**Breaking the Chain of Infection in Older Adults**

A Review of Risk Factors and Strategies for Preventing Device-Related Infections

Gregory Schrank, MD<sup>a</sup>, Westyn Branch-Elliman, MD, MMSc<sup>b</sup>,*

**KEYWORDS**

- Infection prevention
- Multidrug-resistant organisms
- Indwelling devices
- Older adults
- Antimicrobial stewardship

**KEY POINTS**

- Device-related infections are a leading cause of health care–associated infections in older adults.
- Indwelling devices are a risk factor for multidrug-resistant bacterial colonization.
- Host, pathogen, device, and environmental factors all contribute to the development of infection.
- Limiting utilization of these devices and practicing infection prevention techniques can reduce the likelihood of infection and limit transmission of multidrug-resistant pathogens.

**INTRODUCTION**

Device-related infections (DRIs) in older adults are a substantial cause of morbidity and mortality, and they place a significant economic burden on the health care system of the United States.<sup>1–4</sup> As the number of persons the over the age of 65 increases to 83.7 million by 2050, comprising 20% of the total US population, the incidence of health care–associated infections (HAIs), and DRIs in particular, is expected to increase accordingly.<sup>5</sup> At the end of 2014, there were 1.4 million persons residing in long-term care facilities (LTCFs) in the United States, almost 10% of whom were over the age of 85.<sup>6</sup> Studies...
suggest that 5% to 7% of these residents will develop an HAI during their stay. In the United States alone, up to 3.8 million HAIs occur in residents of LTCFs annually.

Indwelling devices provide a portal of entry for potential pathogens to enter a susceptible host and set the stage for future infections. The most common indwelling devices are urinary catheters, which predispose patients to catheter-associated urinary tract infections (CAUTIs). Because of a variety of host factors in older adults, including medical illness and incontinence, approximately 13% of new admissions to skilled nursing facilities from acute care facilities have a urinary catheter in place at the time of admission. Up to 22% of LTCF residents have a urinary catheter in place at any given time, indwelling for an average duration of 105 days. In addition, an estimated 9% of home care recipients have an indwelling urinary catheter.

The other 2 most commonly used indwelling devices in older adults are percutaneous feeding tubes and central venous catheters (CVCs), which include peripherally inserted central catheters (PICCs), central venous lines, midline catheters, and ports. An estimated 6% to 8% of all residents in LTCFs have a feeding tube, with higher rates in patients with cognitive impairments. Because intravenous treatments, such as parenteral nutrition and antimicrobials, are increasingly delivered outside of the acute care setting, use of PICC lines in skilled nursing facilities has increased to a prevalence of at least 22%.

Many factors interact to contribute to the frequency and severity of DRIs in older adults. The “Chain of Infection” is a general infection prevention framework that can be used to evaluate the major elements that lead to HAIs and to identify modifiable risk factors that can be targeted to reduce future infections. Host factors, including immune dysfunction and fragile skin, provide an opening for opportunistic pathogens to invade and cause an infection. Bacterial factors, including antimicrobial resistance and biofilms, provide health care–associated organisms with competitive advantages for invasion and pathogenesis. Environmental factors, including contamination, provide a source of exposure for susceptible hosts. Finally, indwelling devices provide a portal of entry for pathogenic organisms to enter a susceptible host and cause infection. Elements of the model can be used to develop a multifaceted approach to treatment and prevention of these DRIs.

Here, the authors first review host, pathogen, environmental, and device-related factors that put older adults at increased risk of DRI and then discuss strategies for reducing future infections.

**HOST FACTORS**

Host susceptibility is a major determinant of infection; age is a nonmodifiable risk factor that impacts immunity and infection risk in the setting of exposure to a potential pathogen. Physical and functional incapacity, combined with the immunologic changes of aging, including those caused by immunosuppressive medications, make older adults more susceptible to DRIs than their younger counterparts.

Aging is associated with a decline of functional innate and adaptive immunity, a process known as immunosenescence. The underlying mechanisms are unclear, but measurable decreases in functional immunity occur. The total number of circulating immune cells does not decline, although remaining immune cells have diminished capabilities: neutrophils lose some of their capacity for phagocytosis; monocytes and macrophages undergo changes in their ability to release cytokines and provide immune regulation; and natural killer cells have reduced potential to respond to cytokine signaling.
Malnutrition can compound the challenges already presented by immunosenescence. Among older adults residing in the community, 2% to 4% are estimated to suffer from protein-energy malnutrition. This most serious form of nutritional deficiency is more common among hospitalized older adults and is associated with increased postdischarge mortality. Malnutrition contributes to a vicious cycle, whereby poor nutritional status is a risk factor for infection, and infection can worsen underlying malnutrition, because of the increased metabolic demands of acute and chronic illness.

