Nosocomial infections and infection control

David R Jenkins

Abstract

Nosocomial infections are a leading cause of avoidable harm in hospital patients and a substantial, unnecessary drain on healthcare resources. They are frequently caused by bacteria that are resistant to multiple antibiotics, and the treatment of nosocomial infections contributes to the selection of resistant bacteria. Understanding the complex interplay of factors that contribute to nosocomial infection is a necessary first step to improving patient outcomes. This article highlights the role of pathogens, patients, practice and place in both aetiology and management of nosocomial infections, and references additional reading for more detailed information.

Keywords Antibacterial drug resistance; *Clostridium difficile*; disease outbreaks; infection control; meticillin-resistant *Staphylcoccus aureus*; MRCP; nosocomial infections; patient care bundles; surgical wound infection

Key points

- Nosocomial infections are a major cause of harm for hospital patients
- Many infections can be prevented by good infection control practice
- Understanding the four main contributory factors — pathogen, patient, practice and place — helps with effective infection prevention

Defining nosocomial infections

Nosocomial (from the Latin *nosocomium* meaning hospital) infections are infections in hospital inpatients that were neither present nor incubating at the time of the patient's admission to hospital. Because of the difficulty of assessing the presence of an incubating infection, a practical approach is to define any bacterial infection as nosocomial if it becomes apparent >48–72 hours after admission. Viral infections with well-defined incubation periods can be more readily ascribed to community or nosocomial onset.

The epidemiology of nosocomial infections

Nosocomial infections occur frequently. A point prevalence survey of 231,459 patients from 947 acute care hospitals across 30 European countries in 2011/12 revealed that, at any given time, 5.7% of patients had at least one nosocomial infection.[1] Patients of all ages and clinical specialties are affected by nosocomial infections, as are all anatomical sites (Table 1).

The consequences of nosocomial infections

Nosocomial infections can be fatal or cause delayed recovery, functional impairment or aesthetic damage that can have lifelong consequences for patients. Management of these infections often requires prolonged inpatient stay, additional investigations, surgical intervention and antimicrobial treatment, all of which add to healthcare costs.

Across the world, healthcare payers are increasingly refusing to pay for the treatment costs of healthcare infections, claiming they could have been avoided. Hospitals in England are liable to lose the entire payment for an inpatient episode complicated by an avoidable nosocomial bloodstream infection with meticillin-resistant *Staphylococcus aureus* (MRSA). Healthcare regulators increasingly see nosocomial infections as preventable, and view rates of infection as a marker of the general quality of healthcare delivered by an organization.

Antimicrobial resistance

Nosocomial infections are an important factor in the emergence and spread of multidrug-resistant (MDR) bacteria. Broad-spectrum antibiotics, such as vancomycin, third-generation cephalosporins and carbapenems, are often used for empirical treatment of infected patients, thereby selecting for and favouring the persistence of MDR pathogens.

Defined terms are used to describe the extent of resistance. MDR organisms are resistant to at least one agent in three or more antimicrobial categories. Extensive drug resistance (XDR) is resistance to at least one agent in all but two or fewer antimicrobial categories. Pan-drug resistance (PDR) is resistance to all agents in all antimicrobial categories.

Important MDR causes of nosocomial infections include MRSA, vancomycin-resistant enterococci (VRE) and MDR Gram-negative bacilli, particularly *Escherichia coli* and *Klebsiella* species. The development of carbapenem resistance in Gram-negative bacteria, through the emergence of various carbapenemase genes, is increasing the prevalence of infections caused by XDR and PDR pathogens, and threatening the ability to deliver safe healthcare in many countries. Nosocomial infections caused by resistant fungi are also increasingly reported. The developing resistance crisis is worsened by a lack of new antibiotic classes entering clinical practice.

Infection prevention

The 'four Ps' of infection prevention — pathogens, patients, practice and place

Prevention is the best approach to management of nosocomial infections and can be addressed by considering the interaction of **p**athogens and **p**atients within the context of clinical **p**ractice in the **p**lace where healthcare is delivered (Figure 1).

