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CLINICAL PERSPECTIVES

Preventing healthcare-associated infection: risks, healthcare systems and behaviour

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Abstract

More than 177 000 potentially preventable healthcare-associated infections (HAIs) occur per annum in Australia with sizable attributable mortality. Organizational systems to protect against HAI in hospitals in Australia are relatively poorly developed. Awareness and practice of infection control by medical and other healthcare staff are often poor. These lapses in practice create significant risk for patients and staff from HAI. Excessive patient exposure to antimicrobials is another key factor in the emergence of antibiotic-resistant bacteria and *Clostridium difficile* infection. Physicians must ensure that their interactions with patients are safe from the infection prevention standpoint. The critical preventative practice is hand hygiene in accord with the World Health Organization 5 moments model. Improving the use of antimicrobials, asepsis and immunization also has great importance. Hospitals should measure and feed back HAI rates to clinical teams. Physicians as leaders, role models and educators play an important part in promoting adherence to safe practices by other staff and students. They are also potentially effective system engineers who can embed safer practices in all elements of patient care and promote essential structural and organizational change. Patients and the public in general are becoming increasingly aware of the risk of infection when entering a hospital and expect their carers to adhere to safe practice. Poor infection control practice will be regarded in a negative light by patients and their families, regardless of any other manifest skills of the practitioner.

Healthcare-associated infection: time for action

The Quality in Australian Health Care Study (QAHCS)[1] estimated that 5.5% of hospital admissions were affected by healthcare-associated infection (HAI), with an estimate at that time of 155 000 infections per annum across Australia. These figures are consistent with other Australian estimates of between 7.7%[2] and 5.7%[3] and the total estimate of 177 392 infections per annum from the Australian Commission on Safety and Quality in Healthcare review.[4] The QAHCS documented death in 4.9% of all adverse events (including infections) and permanent disability in 13.7%. Although there has not been a systematic study of this size conducted subsequently in Australia, there is no evidence that rates of HAI have decreased and HAI remains a major healthcare safety issue.[1]

The most common patient HAI involves the urinary tract, respiratory tract, surgical sites, intravascular catheters and bloodstream. It is estimated that up to 70% of HAI could be prevented if infection control procedures were followed.[5] Patients increasingly concern themselves with risk of infection when entering a hospital and expect their carers to adhere to safe practice. Poor infection

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control practice will be regarded in a negative light by patients and their families, regardless of any other manifest skills of the practitioner.

Risks for patients

Modern healthcare generates a wide range of infection risks for patients through practices that severely compromise host defences against infection and promote colonization by pathogenic hospital strains of bacteria. Patients are frequently confined in crowded, difficult to clean environments, where they may undergo invasive procedures, be fitted with prosthetic devices, and require broad-spectrum antibiotics or immunosuppressive therapies. These conditions provide ideal opportunities for the adaptation and spread of pathogenic microorganisms, such as methicillin-resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile*, vancomycin-resistant enterococci and multi-resistant *Acinetobacter* species. Pathogens circulating in the general community also enter the hospital and exploit the crowded conditions to spread rapidly within the hospital population. Examples include community-type MRSA, norovirus and severe acute respiratory syndrome (SARS) virus.[4] Some infections are also caused by an admitted patient's own bacterial flora (endogenous infections), due to processes that compromise defences against invasion and infection.

Risks to healthcare staff

Until recently many clinicians have not considered themselves to be at risk from infection by working in healthcare.