Beyond immune dysfunction, specific organ-system changes contribute to risk of DRIs in older adults. Atrophy of the epidermal and dermal layers of the skin predisposes to breakdown and wound formation. Underscoring the importance of these changes, up to 5% of residents of skilled nursing facilities have pressure ulcers. Skin breakdown is a key element of the link between host and portal of entry; ulcers provide a portal of entry for bacterial pathogens and are often the first step in the pathway to infection. The harms associated with skin breakdown and chronic wounds are compounded because these ulcers are at particularly high risk of colonization with multidrug-resistant organisms (MDROs), such as methicillin-resistant Staphylococcus aureus (MRSA) and vancomycin-resistant Enterococci (VRE), which can complicate management if the ulcer becomes infected.

In the genitourinary system, a reduction in bladder capacity, diminished rate of urine outflow, and increased postvoid residual volume all contribute to bacterial

Fig. 1. The “Chain of Infection” is a general infection prevention framework that can be used to evaluate the major elements that lead to HAIs and to identify modifiable risk factors that can be targeted to reduce future infections. Visualized here is the interplay of risk factors contributing to the development of a DRI and potential interventions to “break the link.”
urinary colonization, independent of the risk associated with indwelling urinary catheters. In addition, approximately 1 in 3 residents of skilled nursing facilities suffers from bowel or bladder incontinence, which itself influences the risk of infection. First, incontinence leads to increasing use of invasive devices, such as urinary catheters. Indwelling catheters increase infection risk by providing a portal of entry for potentially pathogenic organisms. Second, incontinent patients who do not have urinary catheters placed are at increased risk of skin breakdown, which can provide a separate portal of entry for opportunistic bacterial organisms.

Neurocognitive deficits also play a role. Almost 15% of skilled nursing facility residents have severe cognitive impairment and near-complete dependence for activities of daily living. Within nursing homes, higher levels of nursing needs, often due to chronic wounds or indwelling devices, are independent predictors of early MRSA and VRE acquisition. Use of antipsychotic medications, used in up to 20% of skilled nursing facility residents, is associated with increased risk of pneumonia. Delirium in older adults can also hinder proper care of other indwelling devices and cause unplanned removal of indwelling devices, placing patients at even higher risk of infection. Furthermore, obtaining and interpreting microbiologic specimens in the cognitively impaired may be more difficult than in other patient groups.

ENVIRONMENTAL FACTORS

MDRO transmission from health care personnel to patients occurs during patient-provider encounters and is common among older adults with indwelling devices present. The duration and nature of the interaction also play a role. There is a dose-dependent association between nursing dependency, defined by physical and self-maintenance assessments, and MRSA/VRE co-colonization. These data suggest that longer durations of contact with health care personnel lead to increases in MDRO exposure, which in turn lead to more MDRO colonization. Bedbound status and receipt of rehabilitation care are both risk factors for MRSA acquisition, in part due to the high rate of direct contact between these patients and health care personnel. A prospective study of more than 400 residents of residential care and a rehabilitation facilities found that residents receiving rehabilitation services that involve frequent and intense contact with health care personnel are at 4-fold greater risk of new MRSA acquisition compared with their counterparts receiving less direct contact.

Contact with contaminated environmental services also facilitates the transfer of bacterial pathogens to susceptible older adults and sets the stage for future DRIs. Rates of environmental contamination in the rooms of patients with VRE colonization or infection can be as high as 70%. Compounding high rates of contamination is the environmental persistence of MDRO organisms. Without appropriate cleaning and decontamination, bacterial organisms can survive on the surfaces of objects for prolonged periods, up to months at a time, and serve as a reservoir for colonization and infections of subsequent patients.

Environmental cleaning and contamination are directly related to patient outcomes and prevention of HAIs: In the nursing home setting, higher rates of MRSA environmental contamination are associated with a higher prevalence of MRSA among residents and less frequent room cleaning. These data suggest that cleaning practices may be modified to decrease the bacterial burden of the environment and thereby limit MDRO exposure and reduce HAIs.
PATHOGEN FACTORS

Exposure to, and colonization with, pathogenic bacteria often precede clinical infection; rates of MDRO colonization may exceed 35% in residents of LTCFs. Colonization with MDROs such as MRSA is associated with increased mortality among older adults, although teasing out the independent effect of MDRO colonization from other patient comorbidities is challenging.

Those with indwelling devices are at particularly high risk. Device insertion sites are the most common location of new MRSA acquisition in previously uncolonized individuals; molecular-typing demonstrates that the new acquisition is typically due to a health care–associated MRSA strain, and that persistent carriage after initial colonization is the norm. A cross-sectional study of 200 residents of 14 community nursing homes in Southeast Michigan found that residents with any type of indwelling device, including urinary catheters, percutaneous feeding tubes, and PICC lines, were more likely to be colonized with MRSA compared with those without devices, after adjusting for functional status, comorbidity, and age (odds ratio 1.97, \( P < .04 \)). Compounding the concern, residents with indwelling devices were also more likely to be colonized with MDROs, such as ceftazidime-resistant gram-negative bacilli, despite no difference in antibiotic exposure history compared with their counterparts without indwelling devices.

