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How Often Do Clinically Diagnosed Catheter-associated Urinary Tract Infections in Nursing Homes Meet Standardized Criteria?

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Conflict of Interest Checklist

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	Yes	No	Yes	No	Yes	No	Yes	No
Employment or Affiliation		X		X		X		X
Grants/Funds		X		X		X		X
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Consultant		X		X		X		X
Stocks		X		X		X		X
Royalties		X		X		X		X
Expert Testimony		X		X		X		X
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Author Contributions

Armbruster: concept and design, analysis, and interpretation of data, drafting and revising the article. Prenovost: analysis and interpretation of data, critically reviewing the article for important intellectual content. Mobley: interpretation of data, critically reviewing the article for important intellectual content. Mody: concept and design, acquisition, analysis, and interpretation of data from the parent study, critically reviewing the article for important intellectual content. All authors reviewed and approved the submitted version of the article.

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Abstract

Objectives—Determine the relationship of clinically diagnosed catheter-associated urinary tract infection (CAUTI) to standardized criteria and assess microorganism-level differences in symptom burden in a cohort of catheterized nursing home (NH) residents.

Design—Post-hoc analysis of a prospective longitudinal study.

Setting—Twelve NHs in Southeast Michigan.

Participants—233 NH residents with indwelling urinary catheters.

Measurements—Clinical and demographic data, including CAUTI epidemiology and symptoms, were obtained at study enrollment, 14 days, and monthly thereafter for up to one year.

Results—One hundred twenty participants with an indwelling catheter (51%) were prescribed systemic antibiotics for 182 clinically diagnosed CAUTIs. Participants were predominantly white (90%), male (52%), with a mean age of 73.7 years. Common signs and symptoms were acute change in mental status (28%), fever (21%), and leukocytosis (13%). Forty percent of clinically diagnosed CAUTIs met Loeb's minimum criteria, 32% met National Health Safety Network (NHSN) criteria, and 50% met either Loeb's minimum or NHSN criteria. CAUTIs involving *Staphylococcus aureus* and *Enterococcus* spp. were least likely to meet criteria. CAUTIs involving *K. pneumoniae* were most likely to meet Loeb's minimum criteria (OR=9.7 [95% CI, 2.3–40.3]), possibly due to an association with acute change in mental status (OR=5.9 [95% CI, 1.8–19.4]).

Conclusion—Fifty percent of clinically diagnosed CAUTIs met standardized criteria, which represents an improvement in antibiotic prescribing practices. At the microorganism-level, our exploratory data indicates that symptom burden may differ between microorganisms. Exploration of CAUTI signs and symptoms associated with specific microorganisms may yield beneficial information to refine existing tools guiding appropriate antibiotic treatment.

Keywords

CAUTI; nursing homes; delirium; infection criteria; *Klebsiella pneumoniae*

Introduction

Urinary tract infection (UTI) and catheter-associated UTI (CAUTI) are the most common infections in nursing homes (NHs) leading to the majority of antibiotic prescriptions,[1] though one-third are misdiagnosed asymptomatic bacteriuria for which antimicrobial therapy is not beneficial.[2, 3] However, catheter-associated bacteriuria can progress to symptomatic cystitis, pyelonephritis, and even bacteremia.[4–7] Approximately 10–50% of individuals catheterized for ≥7 days will develop CAUTI while essentially all individuals catheterized long term will experience at least one CAUTI.[2,14] Thus, it is critical to further refine guidelines for CAUTI diagnosis and initiation of antibiotics.

Current CAUTI diagnosis criteria include clinical signs and symptoms such as fever, rigors, hypotension, flank pain, leukocytosis, and acute changes in mental and functional status, as well as a positive urine culture.[8, 9] Loeb's minimum criteria are standards for initiation of antibiotics in long term care settings based on assessment of infection signs and symptoms,[8] while the National Healthcare Safety Network (NHSN) criteria are standards for CAUTI surveillance in long term care settings.[9] Recent estimates indicate that only 10–16% of prescriptions for UTI in NHs adhere to Loeb's minimum criteria,[10] and only 31% of UTIs prescribed antibiotics meet the NHSN criteria.[11] These discrepancies could be due to several factors, including prescription of antibiotics for asymptomatic bacteriuria and the challenges of accurately identifying infections involving atypical symptoms. Prescribing practices could be improved by investigation of signs and symptoms that are most (and least) common during infection with traditional CAUTI pathogens, such as *Escherichia coli,* compared to microorganisms more likely to be present during asymptomatic bacteriuria, such as *Staphylococcus* and *Enterococcus* species.[3] For instance, if *Staphylococcus aureus* could be clearly differentiated from *E. coli* based on colonization density and symptom burden, this information could aid in guiding appropriate empirical treatment.