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Relative frequency of nosocomial infections and causative organisms in a point-prevalence survey across Europe, 2011/12, in 13,829 infected patients

Infection type	Relative percentage of all nosocomial infections	Most frequent causative organisms (percentage of cases caused by identified pathogen)
Pneumonia	19.4	*Pseudomonas aeruginosa*: 17.4
Other lower respiratory tract infections	4.1	*Staphylococcus aureus*: 12.6
		Klebsiella spp.: 11.4
Surgical site infections	19.6	*Staphylococcus aureus*: 17.9
		Enterococcus spp.: 14.5
		Escherichia coli: 14.0
Urinary tract infections	19.0	*Escherichia coli*: 36.2
		Enterococcus spp.: 12.5
		Klebsiella spp.: 12.0
Bloodstream infections	10.6	Coagulase-negative staphylococci: 18.5[a]
		Staphylococcus aureus: 15.9
		Escherichia coli: 11.0
		Klebsiella spp.: 9.8
Catheter-related infections without bloodstream infection	1.6	
Cardiovascular system infections	1.4	
Gastrointestinal system infections	7.6	*Clostridium difficile*: 48
Skin and soft tissue infections	4.0	
Bone and joint infections	1.6	
Central nervous system infections	0.6	
Eye, ear, nose or mouth infection	3.0	
Reproductive tract infections	0.6	
Systemic infections	6.2	
Other/unknown	0.8	

[a] Coagulase-negative staphylococci are a frequent contaminant of blood cultures, but are genuine pathogens in many device-related nosocomial bloodstream infections.

Data source: European Centre for Disease Prevention and Control. Point prevalence survey of healthcare-associated infections and antimicrobial use in European hospitals 2011–2012 (2013).

Table 1

Pathogens: the range of infecting microorganisms extends from prion proteins (Creutzfeldt–Jakob disease (CJD) and variant CJD), through viruses, bacteria and fungi to parasites and arthropods such as the scabies mite.

The most frequently isolated pathogens in the European survey are shown in Table 1. Many are normal members of the human microbiota – the thousands of microbial species found naturally on the epithelial surfaces of the skin, oropharynx and gastrointestinal and genitourinary tracts. These, along with less frequently isolated microorganisms such as *Acinetobacter baumannii*, *Serratia* species, *Stenotrophomonas maltophilia* and *Aspergillus* species, are important because of their propensity for cross-infection and their ready ability to acquire resistance to multiple antimicrobials.

Certain subspecies of bacteria, characterized by the possession of genes for virulence markers or antimicrobial resistance, have emerged as significant causes of nosocomial infection that can spread on an intercontinental scale. MRSA infections in England in the early 2000s were mostly caused by just two strains, epidemic MRSA 15 and 16. A global epidemic of *Clostridium difficile* infection, peaking in England in 2007, was caused by a single strain, the 027 ribotype. Its spread was facilitated by antibiotic resistance, particularly to fluoroquinolones, and by a gene variant responsible for raised levels of toxin production. This modified gene led to severe diarrhoea and contamination of ward environments with high numbers of *C. difficile* spores, with increased numbers of secondary cases.

Patients: important patient determinants of infection risk include:

- extremes of age
- poor nutritional state
- obesity
- diabetes mellitus, lung, liver or renal disease, malignancy or immunodeficiency
- smoking
- coexisting infections.

Patients requiring emergency surgery are at increased risk of infection relative to elective patients undergoing the same procedure.

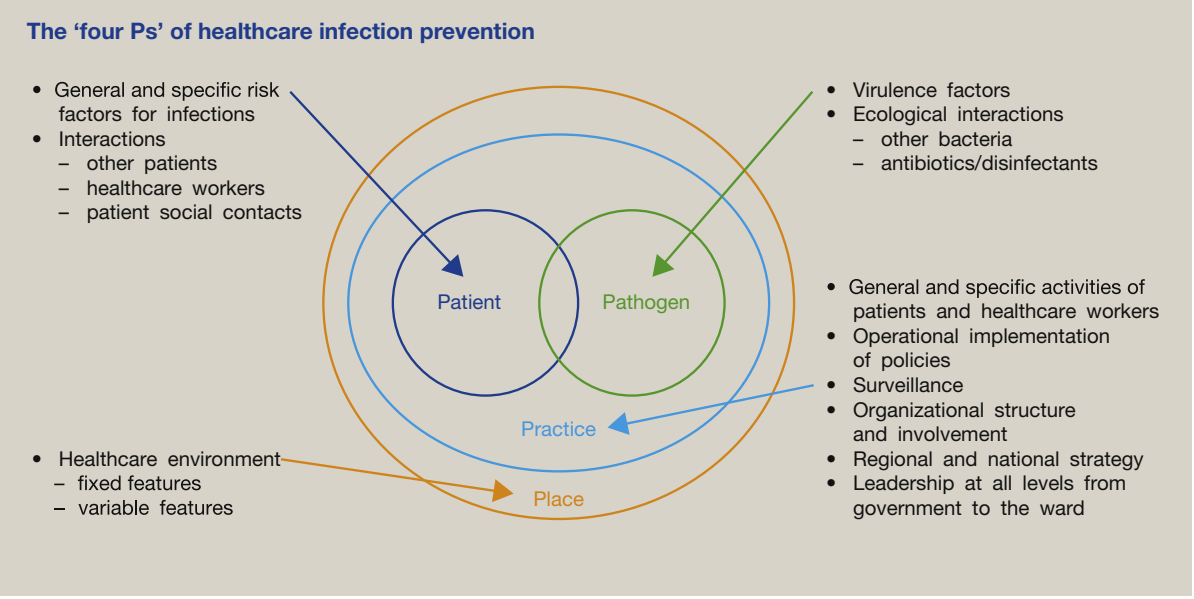

Figure 1

The pathogen–patient interaction (Figure 2):