'Standard Precautions' formerly termed universal precautions (Table 1) are designed to reduce HAI risk for both patients and staff in all healthcare settings, independent of the infectious status of a person.[6] When adhered to closely, they largely eliminate the risk of blood-borne virus (e.g. HIV, Hepatitis B or C) transmission during healthcare without the need to document the infection status of individual patients. There are well-documented cases of blood-borne virus infections in healthcare staff that have resulted from lapses in Standard Precaution practice (e.g. following avoidable needlestick injury or mucosal splash).[7]

The worldwide SARS epidemic provided a stark reminder of risk from pathogenic respiratory illness. In Canada, Hong Kong, Singapore and elsewhere, healthcare staff were at the highest risk of contracting SARS and significant mortality resulted.[8] Other respiratory illnesses such as influenza and respiratory syncytial virus are also frequently spread among staff by infected patients and major morbidity may result. A recent review concludes that tuberculosis remains a very important occupational risk for healthcare staff in low and middle income countries and for staff in some high-income country facilities. Risk appears particularly high when there is increased exposure combined with inadequate infection control measures.[9]

Organisms such as MRSA that are spread mainly by contact (touch), colonize and infect healthcare staff with varying ease dependent on the characteristics of the strain. A review of 127 investigations of hospital MRSA and the involvement of healthcare staff indicated an average of 4.6% of healthcare staff to be carriers of MRSA with 1 in 20 (5.1%) experiencing MRSA infection. Risk factors for staff included chronic skin disease and poor infection control practice. Staff were implicated as the cause of several MRSA clusters.[10] New virulent strains of community-type MRSA have been isolated in most Australian states, causing outbreaks within families, facilities and communities.[11] MRSA infected or colonized patients admitted to hospital increase the risk of MRSA spread to healthcare staff and their families. A recent report highlighted the impact of community-type MRSA on a paediatric clinic in the United States; 16 of 45 staff experienced skin infections and one staff member died from MRSA infection.[12]

How is HAI spreads?

A conventional division specifies three modes of infectious illness dissemination – contact (direct, indirect, common vehicle and vector), droplet and airborne spread; however, in reality a continuum of patterns exist for each pathogen. Table 1 provides examples of agents predominantly spread by each mode and protective measures that are required to reduce cross-transmission.[13]

The hands of healthcare staff are the single most important factor in the transfer of pathogens from patient to patient (contact spread).[14] Colonized patients and staff are the main reservoirs of hospital-adapted pathogens, shedding these organisms into their immediate surroundings. The transfer of these pathogens (usually through direct or indirect contact) to a normally sterile body site or onto an invasive medical device enables an infection to occur.

Healthcare-associated infection that result from exposure to infected aerosols (droplet or airborne transmission) are less frequent. Infections spread by the droplet respiratory mode can also be transmitted through contact spread as many of these infective agents remain viable on hands and surfaces for extended periods. For instance there is compelling evidence that respiratory syncytial virus cross-infection in paediatrics is reduced by increasing compliance of healthcare staff with hand hygiene.[15]

Table 1 How are healthcare-associated infections transmitted and prevented?

Mode of transmission	Infective agents transmitted by this mode (examples)	Protective practices	Rationale (see text as well)
Contact spread (direct/ indirect/common vehicle)	Blood-borne viruses (HIV, Hepatitis B & C, other) Healthcare-associated infections, especially arising from invasive devices or procedures and in staff.	**Standard precautions** • Aseptic technique (effective antisepsis of skin, maximal barrier precautions during procedure, aseptic etiquette) • Hand washing/hand hygiene • Use of personal protective equipment • Safe handling/disposal of sharps/clinical waste • Safe reprocessing of reusable equipment and instruments • Environmental cleaning and spills management • Safe hospital linen and food services **Antibiotic stewardship (see text)** **Immunization (see text)**	Assume every individual's blood or body fluids are infectious Reduce contamination of sterile body sites during invasive procedures Provide additional barrier to prevent direct exposure of staff skin to blood/body fluids Immunocompromised patients are prone to certain food-borne pathogens Reduce antimicrobial selective pressure Reduce host susceptibility
Contact spread (specific pathogens with high epidemic potential)	Methicillin-resistant *Staphylococcus aureus*, other multi-resistant organisms (MRO), *Clostridium difficile* enteric viral infections	**Transmission-based contact precautions**† • MRO screening of at-risk groups • Isolation/cohorting of colonized/infected patients • Impermeable gown/apron and gloves • Enhanced cleaning and disinfection of patient environment and equipment	Identify and contain organism reservoir (colonized or infected individuals) Control of environmental contamination
Droplet spread	Respiratory viruses, such as influenza, Group A streptococcus, *Neisseria meningitidis*	**Transmission-based droplet precautions:** • Separate unprotected contact between infected and non-infected individuals • Isolation or cohorting (grouping) of patients or separation of patients • Fluid repellent (surgical) mask • Protective eye wear	Avoid short distance exposure to infected respiratory droplets by containment and distancing
Airborne spread	Pulmonary tuberculosis, chickenpox, measles	**Transmission-based airborne precautions:** • Barrier isolation in negative pressure room • Fit-tested particulate filter (P2) mask. Staff also fit-check the mask on each occasion a mask is donned • Other personal protective equipment	Healthcare staff and other patients must be protected from infectious fine particle (<5 μM) aerosols that are capable of transmitting infection at low doses