Little is known concerning possible differences in clinical presentation of CAUTI caused by distinct microorganisms, or whether symptom burden may be indicative of CAUTI epidemiology. The innate immune response is largely responsible for the signs and symptoms of UTI, particularly activation of toll-like receptors (TLRs) by pathogen-associated molecular patterns (PAMPs) such as lipopolysaccharide (LPS). TLR signaling, the magnitude of the resulting immune response, and infection symptoms can be modulated by specific virulence factors or PAMP modifications.[12] For example, expression of different fimbrial types by Gram-negative bacteria can modulate LPS-induced TLR signaling cascades and infection outcome in a mouse model of UTI.[12] Dysuria is linked to certain LPS decorations rather than strictly resulting from LPS-induced TLR signaling.[13] Delirium can result from systemic inflammation,[14] and may also be modulated by the level of innate immune activation. Flow cytometry analysis of bacterial, leukocyte, and erythrocyte counts in urine was recently found to be indicative of infection by broad groups of microorganisms in non-catheterized individuals.[15] The value of clinical signs and symptoms for predicting UTI was investigated for individuals with spinal cord injuries on clean intermittent catheterization,[16] but not with respect to specific microorganisms. Thus, classes of microorganisms may be associated with specific patterns of infection signs and symptoms. If so, this information could be useful for guiding appropriate antibiotic treatment in catheterized NH residents, particularly if clear differences exist between CAUTIs caused by microorganisms in which distinct treatment differences exist, such as *S. aureus* versus *E. coli*.

Our study had three primary goals: 1) determine adherence of clinically diagnosed CAUTI from a cohort of NH residents to standardized criteria, 2) determine if specific microorganisms are more likely to be present in clinically diagnosed CAUTIs that meet standardized criteria than others, and 3) conduct an exploratory assessment of associations between CAUTI signs and symptoms and specific microorganisms. We addressed these goals through post-hoc analyses of data collected from a prospective study of catheterized residents from 12 NHs in southeast Michigan.

Methods

Parent Study Design and Population

A secondary, post-hoc analysis was conducted from data collected through the Targeted Infection Prevention (TIP) parent study.[17] The parent study was a cluster-randomized intervention trial conducted in 12 community-based NHs in Michigan from May 2010 to April 2013, focused on reducing prevalence of multi-drug resistant organisms. The study was approved by the University of Michigan Institutional Review Board. Inclusion criteria were: a) any NH resident with an indwelling urinary catheter (Foley or suprapubic) and/or a feeding tube (nasogastric or percutaneous endoscopic gastrostomy tube) for more than 72 hours; and b) informed consent from the resident or their power of attorney. Residents receiving end-of-life care were excluded. This cohort was optimal for our objectives due to prolonged follow-up data (100 days, on average). Demographics, infection, and CAUTI symptoms data were obtained by trained research staff through clinical chart review at monthly visits, as were urine microbiology data. Four hundred eighteen NH residents were enrolled in the TIP study; 292 residents had an indwelling urinary catheter for >72 hours. Of these, full baseline demographic and CAUTI symptom data (if applicable) were available for 233 residents. Study visits occurred at the time of enrollment, on day 14, and monthly thereafter for a maximum of one year (or until death, discharge, or device discontinuation).

Definitions

Clinically diagnosed CAUTI—NH residents with a UTI reported in their medical records, an indwelling catheter in place for >72 hours prior to the date of the UTI, and a corresponding prescription of at least a 3-day course of systemic antibiotics were considered to have a clinically diagnosed CAUTI.[17] In the event of catheter removal, participants were censored from our analysis on the date of removal.