Translocation – most nosocomial infections are caused by the affected patient's own microbiota moving from its natural site to the site of subsequent infection, often because of medical or surgical procedures. Examples include:

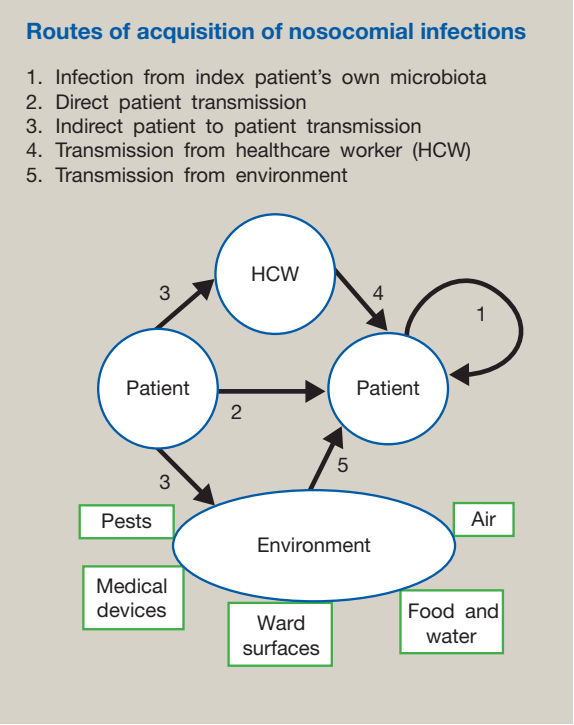

Figure 2

- surgical site infections caused by skin bacteria, especially *S. aureus*, introduced into the surgical wound at or soon after surgery
- catheter-associated urinary tract infections caused by Enterobacteriaceae (coliforms), such as *E. coli*, introduced into the bladder from the urethra during catheterization
- respiratory infections caused by the patient's oropharyngeal bacteria, including *Streptococcus pneumoniae*, entering the lower respiratory tract as a consequence of impaired coordination of swallowing, decreased conscious level, endotracheal intubation or respiratory toileting.

Patient-to-patient transmission – pathogens can be transmitted directly between patients through:

- direct contact (e.g. MRSA, VRE, MDR Enterobacteriaceae)
- respiratory route:
  - droplets (e.g. influenza, respiratory syncytial virus)
  - aerosols (e.g. varicella zoster, pertussis, tuberculosis).

Alternatively, transmission can be indirect, for example:

- by transfer of MRSA via a healthcare worker with suboptimal hand hygiene
- through the shared use of contaminated medical devices
- from shedding of pathogens into the clinical environment and acquisition by a subsequent patient (e.g. norovirus, *C. difficile*).

Healthcare workers as a source of infection – infected and colonized healthcare workers are a risk to patients. Potential threats include surgeons with blood-borne viruses (e.g. HIV, hepatitis B and C) and ward staff with respiratory (e.g. influenza, pertussis, tuberculosis) or skin (e.g. herpetic whitlows) infections.

Infections from the environment – airborne spores of environmental fungi, such as *Aspergillus* species, are a particular risk to immunocompromised patients. Hospital water distribution systems are vulnerable to colonization by *Legionella pneumophila* and *Pseudomonas aeruginosa*. Contaminated water used

for drinking or washing can cause infection with these and similar environmental organisms in susceptible patients. Patients with impaired swallowing reflexes, lung disease or immunosuppression are vulnerable to Legionnaires' pneumonia. Premature neonates, intubated patients on intensive care units and burns patients are particularly susceptible to respiratory and bloodstream infection with *P. aeruginosa*. Contaminated food and water can lead to gastroenteritis by food poisoning bacteria (e.g. *Salmonella*, *Campylobacter*, *E. coli* 0157) and viruses (e.g. norovirus).

Medical devices as a source of infection — reusable medical devices, including surgical instruments and endoscopes, should undergo stringent decontamination to ensure safety for subsequent patients. Modern sterilization processes virtually guarantee the elimination of viruses, bacteria (including bacterial spores) and fungi from surgical instruments, but contamination with CJD prion protein remains a risk, at least theoretically.