†Active screening and isolation for methicillin-resistant *Staphylococcus aureus*-colonized patients/staff is not performed at some Australian sites as it is considered to be an ineffective measure. However, all evidence-based international standards and guidelines support the practice in patients demonstrated to have moderate to high risk for carriage. Active screening for other MROs (e.g. vancomycin-resistant enterococci) is still controversial and varies widely in practice. In large part, screening should be confined to patient populations at highest risk from morbidity (e.g. intensive care, haematology and solid organ transplant patients).

Agents that cause respiratory infection are designated as either spread by droplet or airborne routes (see Table 1) largely based on epidemiological studies; however, this division is artificial to some degree. The process of coughing or sneezing creates droplets of varying size that may be expelled at high velocity across distances up to 6 m, which may facilitate distant transfer of any respiratory infective agent. Furthermore, in low-humidity (e.g. air conditioned) environments, larger droplets may evaporate to form droplet nuclei that remain airborne for extended periods. Whether true airborne transmission of infection occurs depends on such variables as the infectious dose of an agent, the delivered dose to the recipient and what degree of pre-existing immunity the recipient has. The microbes that are most efficiently disseminated by the airborne mode (e.g. tuberculosis, measles, varicella) remain viable in droplet nuclei and have a very low infectious dose in a susceptible individual. In low-humidity environments, influenza more usually spread by 'droplet' may also be spread over short distances via the airborne route as shown from animal studies.[16]

Prevention of HAI – approaches to system and culture change

It is tempting to ascribe the failure to prevent HAI to individual human factors alone – lapses and active failures by doctors and other healthcare staff; however, these lapses occur in a healthcare environment that often fails to facilitate safe systems of care. For instance lack of training or credentialing in standard infection control practices, understaffing and lack of availability of alcohol-based hand rub make adherence to safe practice less likely. To protect patients more effectively, it is crucial that systems of management and care in hospitals are improved such that (i) lapses or active failures are less likely to occur and (ii) there are safeguards to prevent injury in the event of a lapse. A basic premise is that humans are fallible and errors are to be expected. Systems that provide barriers and safeguards must be improved to reduce the capacity for human error to cause an adverse event.[17]

Most existing healthcare systems still have significant potential to create risk for patients and staff from HAI. There are many relatively hidden and important deficiencies (latent unsafe conditions) that contribute to significant HAI risks. Table 2 catalogues Australian healthcare systems, their status of development and examples of latent unsafe conditions with an assessment of the HAI risk from each of these. The risk assessment is a subjective synthesis of the likelihood of an unsafe condition or event coupled to the potential severity of outcome in line with the NSW risk assessment process.[18]

In addition to system change, organizational culture change, that is, the establishment of new norms of behaviour driven by leaders in management and clinical care who have been convinced of need for urgent change is needed.[19] Leaders must provide explicit, unequivocal support for infection control policy and its implementation. They must ensure that all necessary enablers such as bed-side alcohol-based hand rub and universal staff training are in place. Sufficient epidemiologists and infection control professionals are required to effectively manage and implement infection control surveillance, audits and training. Once these measures are in place, there is also a role for social marketing campaigns to healthcare staff and patients to increase awareness of HAI and its prevention.