Loeb's minimum criteria—Clinically diagnosed CAUTIs were considered to meet Loeb's minimum criteria if at least one of the following signs and symptoms were present: 1) fever, defined as having a single temperature >100°F or >2°F above baseline; 2) new costovertebral tenderness; 3) rigors, or 4) acute mental status change.[8] If there was no mention of a particular sign or symptom in the medical record, it was assumed to be absent. Rigors was reported in the records of less than 5% of clinically diagnosed CAUTIs and therefore excluded from microorganism-level analysis.

National Healthcare Safety Network (NHSN) criteria—Clinically diagnosed CAUTIs were considered to meet NHSN criteria if a positive urine culture, defined as $\geq 10^5$ colony-forming units (cfu) of one or two microorganisms per milliliter of urine, was reported and the following signs and symptoms were present: 1) No alternative site of infection and a) fever, defined as a single temperature >100°F, repeated temperatures >99°F, or >2°F above baseline, b) rigors, or c) new hypotension; 2) leukocytosis, defined as >14,000 leukocytes/mm^3 or a left shift (>6% bands or ≥1,500 bands/mm^3) and a) acute mental status change, or b) acute functional decline; 3) new onset suprapubic or costovertebral angle pain or tenderness, or 4) purulent discharge around the catheter or acute pain, swelling or tenderness of testes, epididymis, or prostate.[9] If there was no mention of a particular sign or

symptom in the medical record, it was assumed to be absent. Rigors, hypotension, purulent discharge around the catheter, and acute pain, swelling, or tenderness of testes, epididymis, or prostate were reported in the records of less than 5% of CAUTIs and therefore excluded from microorganism-level analysis.

Acute change in mental status—Fluctuation in behavior, inattention, disorganized thinking, and an altered level of consciousness compared to baseline.[8, 9] Data concerning mental status was obtained by trained research staff through clinical chart review.

Acute change in functional status—Reported by clinical evaluation or by a new 3-point increase in total activities of daily living (ADL) score.[9] Data concerning functional status was obtained by trained research staff through clinical chart review.

Statistical Analysis

Preliminary logistic models explored infection by specific microorganisms as a function of clinical CAUTI signs and symptoms followed by multivariable models that combined CAUTI signs and symptoms. All logistic regressions were adjusted for facility-level clustering to account for residents nested in NHs, and clinically diagnosed CAUTIs were grouped based on urine culture results: 1) *Proteus mirabilis,* 2) *Enterococcus* spp., 3) *Escherichia coli,* 4) *Pseudomonas aeruginosa,* 5) *Staphylococcus aureus,* or 6) *Klebsiella pneumoniae.* Groupings were not mutually exclusive in that the 57 dual-species CAUTIs were each included in two groups, but separate models were run for each microorganism. Data were analyzed using Stata/MP, version 13 (StataCorp LP, College Station, TX).

Results

Description of Study Population

Study participants were predominantly white (90%), male (52%), elderly (mean age 73.7 ± 12.7) with 126 (54%) being ≥75 years of age, and dependent for care (mean physical self-maintenance score 21.6 ± 3.9) as shown in Table 1. The most common conditions upon enrollment were diabetes (99 [42%]), dementia (80 [34%]), a history of cerebrovascular accidents (48 [21%]), and chronic obstructive pulmonary disease (45 [19%]). A total of 274 urine cultures were reported from our cohort of 233 catheterized NH residents. Eleven urine cultures (4%) were reported without an accompanying prescription of antibiotics. The remaining 263 urine cultures came from 120 unique study participants and had an accompanying prescription of systemic antibiotics and symptom data. For the purposes of our study, these 263 cases will be considered “clinically diagnosed” CAUTIs. There were no major discernable differences between groups of catheterized NH residents, although dementia was approximately twice as common in residents with clinically diagnosed CAUTI compared to those without (odds ratio, OR=2.0 [95% CI 1.2–3.4]; $P<0.012$).