Reusable endoscopes present a decontamination challenge. These heat-sensitive instruments cannot be sterilized using autoclaves; instead, they undergo high-level decontamination with disinfectants. These noxious chemicals have to be rinsed off with water, which presents the possibility of recontamination with waterborne organisms including *P. aeruginosa* and environmental mycobacterial species, causing both genuine and pseudoinfections. Environmental mycobacteria can cause disease in susceptible patients, including individuals with cystic fibrosis. They can also mimic the appearance of *Mycobacterium tuberculosis* during the laboratory microscopic examination of bronchoalveolar lavage specimens, falsely implying the patient has tuberculosis.

Mycobacterium chimaera infection — an example of a new threat — since 2011, there has been a growing number of reports of endocarditis caused by this slow-growing mycobacterium in patients who had undergone cardiac surgery months to years earlier.

Contaminated water in the reservoirs of heater–cooler units used during bypass surgery has been identified as the source. Pumps in the heater–cooler units generate infectious aerosols that settle in the operative site and develop into infection. Whole-genome sequencing of *M. chimaera* isolates from patients and from the heater–cooler factory indicates that the heater–cooler units were probably contaminated during manufacture. *M. chimaera* infection following cardiac surgery has a high mortality rate: of 30 UK cases so far, 16 patients have died.

Practice: many nosocomial infections can be prevented by good infection prevention polices and practice. The frequent use of the hands in delivering healthcare underscores the critical importance of hand hygiene in infection prevention.

A recent systematic review from the World Health Organization (WHO) found convincing evidence that improvements in hand hygiene practice lead to reductions in transmission, colonization and infection by MDR bacteria.[2] The WHO promotes a hand hygiene programme, *My 5 Moments for Hand Hygiene* (before touching a patient, before clean/aseptic procedures, after body fluid exposure/risk, after touching a patient, after touching patient surroundings), recommending the use of alcohol-based hand rub as the routine method of hand decontamination.

Infection prevention care bundles — modern infection prevention approaches advocate the simultaneous implementation of multiple coordinated interventions. Compendia of evidence-based interventions have been published by a number of national bodies.

The Department of Health document, *epic3: National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England*, provides recommendations covering the areas of hospital environmental hygiene, hand hygiene, use of personal protective equipment (PPE), safe use and disposal of sharps, and principles of asepsis.[3] The Society for Healthcare Epidemiology of America and Infectious Diseases Society of America have published joint infection prevention guidelines, the latest of which addresses catheter-associated urinary tract infections, *C. difficile*, surgical site infections, central line-associated bloodstream infections, MRSA transmission and infection, ventilator-associated pneumonia and hand hygiene.[4]

Infection prevention practice themes include the following:

- **Prevent introduction of pathogens to the healthcare environment and patients** (e.g. identify patients who pose a cross-infection risk because of MDR carriage, respiratory infection, infectious diarrhoea or blood-borne viruses, through patient history, examination and microbiological screens; isolation of infectious patients, pre-admission antiseptic body washes, occupational health screens to identify infectious staff, staff vaccination).
- **Maintain a clean clinical environment** (e.g. ensure routine cleaning meets approved standards, use enhanced methods such as hydrogen peroxide vapour to decontaminate wards following occupation by patients carrying resistant or virulent organisms, monitor hospital water microbiological quality for *Legionella* and *Pseudomonas* species, ensure good food hygiene standards).
- **Prevent translocation of bacteria to potential sites of infection** (e.g. avoid use, or limit duration, of intravascular devices and urinary catheters, use patient skin disinfection before insertion of intravascular devices and surgery, use aseptic non-touch techniques for sterile procedures, use appropriate peroperative antibiotic prophylaxis, use non-invasive ventilation if possible, or endotracheal tubes with subglottic secretion drainage ports and selective oral decontamination in intubated intensive care patients).
- **Train staff** in awareness of high-risk patients and situations, appropriate use of isolation facilities and PPE, and appropriate antibiotic-prescribing strategies.
- **Monitor and improve processes and outcomes** through policy and guidelines development, audit and surveillance.

Place: the place where healthcare is delivered is usually a fixed element in hospital care but plays an important role in nosocomial infections. Ward design (e.g. number of beds, space between beds, availability of single-occupancy rooms, toilets and wash hand basins, adjacencies of services, ventilation and water distribution systems) and choice of furnishings and furniture contribute to the transmissibility of pathogens, the ability of staff to practise good infection control precautions and the ease of environmental cleaning. Best practice guidance on designing and

building healthcare buildings to prevent infections is available from the English Department of Health.[5] ◆

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