Reducing HAI risk: the physician's role

Physicians as leaders, role models, patient advocates and educators play a crucial role in efforts to improve safety of healthcare. A persuasive, detailed case for clinician-led reform was made by Scott *et al.* recently in this journal.[20] Physicians are uniquely placed to drive clinical practice reform that embeds specific evidence-based patient safety practices across all relevant patient groups. As argued by Scott *et al.*, to achieve this, significant changes in clinical workforce organization, teamwork, patient participation, interventional supervision, clinical governance and information technology for monitoring performance are required. Systems design principles, using approaches derived from industry, can help to make clinical care safer and less variable and improve safety. The active involvement of clinicians in these changes is paramount.

At an individual level, physicians can make a difference by:

- Participating in the orientation and performance management of their clinical team
- Ensuring that quality and safety issues are addressed at clinical unit meetings
- Supporting clinical unit level programmes that facilitate quality and safety improvement and performance audit
- Demonstrating safe practice by actions and words and promoting safe practice among colleagues and team. Standard and additional (transmission-based) precautions (Table 1) specify essential minimum requirements for infection control practice.
- Increasing awareness and training about HAI prevention at undergraduate and post-graduate levels. For instance, requiring satisfactory compliance with hand hygiene and other infection control measures as part of assessment criteria for clinical vivas.

Hand hygiene

Hand hygiene is the most important element of 'Standard Precautions'. Microorganisms which cause infection can be transmitted through the hands of healthcare workers during their normal work activities. Common occurrences of this are:

- Transfer of a patient's own microorganisms from one body site to another
- Transfer of microorganisms from one patient to another patient
- Transfer of microorganisms to and from the environment and healthcare equipment
- Transferring of microorganisms colonising the healthcare worker.

Hand hygiene involves either hand washing or the use of antiseptic alcohol-based hand rubs. Semmelweiss (1845) famously demonstrated significant sustained reductions in maternal postnatal mortality after enforcing hand antisepsis with a chlorinated lime solution prior to patient care.[21] Three large studies have demonstrated that multimodal programmes to achieve sustained increases in

Table 2 Healthcare systems and potential for creating risk to patients and staff from healthcare-associated infection (HAI)

System elements	Existing status of this element†	Latent unsafe conditions that increase the risk of HAI	Risk rating‡
Personnel management			
Infection control training	✓ Variable	Staff not mandated to attend training Staff unaware of infection control precautions Inconsistent undergraduate training IC requirements not integrated in to other training	Extreme
Invasive procedure credentialing	✓	Deficient asepsis during procedures and care of devices (e.g. insertion of intravascular line)	High
Occupational health and safety training	✓✓	Unsafe use/disposal of sharps Variable reporting and management of blood-borne virus exposures	Medium
Immunization	✓✓	Non-immune or staff carrying blood-borne virus allowed to practice in situations that create patient risk (e.g. surgery)	Medium
Clinical care			
Standard and additional precautions	✓✓ Variable	Variable compliance with hand hygiene and other requirements	High
Antibiotic stewardship	✓	Indiscriminate antibiotic exposure increases selection of multi-resistant HAI and increases the incidence of HAI	High
Infectious disease management	✓✓	Lack of availability or active recourse to consultation leads to risk of death/relapse from HAI	Medium
Environmental management			
Environmental cleaning and disinfection	✓ Variable	Variable resources and priority given to cleaning. Variable standards of practice. Variable training of cleaning staff. Environmental auditing not rigorous enough. Technology; variable adoption of more effective methods of cleaning (e.g. new disinfection agents and modes of delivery) and audit (e.g. use of removable surface fluorescent dye markers to assess adequacy of cleaning)	High
Built environment (e.g. facility design)	✓ Variable	Lack of required isolation facilities for methicillin-resistant *Staphylococcus aureus* and respiratory pathogens Poor maintenance or design elements that impede cleaning	Medium
Water	✓✓✓	Rare	Low
Ventilation	✓✓ Variable	Lack of specified respiratory isolation facilities	Low
Waste	✓✓✓	Rare	Low
Food	✓✓✓	Adequacy of hazard analysis and critical control point plans	Low
Quality systems			
Document control	✓ Variable	Informal or out-of-date guidelines remain accessible	High
Communication	✓ Variable	Poorly developed communication channels among clinicians and between management and clinicians	Medium
HAI surveillance	✓✓	Increases in infection rates or outbreaks variably detected. HAI events not validated/checked by most jurisdictions	Medium
Clinical pathways for common infective syndromes	✓	Tolerance of variable clinical practice including delays in time to first antibiotic dose in septic patients	Medium
IC audit programmes	✓✓	Audits too infrequent, not rigorous in method; data not fed back to clinicians	Medium
Support services			
Sterilization of surgical equipment	✓✓✓	Rare	Low
Sterilization and disinfection of endoscopes	✓✓	Variable practices and training of staff	Medium
Supplier controls	✓✓✓	Rare	Low
Medication supply, compounding, prescription and administration	✓✓	Rare	Low