Epidemiology of Clinically Diagnosed CAUTI in NH Residents

Full identification of microorganisms was available in the records for 182 of the 263 urine cultures (69%) (Table 2). The most common microorganisms overall were *P. mirabilis, Enterococcus* spp., *E. coli, P. aeruginosa, S. aureus,* and *K. pneumoniae.* One hundred

twenty-five CAUTIs (69%) were single-species and predominantly caused by *P. mirabilis* (28 [22%]), *E. coli* (23 [18%]), and *P. aeruginosa* (18 [14%]), and fifty-seven CAUTIs (31%) involved two species and were predominantly caused by *Enterococcus* spp. (23 [40% of the 57 dual-species CAUTIs]), *P. mirabilis* (20 [35%]), and *P. aeruginosa* (16 [28%]). The most common combinations in dual-species infection were *P. aeruginosa* with *Enterococcus* spp. (n=6), *P. mirabilis* with *Enterococcus* spp. (n=5), and *P. mirabilis* with *P. aeruginosa* (n=4).

Adherence of Clinically Diagnosed CAUTIs to Standardized Criteria

The proportion of CAUTIs that met standardized criteria are shown in Table 3 and grouped by predominant microorganism. All 182 clinically diagnosed CAUTIs were prescribed systemic antibiotics; 74 (40%) met Loeb's minimum criteria; 59 (32%) met NHSN criteria; 91 (50%) met at least one standardized definition of symptomatic CAUTI. The most common findings were $\geq 10^5$ cfu of at least one microorganism (161 [90%]), an acute change in mental status (51 [28%]), fever (38 [21%]), leukocytosis or neutrophilia (23 [13%]), and an acute change in functional status (12 [7%]). Fourteen (8%) CAUTI cases had concurrent pneumonia noted in the charts; 12 (86%) had positive urine cultures, 7 (50%) had fever, and 6 (43%) had acute mental status change (data not shown). Seven of the 12 cases with positive urine cultures met NHSN criteria, which excludes fever as a criterion if there is an alternate source of infection. In the remaining 5 cases, systemic antimicrobial use could potentially be attributed to either pneumonia or CAUTI.

Microorganism-level Differences in CAUTI Signs and Symptoms

CAUTIs involving *S. aureus* had the lowest percentages that met Loeb's minimum (30%) or NHSN (5%) criteria, followed by CAUTIs involving *Enterococcus* species (Table 3). CAUTIs involving *K. pneumoniae* had the highest percentage that met Loeb's minimum (86%) or NHSN criteria (43%). Logistic models using Firth's bias correction were run for any microorganism that had at least ten occurrences of a CAUTI criterion.[18] As Firth models do not allow for clustering, dummy coded facility variables were included. Despite small sample sizes, firthlogit models indicated that CAUTIs caused by *K. pneumoniae* were approximately ten times more likely to meet Loeb's minimum criteria than CAUTIs caused by other microorganisms (OR=9.7 [95% CI, 2.3–40.3]; $P<0.003$). Ten of the 51 CAUTIs that reported an acute change in mental status (20%) involved *K. pneumoniae,* suggesting that this criterion may contribute to an increased likelihood of *K. pneumoniae* CAUTIs meeting criteria. Indeed, CAUTIs involving *K. pneumoniae* were more likely to have a reported acute change in mental status compared to CAUTIs caused by other microorganisms (OR=5.9 [95% CI, 1.8–19.4]; $P<0.004$). The association between *K. pneumoniae* and acute change in mental status remained robust in a multivariable model adjusted for age, gender, dementia, and facility (adjusted odds ratio, aOR=6.2 [95%CI 1.7–22.9]; $P<0.003$).

Discussion

In this study, we assessed adherence of clinically diagnosed CAUTIs to Loeb's minimum and NHSN CAUTI criteria in a cohort of NH residents and conducted an exploratory assessment of associations between CAUTI signs and symptoms and specific microorganisms. Fifty percent of the catheterized NH residents participating in the study had

a clinically diagnosed CAUTI, and CAUTIs were often recurrent. Thirty-two percent of clinically diagnosed CAUTIs met NHSN criteria, consistent with a recent report of similar CAUTI criteria in aged-care facilities in Australia,[11] and forty percent met Loeb's minimum criteria for initiation of antibiotics, which is in alignment with a recent study concerning NH residents with dementia.[19] Overall, 50% of clinically diagnosed CAUTIs prescribed antibiotics met standardized criteria, which is a significant improvement over the 17% of all infections estimated to meet either set of criteria in 2012.[20] Taken together, these studies indicate that adherence to criteria for initiating antibiotic prescription may be improving in long term care facilities.