THE ROLE OF BIOFILMS

A diverse array of gram-positive and gram-negative pathogens, including \textit{S. aureus}, \textit{Enterococcus faecalis}, and \textit{Pseudomonas aeruginosa}, is able to produce biofilms on indwelling devices. Organisms that reside within biofilms can originate from multiple different sources, including the host, health care personnel involved in the placement or maintenance of the device, the surrounding environment, and, in the case of CVCs, contaminated infusates. Although the portal of entry is specific to the type of indwelling device, in all circumstances, attachment of bacteria to the device is required before a dynamic biofilm can be established.

Biofilms adhere to device surfaces and protect bacterial populations by encasing organisms in a complex extracellular matrix that is impervious to external protections that would normally help to prevent infection: Biofilms protect bacterial inhabitants from host immune systems and also from antibacterial medications. Because of their dynamic and active nature, biofilms are particularly insidious because they facilitate cellular growth and communication between different bacterial organisms, including transfer of genetic elements that confer antimicrobial resistance. An additional management challenge is that some bacteria contained within the biofilm exist in a nutrient-limited state and have a very slow growth rate. Because many antibacterials work most effectively against actively dividing bacteria, the slow growth rate may further decrease antimicrobial effectiveness. Because of all of these factors, once a biofilm develops on an indwelling device, eradication of these organisms becomes extremely challenging.

IMPACT OF INDWELLING DEVICES ON ANTIMICROBIAL USE

In addition to predisposing patients to infection, indwelling devices place older adults at risk of other adverse events, including overdiagnosis of infections that leads to unnecessary antibiotic use. For example, among nursing homes residents with indwelling urinary catheters, up to 95% have significant bacteriuria with greater than 50,000 colony forming units per milliliter; the high prevalence of bacteriuria diminishes
the positive predictive value of culture results. Due in part to difficulties with diagnosis in the catheterized population, up to one-third of antimicrobials prescribed for suspected urinary tract infections (UTIs) in LTCFs are for residents with asymptomatic bacteriuria that does not merit treatment.

BREAKING THE LINKS

**General Prevention Strategies for Reducing Device-Related Infections**

Indwelling devices are risk factors for MDRO colonization and acquisition, particularly in wounds, at the groin, and at device insertion sites. Indwelling devices also contribute to colonization with multiple MDROs: After controlling for other host factors, the presence of an indwelling device is associated with a 5.2-fold increase in the incidence of MRSA and VRE co-colonization. Thus, the challenge is 2-fold: Patients with invasive devices are at significantly higher risk for infection, and also at higher risk for antimicrobial-resistant infections. These challenges underscore the need for prevention efforts that focus on reducing the use of indwelling devices and also on stewardship efforts to reduce the development and spread of antibiotic-resistant infections, thereby breaking the link between the portal of entry and the bacterial pathogen.

**Device Management**

Training in device management and care is a fundamental prevention strategy. Despite the frequency with which older adults have an indwelling device present in skilled nursing facilities, several studies demonstrate that device management training is limited. One survey found that although most nurses in post–acute care facilities received specific training on the management of indwelling urinary catheters, only 40% of other health care personnel providing direct patient care, including nursing assistants, nursing students, and environmental service workers, received similar focused training. These nonnurse health care personnel may be directly involved in activities associated with device management, and potentially contamination. Thus, formal training and the expectation of all front-line health care personnel to be able to identify and address risk factors for contamination and infection, such as the presence of a urine collection bag on the floor, is important when developing a DRI prevention program.

A critical and often overlooked element of programs to reduce DRI is ongoing health care personnel education. Urinary catheters are most commonly placed by nurses; however, a recent study found that only 64% of nurses underwent training to prevent CAUTIs when starting at their position, and less than half had validated competency. Closed catheter systems and limiting bladder irrigation are 2 interventions that can reduce CAUTI by preventing pathogens from gaining entry. Despite the importance of these simple interventions, a recent survey in Michigan skilled nursing facilities found that more than 50% of health care personnel were unaware of how to maintain a closed catheter drainage system, and a larger number were unaware of recommendations against bladder irrigation. Likely contributing to the lack of appreciation for infection prevention guidelines is the high rate of nursing assistant turnover in the United States, which has been associated with increases in adverse outcomes among older adults, including UTIs.