†The number of ticks is a subjective assessment by the author that indicates the extent to which the system concerned has been developed and uniformly applied across healthcare in Australia. ‡Risk stratification approach is derived from NSW Health classification (see text).[18] IC, infection control.

hand hygiene compliance have been associated with reductions in HAI, including MRSA.[22–24]

A national initiative commenced in 2008 to improve hand hygiene, focusing on education, provision of alcohol-based hand rub at every bedside, reliable, regular audits of compliance with effective feedback to staff and management, and measurement of patient infection outcomes (healthcare-associated *S. aureus* bloodstream infections). The programme is modelled on the five moments for hand hygiene programme developed by the World Health Organization. A central message is to clean your hands before and after every patient contact.

In observational audits, medical staff are often demonstrated to have the poorest hand hygiene adherence and thereby expose their patients to significant risk. As leaders, mentors, educators and patient advocates, physicians must urgently adopt a best practice of hand hygiene throughout their practice settings. System aspects include making sure that hand alcohol-based hand rub is available for use at each bed-side and practice setting. Just as the culture change that normalized the use of seat belts was essential to improvements in road safety, sustained changes in compliance with hand hygiene will only arise out medical support for a pervasive organizational (and perhaps regulatory) approach to culture change.

Other elements of the hospital ward round may create significant risk to patients and staff due to lack of compliance with Standard Precautions. In particular, portable equipment (e.g. stethoscope) taken to the bedside must be cleaned or disinfected prior to contact with a patient or their environs. A good system of care on ward rounds is to provide a separate ward round trolley equipped with alcohol-based hand rub and large alcohol-impregnated wipes for disinfecting stethoscopes and other equipment. Such a trolley can also hold the patient clinical files and provide a surface for writing, avoiding cross-contamination with the patient environment.

Asepsis during invasive procedures

Asepsis encompasses techniques, including disinfection, that reduce the potential for microorganisms to contaminate sterile body sites during invasive procedures. As an example, studies of central intravascular lines document significant reduction in risk from infection when optimal aseptic practices are systematically adopted. A care 'bundle' that includes performance of hand hygiene by the operator prior to insertion, application of effective skin antiseptic, allowing it sufficient time to work, wearing sterile protective apparel, and using a large sterile drape for the insertion site virtually eliminates intensive care central line-associated bloodstream infection.[25]

Antimicrobial stewardship

Prior patient exposure to antimicrobials is a key risk factor for colonization and infection due to antibiotic-resistant bacteria and *C. difficile* infection. These infections usually add to the infectious burden rather than just replacing existing cases of infection caused by less resistant pathogens. Evidence from community and hospital practice shows that use of systemic antimicrobials is often indiscriminate or ineffectively targeted against the likely or proven pathogen.