The most common signs and symptoms of CAUTI were a positive urine culture, acute change in mental status, and fever. Consistent with data indicating that only 20–50% of older adults present with fever during acute infection,[10, 21] only 21% of clinically diagnosed CAUTIs in our study had fever meeting standardized criteria cutoffs. Twenty-eight percent of the CAUTIs in our study had an acute change in mental status as a symptom of infection, which is higher than other recent studies and may reflect epidemiological differences discussed below.[19]

Staphylococcus species and *Enterococcus* species are common in asymptomatic bacteriuria, and also frequently considered to be contaminants in urine cultures.[3] It is therefore not surprising that the clinically diagnosed CAUTIs involving these microorganisms had the lowest percentages that met standardized criteria in our cohort. Among clinically diagnosed CAUTIs caused by more traditional pathogens, those involving *K. pneumoniae* were the most likely to meet at least one standardized definition. Although limited by a small sample size, CAUTIs involving *K. pneumoniae* appeared to be associated with an acute change in mental status, causing these CAUTIs to meet Loeb's minimum criteria without necessarily meeting NHSN criteria. For example, 10 of the 14 CAUTIs involving *K. pneumoniae* had an acute change in mental status and therefore met Loeb's minimum criteria, while only 4 of these 10 CAUTIs met NHSN criteria. It is important to note that three *K. pneumoniae* CAUTIs with acute change in mental status also had pneumonia reported in the charts at the study visit. While all three cases met NHSN CAUTI criteria, pneumonia may have been the underlying cause for fever, leukocytosis, or mental status change. Further exploration of CAUTI symptom burden at the microorganism-level is necessary to confirm these exploratory findings, and to explore molecular mechanisms underlying the association between *K. pneumoniae* and mental status changes if these findings remain robust in a larger sample. If particular microorganisms are indeed associated with specific patterns in symptom burden, these associations might be of use in refining existing tools for guiding initiation of antibiotic treatment. For instance, if *S. aureus* can be differentiated from *E. coli* based on symptom burden, this information could aid in guiding appropriate empirical treatment.

Strengths of this study include analysis of CAUTI at multiple NH facilities, collection of data pertaining to standardized CAUTI signs and symptoms for each enrolled NH resident by trained research staff at monthly follow-up visits, and alignment of standardized CAUTI definitions and symptoms to specific microorganisms. However, the results of this study should be interpreted in the context of a few notable limitations. First, as this study

represents a post-hoc analysis of data collected for a prospective parent study, we relied on clinical record keeping, the microbiology laboratories conducting urine cultures for each NH facility, and the judgement of the healthcare personnel caring for the enrolled participants to assess and document CAUTI symptoms and microbiological results. As such, any resident characteristics or CAUTI symptoms not recorded in the medical records were assumed to be absent. As signs and symptoms pertaining to standardized criteria may have been present but not recorded for some clinically diagnosed CAUTIs, we may have underestimated the percentage meeting each definition. This is particularly important for mental status change as a recent study found that only 2–53% of symptoms in nursing home residents with delirium were documented in the nursing notes.[22] Second, signs and symptoms of infection were only recorded at study visits if the resident had a record of a clinically diagnosed infection, so we are not able to determine the likelihood of each sign and symptom being appropriately attributed to CAUTI verses another etiology. Finally, the total number of CAUTIs caused by each microorganism for our analysis was limited. Further exploration of these preliminary findings will require a prospective, longitudinal study with systematic assessment of signs and symptoms of possible infection, particularly mental status, as well as routine urine culturing to better distinguish between asymptomatic bacteriuria and infection.

Bacteriuria in catheterized individuals is frequently asymptomatic and inappropriately treated with antibiotics, contributing to the rise of antibiotic resistance in NHs and hospitals.[23–27] While our study is exploratory in nature and utilizes a limited sample of participants and CAUTIs, further investigations of this nature may uncover a core pattern of clinical signs and symptoms associated with specific microorganisms. If a combination of standardized CAUTI symptoms are indeed indicative of infection by specific microorganisms, this information would be invaluable for refining existing tools and determining which course of action should be taken to manage the infection. Predictive factors for specific microorganisms could therefore guide appropriate antibiotic use for catheterized individuals and may reduce inappropriate antibiotic use for asymptomatic bacteriuria, particularly for older adults in hospital and long-term care settings.

