosp Epidemiol 2007;28(8):932-40.
45. Kim J, Smathers SA, Prasad P, et al. Epidemiological features of Clostridium difficile-associated disease among inpatients at children's hospitals in the United States, 2001-2006. Pediatrics 2008;122:1266-70.
46. Eriksen HM, Iversen BG, Aavitsland P. Prevalence of nosocomial infections in hospitals in Norway, 2002 and 2003. J Hosp Infect 2005;60:40-5.
47. Klavs J, Bufon Luznik T, Skerl M, et al. Prevalence of and risk factors for hospital-acquired infections in Slovenia—Results of the first national survey, 2001. J Hosp Infect 2003;54:149-57.
48. Starakis J, Marangos M, Gikas A, et al. Repeated point prevalence survey of nosocomial infections in a Greek University Hospital. J Chemother 2002;14:272-8.
49. Dunn PM, Semmelweis I. Of Budapest and the prevention of puerperal fever. Arch Dis Child Fetal Neonatal Ed 2005;90(4):F345-8.
50. Taisuke H, Kawaoka Y. Influenza: Lessons from past pandemics, warnings from current incidents. Nat Rev Microbiol 2005;3:591-600.
51. Centers for Disease Control and Prevention. Deaths—Leading causes. Available at: http://www.cdc.gov/nchs/fastats/lcod.htm. Accessed May 28, 2006.
52. Zigmund J. No more room; overcrowding blamed for ambulance diversions http://Modernhealthcare.com. Available at: http://www.modernhealthcare.com/printwindow.cms?articleId=38689&pageType=article.
53. Guideline for hand hygiene in Health Care Settings. Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. A report of the CDC. Morb Mortal Wkly Rep 2002;51:RR-16.
54. Langmuir AD. Changing concepts of airborne infection of acute contagious diseases: A reconsideration of classic epidemiologic theories. Ann NY Acad Sci 1980;353:35-44.
55. McFee RB. Preparing for an era of weapons of mass destruction (WMD): Are we there yet? Why we should all be concerned. Part I. Vet Human Toxicol 2002;44:193-9.
56. Smith SM. Where have you been? The potential to overlook imported disease in the acute setting. Eur J Emerg Med 2005;12:230-3.
57. Madren LK, Shipman C Jr, Hayden FG. In vitro inhibitory effects of combinations of anti-influenza agents. Antivir Chem Chemother 1995;6:109-113, 2005;12:230-3.
58. Aronson NE, Sanders JW, Moran KA. In harm's way: Infections in deployed American military Forces. Clin Infect Dis 2006;43:1045-51.
59. Centers for Disease Control and Prevention. Acinetobacter baumanii infections among patients at military medical facilities treating injured US service members 2002-2004. MMWR Morb Mortal Wkly Rep 2004;53:1063-6.
60. Joint Commission Accreditation Healthcare Organizations. http://www.jointcommission.org/.
61. Cunningham R, Dial S. Is over use of proton pump inhibitors fueling the current epidemic of Clostridium difficile associated diarrhea? J Hosp Infect 2008;70:1-6.
62. Aseeri M, Schroeder T, Kramer J, et al. Gastric acid suppression by proton pump inhibitors as a risk factor for Clostridium difficile associated diarrhea in hospitalized patients. Am J Gastroenterol 2008;103:2308-13.

63. Akhtar AJ, Shaheen M. Increasing incidence of Clostridium difficile associated diarrhea in African American and Hispanic patients: Association with the use of proton pump inhibitor therapy. J Natl Med Assoc 2007;99:500-4.
64. Creedon SA. Healthcare workers' hand decontamination practices: Compliance with recommended guidelines. J Adv Nurs 2005;51:208-16.
65. Boyce JM. Hand hygiene compliance monitoring: Current perspectives from the USA. J Hosp Infect 2008;70(Suppl 1):2-7.
66. Cohen MB. Clostridium difficile infections: emerging epidemiology and new treatments. J Pediatr Gastroenterol Nutr 2009;48(Suppl 2):S63-5.
67. Yuen KY, Wong SSY. Human infection by avian influenza A H5N1. Hong Kong Med J 2005;11:189-99.
68. Beigel JH, Farrar J, Han AM, et al. Avian influenza A (H5N1) infection in humans. N Engl J Med 2005;353:1374-85.
69. US Department of Health and Human Services. Available at: http://www.pandemicflu.gov/vaccine.
70. World Health Organization, WHO. Interim guidelines on clinical management of humans infected by influenza A (H5N1). Available at: http://www.who.int/csr/disease/avian_influenza/guidelines/Guidelines_Clinical%20Management_H5N1_rev.pdf.
71. McFee RB. Gulf War servicemen and servicewomen: The long road home and the role of health care professionals to enhance the troop's health and healing. Dis Mon 2008;54:257-336.
72. Centers for Disease Control and Prevention. Overview of drug resistant acinetobacter infections in healthcare settings. Released September 24, 2004. http://www.cdc.gov/ncidod/dhqp/ar_acinetobacter.html.
73. Frattarelli DA, Reed MD, Giacoia GP, et al. Antifungals in systemic neonatal candidiasis. Drugs 2004;64:949-68.
74. Manzoni P, Stolfi I, Pugni L, et al. A multicenter, randomized trial of prophylactic fluconazole in preterm neonates. N Engl J Med 2007;356:2483-95.
75. Kaufman D, Boyle R, Hazen KC, et al. Fluconazole prophylaxis against fungal colonization and infection in preterm infants. N Engl J Med 2001;345:1660-6.
76. Moss L. Hospital C difficile deaths: The patients let down by those they trusted. http://news.scotsman.com/latestnews/-Hospital-c-difficile-deaths.4370831.jp. Accessed August 12, 2008.