Antimicrobial stewardship programmes attempt to improve prescribing to reduce unnecessary use and promote effective directed antibiotic treatment in line with guidelines and demonstrated incidence of antibiotic resistance. Successful stewardship programmes have been shown to reduce not only resistance rates in hospitalized patients but also morbidity, mortality and cost.[26] The Australian Commission on Safety and Quality in Healthcare has recently established a project to improve antibiotic stewardship in Australian hospitals.[27]

Key practice points include[27,28]

- Potentially septic patients need appropriate investigation prior to antibiotic treatment – at least two blood culture sets from different peripheral sites, other microbiology as indicated
- Empiric antimicrobial choice and dose for septic patients should be based on recommendations from *Therapeutic Guidelines: Antibiotic* or local Infectious Diseases/Microbiology expert advice – inadequate initial therapy is a demonstrated risk factor for adverse outcomes
- Indications for antimicrobial treatment and duration should always be documented
- Patients who are on antimicrobials need regular evaluation to determine: need for ongoing treatment and/or need to target (or direct) treatment against a demonstrated pathogen (select alternative agent, consider correct dose, switch to oral, modify treatment plan including duration of treatment)
- Follow recommended surgical antibiotic prophylaxis (right drug, right dose, right timing – administer within 60 min of procedure commencement, no post-operative doses)
- Evidence-based computerized decision support systems facilitate better prescribing and lower bacterial resistance.

Immunization

Immunization of healthcare staff helps protect the individual and also reduces risk from vaccine preventable disease in patients. For instance high uptake rates of annual influenza immunization by healthcare staff in aged care facilities has been shown to reduce mortality in their elderly patients.[29]

All healthcare staff with direct patient contact need to ensure that their immune status is optimized for hepatitis B, tuberculosis, measles, chickenpox, influenza and pertussis. Medical staff should visit their staff health service annually to update their immunization and have their immune status checked as required.

The Australian Immunisation handbook defines many situations in which patients who are over 65 years and younger patients with various chronic medical conditions should receive additional regular immunizations. These include patients with splenectomy or hyposplenism. Various surveys of these patients indicate that compliance with immunization guidelines is poor.[30] All physicians should implement systems of care to identify their at-risk patients to enable opportunistic immunization as recommended.

Surveillance

Measurement of the incidence of major types of HAI is an essential component of control programmes.[1] Bloodstream infections, surgical site infections, intensive care infections, infections and colonizations due to multiresistant organisms are usually documented by routine surveillance systems and reported to State and National bodies.

Clinical teams should receive regular feedback about HAI, antibiotic resistance and usage in their patients.

Conclusions

Current levels of HAI in Australian hospitals are unacceptable and lead to preventable morbidity. Physicians can drive widespread system and practice change towards safer care using existing knowledge about quality improvement. The impact of such changes will be evident from HAI surveillance data and will serve to increase the community's trust in the healthcare system.

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Appendix 1

Ten commandments of infection prevention for physicians

1. Always disinfect your hands with alcohol-based hand rub BEFORE and AFTER touching a patient or performing a procedure. Set the example for your team and expect others to follow your lead.
2. Dress well for safer care – abandon ties and lanyards, bare your arms to the elbow – no wrist watches or jewellery.
3. Insist on the provision of alcohol-based hand rubs at the patient bedside and in your clinic/rooms.
4. Take alcohol-impregnated wipes on your ward rounds to disinfect equipment, such as stethoscopes and pulse oximeters between use on every patient.
5. Ensure your team follows a standard, methodical, sterile (aseptic) approach for all invasive procedures (especially IV line insertion).
6. Invasive devices are potentially dangerous – remove them as soon as you can (within 3 days for peripheral cannulae).
7. Target antimicrobial therapy – consult *Therapeutic Guidelines: Antibiotic* for the most appropriate agent(s), dose, route and duration.
8. Be the first on your team to have the influenza vaccine every year and make it known to others.
9. If you're not receiving regular, relevant feedback about healthcare-associated infections like MRSA involving your patients, then you're missing out – insist on it.
10. Look beyond the obvious when seeking source(s) of infection. Surgical wound and device-related infection may be present even in the absence of visible local inflammation.