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References

1. Loeb M, Brazil K, Lohfeld L, et al. Optimizing antibiotics in residents of nursing homes: protocol of a randomized trial. BMC health services research. 2002; 2:17. [PubMed: 12207826]
2. Loeb M, Simor AE, Landry L, et al. Antibiotic use in Ontario facilities that provide chronic care. Journal of general internal medicine. 2001; 16:376–383. [PubMed: 11422634]

3. Nicolle LE, Bradley S, Colgan R, et al. Infectious Diseases Society of America guidelines for the diagnosis and treatment of asymptomatic bacteriuria in adults. Clin Infect Dis. 2005; 40:643–654. [PubMed: 15714408]
4. Daniels KR, Lee GC, Frei CR. Trends in catheter-associated urinary tract infections among a national cohort of hospitalized adults, 2001–2010. American Journal of Infection Control. 2014; 42:17–22. [PubMed: 24268457]
5. Hooton TM, Bradley SF, Cardenas DD, et al. Diagnosis, Prevention, and Treatment of Catheter-Associated Urinary Tract Infection in Adults: 2009 International Clinical Practice Guidelines from the Infectious Diseases Society of America. Clinical Infectious Diseases. 2010; 50:625–663. [PubMed: 20175247]
6. Nicolle LE. Catheter-related urinary tract infection: practical management in the elderly. Drugs Aging. 2014; 31:1–10. [PubMed: 24288197]
7. Warren JW, Damron D, Tenney JH, et al. Fever, bacteremia, and death as complications of bacteriuria in women with long-term urethral catheters. J Infect Dis. 1987; 155:1151–1158. [PubMed: 3572035]
8. Loeb M, Bentley DW, Bradley S, et al. Development of minimum criteria for the initiation of antibiotics in residents of long-term-care facilities: results of a consensus conference. Infect Control Hosp Epidemiol. 2001; 22:120–124. [PubMed: 11232875]
9. Stone ND, Ashraf MS, Calder J, et al. Surveillance definitions of infections in long-term care facilities: revisiting the McGeer criteria. Infect Control Hosp Epidemiol. 2012; 33:965–977. [PubMed: 22961014]
10. Olsho LE, Bertrand RM, Edwards AS, et al. Does adherence to the Loeb minimum criteria reduce antibiotic prescribing rates in nursing homes? J Am Med Dir Assoc. 2013; 14:309 e301–307.
11. Bennett NJ, Johnson SA, Richards MJ, et al. Infections in Australian Aged-Care Facilities: Evaluating the Impact of Revised McGeer Criteria for Surveillance of Urinary Tract Infections. Infect Control Hosp Epidemiol. 2016:1–3.
12. Fischer H, Yamamoto M, Akira S, et al. Mechanism of pathogen-specific TLR4 activation in the mucosa: Fimbriae, recognition receptors and adaptor protein selection. European Journal of Immunology. 2006; 36:267–277. [PubMed: 16385628]
13. Rudick CN, Jiang M, Yaggie RE, et al. O-antigen modulates infection-induced pain states. PLoS One. 2012; 7:e41273. [PubMed: 22899994]
14. Sankowski R, Mader S, Valdes-Ferrer SI. Systemic inflammation and the brain: novel roles of genetic, molecular, and environmental cues as drivers of neurodegeneration. Frontiers in cellular neuroscience. 2015; 9:28. [PubMed: 25698933]
15. Monsen T, Rydén P. Flow Cytometry Analysis Using Sysmex UF-1000i Classifies Uropathogens Based on Bacterial, Leukocyte, and Erythrocyte Counts in Urine Specimens among Patients with Urinary Tract Infections. J Clin Microbiol. 2015; 53:539–545. [PubMed: 25472486]
16. Massa LM, Hoffman JM, Cardenas DD. Validity, Accuracy, and Predictive Value of Urinary Tract Infection Signs and Symptoms in Individuals With Spinal Cord Injury on Intermittent Catheterization. The Journal of Spinal Cord Medicine. 2009; 32:568–573. [PubMed: 20025153]
17. Mody L, Krein SL, Saint S, et al. A targeted infection prevention intervention in nursing home residents with indwelling devices: A randomized clinical trial. JAMA Internal Medicine. 2015; 175:714–723. [PubMed: 25775048]
18. FIRTH D. Bias reduction of maximum likelihood estimates. Biometrika. 1993; 80:27–38.
19. D'Agata E, Loeb MB, Mitchell SL. Challenges in assessing nursing home residents with advanced dementia for suspected urinary tract infections. J Am Geriatr Soc. 2013; 61:62–66. [PubMed: 23311553]
20. Wang L, Lansing B, Symons K, et al. Infection rate and colonization with antibiotic-resistant organisms in skilled nursing facility residents with indwelling devices. Eur J Clin Microbiol Infect Dis. 2012; 31:1797–1804. [PubMed: 22274858]
21. Bellmann-Weiler R, Weiss G. Pitfalls in the diagnosis and therapy of infections in elderly patients--a mini-review. Gerontology. 2009; 55:241–249. [PubMed: 19147988]