In addition to specific training about optimal device management to reduce exposure, educational efforts directed toward hand hygiene, proper device insertion with aseptic technique, maintenance, and prompt removal once no longer medically needed are crucial aspects of successful programs for reducing DRIs. These
educational efforts should be directed across the spectrum of health care personnel at the facility, because the primary caregiver may vary depending on the setting. Because of the transient nature of the effect that individual educational efforts may have on health care personnel behaviors, these initiatives should be ideally accompanied by intermittent outreach, observation and feedback, and possible recertification at designated intervals to ensure appropriate infection prevention techniques are being applied.56,57

**Surveillance and Device Removal**

Among patients admitted to LTCFs, there is a dose-dependent increase in infection rates when multiple indwelling devices are present.13 Most DRIs can be prevented by simply removing the indwelling device; this is the single most important DRI prevention intervention.13 Surveillance of device use and DRIs with direct feedback to providers can be used to reduce device-days and improve practice, thereby reducing patient risk.

A national Centers for Medicare and Medicaid (CMS) mandate requires that nursing homes report appropriateness of urinary catheter use.6 As nursing homes are now evaluated to “ensure each resident who enters the nursing home without a catheter is not given a catheter, unless medically necessary, and that incontinent patients receive proper services to prevent urinary tract infection and restore normal bladder functions,” use of indwelling urinary catheters is decreasing.6

The Federal Steering Committee for the Prevention of Health Care–Associated Infections established metrics of reporting from LTCFs, including CAUTI incidence rates and a urinary catheter utilization ratio: catheter-days/resident-days.16 The goal of urinary catheter utilization ratio reporting is to encourage the implementation of prevention practices that reduce catheter-days, such as avoidance of indwelling urinary catheters whenever possible, performing regular assessments of ongoing need, and early catheter removal. In the acute care setting, stop orders for device removal and catheter assessment protocols increase catheter discontinuation when they are no longer medically indicated.58,59 Nursing-driven initiatives to evaluate catheter necessity coupled with protocol-based device removal are another method that has demonstrated significant and sustained reductions in the number of catheter-days when compared to usual practice.50,61 Similar multidisciplinary initiatives involving venous access teams to evaluate the need for CVCs and the selection of catheter type can lead to a reduction in the prevalence of CVCs, with a corresponding decrease in risk of catheter-associated bloodstream infections (CLABSIs).

**Horizontal Versus Vertical Approaches to Infection Prevention**

Historically, acute care hospitals have taken a “vertical approach” to infection control, intensively targeting specific high-burden MDRO pathogens, such as MRSA, VRE, and carbapenem-resistant *Enterobacteriaceae*, with methods of active surveillance, pathogen-directed contact precautions, and targeted decolonization.62 Vertical strategies are designed to reduce colonization, infection, and potential transmission of these predetermined high-risk pathogens, but the impact of these interventions on other potential pathogens is limited. In contrast, horizontal interventions are designed to reduce overall infection risk, rather than target any specific pathogen. Examples of horizontal interventions include hand hygiene campaigns, antimicrobial stewardship programs, and programs to limit the use of indwelling devices.62 As vertical infection strategies control are resource intensive, post–acute care facilities may favor horizontal interventions that can be focused on high-risk individuals with intensive, multifaceted approaches.62,63
Standard Precautions and Hand Hygiene

Standard precautions are the most basic set of prevention interventions that should be applied to all patient encounters to protect both patients and health care personnel from infection. Standard precautions include hand hygiene before and after any patient contact, respiratory hygiene, use of personal protective equipment when needed, safe injection practices, and safe handling of potentially contaminated equipment and surfaces. An essential aspect of standard precautions is effective hand hygiene, a priority area of outreach by the Centers for Disease Control and Prevention (CDC). Emphasizing excellent hand hygiene is particularly important for nursing home personnel, because their hands are frequently colonized with pathogenic organisms, including gram-negative bacilli, Candida sp, S aureus, and VRE. Despite the well-known benefits of this simple intervention, hand hygiene compliance in LTCFs is low, and several studies demonstrate limited understanding of standard precautions principles and the importance of hand hygiene for preventing HAIs.

Contact Precautions

The most recent guidelines for infection control in LTCFs recommend instituting contact precautions based on clinical risk factors and general assessment of likelihood of transmitting MDRO pathogens. Several states passed legislation to mandate screening for MRSA colonization in hospitals and LTCFs. Despite these recommendations, implementing contact precautions for patients colonized with MDROs is controversial. Placement of patients in private rooms creates logistical challenges in long-term care, particularly for facilities with limited bed capacity. Furthermore, use of contact precautions for prevention of some pathogens, such as MRSA and VRE, is increasingly a subject of debate. Limited evidence suggests that cohabitation with an MRSA-colonized roommate does not significantly impact MRSA acquisition, possibly because of the nature of patient-patient and patient-provider interactions in skilled nursing facilities. Residents in skilled nursing facilities are exposed to a spectrum of patients and environments; thus interventions that focus on limiting specific patient-to-patient interactions may be ineffective for reducing MDRO transmission. From a practical standpoint, isolation may not be feasible, because of the need for residents to participate in various activities outside of their room, including physical therapy, social programs, meals, and other forms of rehabilitation.

Further clouding the picture, recent studies suggest that placing patients, particularly older adults, into isolation is associated with adverse outcomes and measurable increased morbidity. Adverse impacts of contact precautions include less attention from staff and increased rates of delirium. With these issues in mind, many acute care facilities continue to perform active surveillance of MDROs, which remains an area of ongoing research. Given these challenges, most community nursing homes are using standard precautions without additional contact isolation to care for residents colonized with MRSA.

Bundled Approaches

In older adults with indwelling devices, the presence of comorbidities and functional disability makes infection prevention efforts more challenging. Prevention bundles, which include evidence-based sets of interventions designed to reduce infection, are one method of reducing DRIs. Implementation of prevention bundles has...
successfully reduced the rates of many DRIs, including CAUTIs and central line-associated bloodstream infections, among others.\textsuperscript{80}

A randomized, controlled trial with the “bundle” of active surveillance, enhanced contact precautions, and intensive education programs of hand hygiene and infection prevention focused on indwelling devices found a significant reduction in the prevalence density rate of MDRO colonization, incident CAUTIs, and antibiotic use when compared with usual care. Study authors hypothesized that barrier precautions led to decreased new MDRO colonization, whereas staff education simultaneously led to decreased transmission of pathogens and subsequent development of CAUTIs.\textsuperscript{17} Although the intervention required substantial effort, it was targeted at particularly high-risk individuals with indwelling devices and provided benefits to all facility residents.

**Environmental Cleaning**

Effective environmental cleaning can help to break the link between the pathogenic organisms and the health care environment in the chain of infection. Cleaning of health care facilities is associated with HAI reductions.\textsuperscript{81} Direct cleansing and disinfection of contaminated surfaces and equipment is the primary method of these efforts. It relies on the training of staff to properly use cleaning supplies to ensure the maximum reduction of pathogen burden.\textsuperscript{33,82} Enhanced educational programs directed at staff, including a system of performance feedback such as fluorescent markers or adenosine triphosphate measurement, are effective at improving the quality of cleaning.\textsuperscript{83–88} Despite these findings, incomplete cleaning or the incorrect utilization of cleansing products occurs with frequency, leaving behind potentially pathogenic organisms on environmental surfaces.\textsuperscript{89–92} As a result, there is great interest in the development and application of emerging technologies to augment the efforts of environmental services staff, including the use of UV radiation devices, hydrogen peroxide vapor, and self-disinfecting materials impregnated with heavy metals or germicides.\textsuperscript{33}

**Antimicrobial Stewardship**

Improving antimicrobial use with an active antimicrobial stewardship program can reduce \textit{Clostridium difficile} infection and antibiotic utilization and lower pharmacy costs.\textsuperscript{93,94} Issues surrounding antimicrobial stewardship are covered in more detail in McElligott and colleagues’ article, “Antibiotic Stewardship in Nursing Facilities,” in this issue.

Because of limited staffing and diagnostic resources, many antibiotic prescriptions are dispensed empirically before evaluation by a trained clinician and without appropriate testing.\textsuperscript{25,95} Given the high rates of bacterial colonization among older adults with devices, particularly bacteriuria with indwelling urinary catheters, improving antimicrobial use can improve outcomes by limiting selection of MDRO pathogens and reducing medication toxicity. Increases in antimicrobial use are also associated with increased density of VRE colonization in the stool of hospitalized patients. Thus, reduction in the use or duration of antimicrobial therapy may help to limit the burden of resistant organisms found in the environment, thereby potentially limiting exposures and ultimately DRIs.\textsuperscript{96}

**Targeting Specific Device-Related Infections**

The following sections focus on specific infection-prevention practices for reducing infections associated with the 3 most common indwelling devices in older adults: urinary catheters, vascular catheters, and percutaneous feeding tubes.
Urinary catheters

Indwelling urinary catheters provide a portal of entry for pathogenic bacteria to invade a susceptible host. As such, they are a major risk factor for UTI. In catheterized patients, UTI incidence is 6.2 per 1000 patient-days, more than double the incidence of patients without indwelling catheters (2.8 per 1000 patient-days). Furthermore, presence of an indwelling urinary catheter is associated with worsening UTI severity, including pyelonephritis, prostatitis, and bacteremia. CAUTIs are also associated with substantial cost, up to $896 per episode, that may not be reimbursed by insurance carriers, including CMS payers. Nonreimbursement theoretically provides additional motivations to prevent these infections, but recent analyses suggest that this policy did not lead to significant reductions in infection rates.