22. Voyer P, McCusker J, Cole MG, et al. Nursing documentation in long-term care settings: New empirical evidence demands changes be made. Clin Nurs Res. 2014; 23:442–461. [PubMed: 23431024]

23. Tambyah PA, Maki DG. Catheter-associated urinary tract infection is rarely symptomatic: a prospective study of 1,497 catheterized patients. Arch Intern Med. 2000; 160:678–682. [PubMed: 10724054]

24. Cope M, Cevallos ME, Cadle RM, et al. Inappropriate treatment of catheter-associated asymptomatic bacteriuria in a tertiary care hospital. Clin Infect Dis. 2009; 48:1182–1188. [PubMed: 19292664]

25. Dommeti PMD, Wang LBS, Flannery EL, et al. Patterns of Ciprofloxacin-Resistant Gram-Negative Bacteria Colonization in Nursing Home Residents. Infection Control and Hospital Epidemiology. 2011; 32:177–180. [PubMed: 21460474]

26. Mody L, Maheshwari S, Galecki A, et al. Indwelling device use and antibiotic resistance in nursing homes: identifying a high-risk group. J Am Geriatr Soc. 2007; 55:1921–1926. [PubMed: 18081670]

27. Rogers MA, Mody L, Chenoweth C, et al. Incidence of antibiotic-resistant infection in long-term residents of skilled nursing facilities. Am J Infect Control. 2008; 36:472–475. [PubMed: 18786449]

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Table 1

Demographic Characteristics of Catheterized Nursing Home Residents.

Characteristic	Total (n=233)	Clinically diagnosed CAUTI (n=120)	No clinically diagnosed CAUTI (n=113)	[a] *P* value
Age, mean (SD; range), years	73.7 (12.7; 35–105)	75.0 (11.9; 35–105)	72.4 (13.4; 38–97)	.257
Comorbidity score, mean (SD; range)	2.8 (1.9; 0–10)	2.9 (1.9; 0–10)	2.7 (1.8; 0–9)	.533
PSMS score, mean (SD; range)	21.6 (3.9; 13–30)	22.1 (3.8; 14–30)	21.0 (4.0; 13–30)	.150
Gender				
Male	121 (52)	63 (52)	58 (51)	.809
Female	112 (48)	57 (48)	55 (49)	.809
Race				
White	209 (90)	106 (88)	103 (91)	.430
Black or African American	21 (9)	12 (10)	9 (8)	.527
Other	3 (1)	2 (2)	1 (1)	.387
Underlying conditions				
Diabetes	99 (42)	47 (39)	52 (46)	.207
Dementia	80 (34)	50 (42)	30 (26)	.012
CVA	48 (21)	28 (23)	20 (18)	.255
COPD	45 (19)	24 (20)	21 (19)	.725
Hemiplegia	32 (14)	21 (17)	11 (10)	.190
Renal disease	29 (12)	15 (12)	14 (12)	.987
Tumor (any)	23 (10)	11 (9)	12 (10)	.772
Myocardial infarction	23 (10)	11 (9)	12 (10)	.770

Note. Data are No. (%) of residents, unless otherwise indicated. CAUTI, catheter-associated urinary tract infection; SD, standard deviation; PSMS, physical self-maintenance score; CVA, cerebrovascular accident; COPD, chronic obstructive pulmonary disease.