The most important prevention strategy for reducing CAUTIs is reducing exposure to urinary catheters. Thus, the Healthcare Infection Control Practices Advisory Committee guidelines emphasize that urinary catheters should only be used in circumstances of necessity, such as urinary retention, rather than routinely or for convenience. Implementing a mandatory daily review of catheter necessity and leveraging the electronic medical record for evaluation are 2 strategies that reduce indwelling catheter days and are mainstays of prevention practices. Nurse-driven protocols are another effective approach. Of note, indwelling urinary catheters also predispose older adults to other adverse health care-associated conditions, including reduced mobility, falls, venous thromboembolism, pressure ulcers, and damage to the urethra and lower urinary tract. Thus, reducing catheter use has additional benefits beyond CAUTI reduction.

If avoidance of a urinary catheter is not possible, several steps can be taken to reduce infection risk. Universal application of the most recent CDC guidelines for the prevention of CAUTIs, which focuses on the appropriate use of indwelling catheters, proper techniques for insertion and maintenance, and CAUTI surveillance, is estimated to reduce CAUTI by 20% to 70%.

If an indwelling urinary catheter is unavoidable, efforts to prevent CAUTI include hand hygiene before and after device management, cleansing and performing care to the groin before insertion, using aseptic technique with sterile supplies, and securing the device to prevent movement of the catheter. These interventions are designed to reduce pathogen exposure, potentially breaking the link between the bacterial pathogen and the portal of entry. Practice bundles for catheter placement and management also include maintaining a sterile, continuous, closed system and eliminating loops or kinks in the drainage tubing so as to prevent stasis or retrograde flow of urine and reduce the risk of bacteriuria. Positioning of the collecting bag below the level of the bladder and emptying urine from the collecting bag regularly further limits contamination and colonization.

Devices that do not enter the bladder, and therefore do not provide a direct portal of entry into the host, can be used instead of indwelling catheters in some patients, particularly if obstruction and retention are not the reason for the catheter. Examples of external urinary collection systems include condom catheters and the ReliaFit (Eloquest Healthcare, Fentdale, MI, USA) male urinary device. When compared with indwelling urinary catheters, condom catheters reduce symptomatic UTI, bacteriuria, and death in older men, particularly those without dementia. In patients where external devices are not an option, such as patients with neurogenic bladder, intermittent catheterization decreases symptomatic UTI and bacteriuria when compared with chronic indwelling catheters.

In facilities with particularly high CAUTI incidence, additional more aggressive prevention strategies may be considered. Altering the design of the urinary catheter is an engineering approach that may reduce the incidence of CAUTI independent of health care
personnel practices. Urinary catheters can be constructed of hydrophilic latex or silicone tubing and may be coated with antimicrobial substances, such as silver. Hydrophilic latex catheters are associated with improvements in patient satisfaction, pain, and decreased incidence of hematuria when compared with silicone, but a reduction in CAUTI has not been demonstrated.99 Antimicrobial-impregnated and silver-coated catheters are designed to reduce catheter colonization, theoretically reducing biofilm formation and infections. In a large, multicenter trial, patients requiring indwelling catheterization were randomized to receive either a silver alloy–coated catheter, a nitrofural-impregnated catheter, or a control catheter; primary outcome was incidence of symptomatic CAUTI. The study authors found no difference in the rates of CAUTI between the intervention and control arms (−0.1% [95% confidence interval, CI, −2.4–2.2] and −2.1% [95% CI −4.2–0.1], respectively).109 These findings were supported by a recent meta-analysis that found that silver alloy–coated catheters were not associated with a reduction in CAUTIs when compared with other catheter designs. Similarly, no significant difference in clinical outcomes was found between patients receiving nitrofural-impregnated catheters compared with standard catheters, although some studies suggested a lower rate of symptomatic CAUTI and bacteriuria.110 Cost is another consideration: these coated catheters cost between 2.5- and 6.6-fold more than standard catheters, and large clinical trials have failed to demonstrate significant improvements.111,112 Thus, their uptake into clinical practice has been limited. Nonetheless, they are a consideration in settings with high CAUTI rates where more standard interventions have been ineffective.

In particularly high-risk individuals with indwelling urinary catheters, for whom traditional methods of infection prevention have had limited success, bacterial interference has been attempted. Bacterial interference includes intentional colonization of low-virulence bacteria into an individual’s urinary tract. The theory behind bacterial interference is that the low-virulence organisms will not cause clinical infections, but will out-compete potentially pathogenic strains, thereby limiting infections. Reducing infections, in turn, limits antimicrobial exposure, which then limits the emergence of antimicrobial resistance and adverse drug events that accompany prevention strategies that employ chronic antimicrobials.113 Multiple small studies demonstrate that the use of nonpathogenic Escherichia coli strains to inoculate the bladder, through instillation of bacteria-laden normal saline solution, can lead to long-term asymptomatic colonization.114–116 Although a reduction in rates of symptomatic CAUTIs has been found among patients colonized with these nonpathogenic strains, including a more than 2-fold reduction over a year in a randomized controlled trial of patients with neurogenic bladder, achieving long-term colonization can be challenging and resource intensive, requiring patients to undergo repeated inoculation procedures.113 As a result, adoption of bacterial interference has not been widespread.

Central venous catheters
CVCs are used in older adults for many reasons, including delivery of parenteral medications, administration of nutrition, and as a means of performing hemodialysis. However, CVCs also serve as a direct portal of entry for pathogenic bacteria. CLABSIs are a major cause of morbidity and mortality in the United States, with an estimated 41,000 cases in 2009. Mortalities following CLABSI approach 25%.117,118

Analogous to indwelling urinary catheters, the most effective means of limiting the risk of CLABSI is to minimize exposure to CVCs. The clinical indications and need for a CVC are often more apparent than those of a urinary catheter; however, the challenges of ensuring appropriate monitoring and prompt removal when no longer required are similar. Prompt discontinuation of CVCs when they are no longer clinically indicated is particularly challenging with older adults in post-acute care or long-term
care settings, where limited resources and less frequent interactions with health care staff may inadvertently prolong the number of CVC days, particularly if a needs assessment is not integrated into routine patient care. In the intensive care unit, the inclusion of process measures, such as the documentation of CVC presence and duration, contributes to CLABSI reduction. In skilled nursing facilities and the home care environment, lack of consistent documentation concerning central catheter indication and planned duration is a frequent quality gap.

CVCs can become colonized and serve as a portal of entry for potentially pathogenic bacteria via 2 major mechanisms: colonization at the insertion site with migration along the external surface of the catheter or direct inoculation of the connectors or hubs, leading to internal colonization. Once contaminated, pathogens can migrate to the bloodstream and cause infection.

Because contamination is the first step in the pathway to infection, interventions targeted toward preventing device contamination at the time of placement can break the link between the pathogen and the portal of entry. Hand hygiene campaigns, use of chlorhexidine gluconate (CHG)-alcohol antiseptic for skin preparation (as compared with povidone-iodine preparation), and the use of sterile barrier precautions are basic prevention strategies that reduce bacterial contamination and thereby reduce CLABSI. Because inoculation of catheter tubing and hubs is a mechanism of bacterial contamination, limiting the number of catheter lumens is also associated with reduced rates of bloodstream infections, particularly for PICCs.

Antiseptic and antimicrobial impregnated CVCs, to reduce bacterial colonization and biofilm formation, are another consideration. Minocycline/rifampin-impregnated catheters are associated with reductions in bacterial colonization (7.9% vs 22.8%, P < .001) and CLABSI (3.4% vs 0.3%, P < .002). A second-generation chlorhexidine/silver sulfadiazine catheter, with antiseptic coating both the internal and the external aspects of the device, demonstrates additional improvements. Chlorhexidine-impregnated PICCs are also available, but studies demonstrate mixed results with these devices. Clinically, impregnated and standard catheters have similar CLABSI risk during the first 10 days after placement, and a cost-effectiveness analysis suggested that minocycline/rifampin catheters are an attractive strategy only if the catheter is in place for 8 days or more. Considering the higher costs associated with these interventions and the limited resources for infection prevention available at LTCFs, the decision to implement these additional infection prevention measures should be considered based on the risk of incident CLABSI and anticipated duration of CVC need.

Once a CVC is placed, interventions that limit bacterial contamination reduce infections. Basic practices to reduce contamination include hand hygiene before device handling, disinfection of catheter hubs and connections before access, and minimizing unnecessary manipulation of the line, including for blood draws. Alcohol-containing connector caps and CHG-containing device dressings are also effective. Among particularly high-risk patients, such as those with long-term hemodialysis catheters, total parenteral nutrition requirements, or a history of recurrent CLABSIs, antibiotic or alcohol lock solutions may lead to additional reductions.