[a] Clustered bivariate logistic regression.

Table 2

Epidemiology of Single-Species and Dual-Species Clinically Diagnosed Catheter-Associated Urinary Tract Infection in Nursing Home Residents.

		Single-Species Urine Cultures		Dual-Species Urine Cultures	
Microorganism	**[a] Total No. Urine Cultures**	**[b] No. of Urine Cultures**	**[c] Percent (%)**	**[d] No. of Urine Cultures**	**[e] Percent (%)**
Proteus mirabilis	48	28	22	20	35
Enterococcus spp.	38	15	12	23	40
Escherichia coli	37	23	18	14	25
Pseudomonas aeruginosa	34	18	14	16	28
Staphylococcus aureus	20	11	9	9	16
Klebsiella pneumoniae	14	6	5	8	14
Citrobacter spp.	9	3	2	6	11
Morganella morganii	7	2	2	5	9
Providencia stuartii	7	3	2	4	7
Yeast	6	3	2	3	5
Acinetobacter baumanii	4	2	2	2	3
Enterobacter spp.	5	5	4	0	0
Serratia marscesens	1	1	1	0	0
Corynobacterium spp.	1	1	1	0	0
Other	8	4	3	4	7
Total	182	125	100	57	100

[a] Number of urine cultures containing each microorganism.

[b] Number of single-species urine cultures containing each microorganism.

[c] Percent of all single-species cultures represented by each microorganism.

[d] Number of dual-species urine cultures containing each microorganism.

[e] Percent of all dual-species cultures represented by each microorganism

Table 3

Characteristics of Clinically Diagnosed Catheter-Associated Urinary Tract Infections Caused by Specific Microorganisms.

Characteristics of clinically diagnosed CAUTIs	[b] Total [n=182]	*Pm* [n=48]	*Ent* [n=38]	*Ec* [n=37]	*Pa* [n=34]	*Sa* [n=20]	*Kp* [n=14]
[a] Standardized CAUTI Definitions							
Loeb's minimum criteria [n=182]	74 (40)	16 (33)	12 (32)	20 (54)	14 (41)	6 (30)	12 (86)*
NHSN criteria [n=182]	59 (32)	17 (35)	10 (26)	15 (40)	12 (35)	1 (5)	6 (43)
Either criteria [n=182]	91 (50)	22 (46)	16 (42)	24 (65)	19 (56)	6 (30)	12 (86)*
[b] Individual criteria							
Acute mental status change [n=182]	51 (28)	10 (21)	10 (26)	13 (35)	10 (29)	5 (25)	10 (71)*
Fever >100°F, repeated temperatures >99°F, or >2°F above baseline [n=182]	38 (21)	13 (27)	6 (16)	10 (27)	7 (20)	2 (10)	4 (29)
Leukocytosis/ neutrophilia >14,000/mm^3 [n=182]	23 (13)	4 (8)	6 (16)	6 (16)	6 (18)	1 (5)	3 (21)
Acute functional status change [n=179]	12 (7)	2 (4)	7 (3)	5 (13)	2 (6)	2 (10)	2 (14)
Urine culture ≥ 10^5 cfu/ml [n=178]	161 (90)	45 (94)	31 (84)	36 (97)	30 (88)	15 (75)	14 (100)

Note. Data are No. (%) of clinically diagnosed CAUTIs, by microorganism, presenting with each criterion. See "Methods" for definition of standardized criteria. NHSN, National Healthcare Safety Network; CAUTI, catheter-associated urinary tract infection; *Pm, Proteus mirabilis; Ent, Enterococcus* species; *Ec, Escherichia coli; Pa, Pseudomonas aeruginosa; Sa, Staphylococcus aureus; Kp, Klebsiella pneumonia.*

[a] Number of clinically diagnosed CAUTIs assessed for meeting each definition is given in brackets.

[b] Number of clinically diagnosed CAUTIs assessed for each criterion is given in brackets.

[c] Number of clinically diagnosed CAUTIs attributed to each microorganism is given in brackets.

* $P<.05$ by logistic models with Firth's bias correction.