**Percutaneous feeding tubes**

Although controversial, many older adults, particularly those with advanced dementia and difficulty swallowing, receive percutaneous feeding tubes. These feeding tubes are associated with many risks, including pneumonia, skin and soft tissue infections, and higher rates of *C difficile* infections. Teasing out the independent impact of the feeding tube
from overall elevated infection risk in older adults is difficult, but a small observational study of 30 LTCF residents with feeding tubes found that 57% developed 23 distinct infections over 100 resident-months, most of which were pneumonias and UTIs.\textsuperscript{13}

Among older adults with dementia, observational studies demonstrate higher rates of mortality due to pneumonia in tube-fed patients as compared with those who are fed orally; however, confounding by indication is a consideration.\textsuperscript{139} Feeding tubes are associated with increased rates of reflux and aspiration of gastric contents, potentially leading to aspiration events and aspiration pneumonia.\textsuperscript{140} Interventions that increase the incidence of pneumonia are concerning because pneumonia is the leading cause of mortality in the LTCF population and is also the primary indication for transfer to higher-acuity facilities. In the United States, 10% to 18% of all pneumonia hospitalizations are initiated as a transfer from LTCFs.\textsuperscript{141}

Several steps can be taken to limit infection risk associated with feeding tube-related infections. Skin and soft tissue infections can be reduced with periprocedural antimicrobial prophylaxis, excellent wound care, and MRSA decolonization.\textsuperscript{142,143} \textit{C difficile} infections can be reduced through antimicrobial stewardship efforts.\textsuperscript{144} Pneumonia prevention efforts may include aspiration and delirium precautions, elevating the head of the bed, and avoidance of unnecessary proton pump inhibitors.\textsuperscript{145}

The “Quest for Zero”

Increasingly, health care organizations are striving toward a goal of eliminating all HAIs, including DRIs.\textsuperscript{146} The prevailing notion of a “Quest for Zero” promotes aggressive DRI reduction measures, but the impact of these policies on health care quality is unclear.\textsuperscript{147} Public reporting of facility-specific HAI rates is a nationwide strategy that was implemented to improve prevention practices. Beginning in 2011, hospitals were required to report CLABSIs acquired in the intensive care unit. CAUTI reporting was added in 2012.\textsuperscript{80} Public reporting was expanded to include general medical and surgical units in 2015.\textsuperscript{80} By requiring reporting and transparency, incentivized through additional funding, the mandate of these policies is to encourage and reinforce infection prevention. However, despite these goals, analysis of policies regarding CMS nonpayment for HAIs has not resulted in changes to provider behaviors or facility infection rates.\textsuperscript{98,148} Beyond infection prevention, the implementation of public reporting policies to increase transparency has unfortunately worsened outcomes in other areas of clinical medicine, calling into question the benefits of this approach.\textsuperscript{149,150} Another attempt to improve care through payment restructuring is The Improving Medicare Post–Acute Care Transformation Act of 2014, which aims to increase quality across post–acute care settings by aligning the measures of quality across all types of providers, thereby incentivizing appropriate use and care of indwelling devices in older adults.\textsuperscript{151} The impact of better defining quality measures for providers in post-acute care settings on clinical outcomes is not yet known.

Resource Constraints and Economic Considerations

As a shift away from inpatient clinical care settings has occurred, older adults, with indwelling devices and increasingly complex comorbidities, are being cared for in lower acuity settings; 42% of Medicare recipients discharged from an acute care hospital were transferred to a subacute facility.\textsuperscript{50,152,153} Many of these patients have indwelling devices, are often colonized with MDROs, and move between facilities. Frequent transfers increase the risk of horizontal transmission to other patients and health care personnel alike.\textsuperscript{152}

As a result of frequent transitions between acute care facilities, post–acute care, rehabilitation, and home health care, older adults will often experience different and conflicting approaches to infection prevention and maintenance of indwelling
devices. Without clear consensus on how best to prevent and control bacterial colonization, it is left to individual facilities to determine how often to screen patients for MDROs, where to obtain specimens, and what forms of precautions are necessary, including isolation. Heterogeneity in practice between different health care facilities results in practice variations in the management of possible infections.

Implementation of guidelines for prevention and management of HAIs in LTCFs is limited. Although officially a requirement of CMS, a recent review found that failure to implement an infection prevention program was the most frequently cited health deficiency in these facilities. Furthermore, even when programs are in place, less than 10% of infection preventionists working in LTCFs have specific training in the area.

High leadership turnover is another challenge faced by post–acute care facilities. Turnover leads to limited support for educational and philosophic efforts to improve infection prevention practices. Without local leadership to encourage best practice, unclear perceptions and varying adherence persist. Lack of an on-site physician can present additional challenges, because nurses and nursing assistants perform clinical evaluations and are tasked with early identification of infections, despite limited training. Compounding the problem of limited training, nursing turnover at post–acute care facilities is high and also associated with increased risk of HAIs and hospitalizations due to infection.

SUMMARY

DRIs are a major cause of morbidity and mortality among older adults. The frequent use of indwelling devices in this vulnerable population results in a significant burden to the health care system and is an important target for infection prevention and antimicrobial stewardship efforts. Fortunately, within the chain of infection that leads to DRIs in older adults, there are multiple opportunities to implement interventions to “break the links” and reduce MDRO colonization and infections and to improve antimicrobial use.

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