HHS Public Access

Author manuscript

Am J Infect Control. Author manuscript; available in PMC 2018 January 02.

Published in final edited form as:

Am J Infect Control. 2016 November 01; 44(11): 1269–1274. doi:10.1016/j.ajic.2016.03.034.

Factors associated with the receipt of antimicrobials among chronic hemodialysis patients

Graham M. Snyder, MD, SM[a,*], **Priti R. Patel, MD, MPH**[b], **Alexander J. Kallen, MD, MPH**[b], **James A. Strom, MD**[c], **J. Kevin Tucker, MD**[d], and **Erika M.C. D'Agata, MD, MPH**[e]

[a]Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA

[b]Centers for Disease Control and Prevention, Atlanta, GA

[c]St. Elizabeth's Medical Center, Tufts University School of Medicine, Boston, MA

[d]Brigham and Women's Hospital, Harvard Medical School, Boston, MA

[e]Rhode Island Hospital, Brown University School of Medicine, Providence, RI

Abstract

Background—Antimicrobial use is common among patients receiving chronic hemodialysis (CHD) and may represent an important antimicrobial stewardship opportunity. The objective of this study is to characterize CHD patients at increased risk of receiving antimicrobials, including not indicated antimicrobials.

Methods—We conducted a prospective cohort study over a 12-month period among patients receiving CHD in 2 outpatient dialysis units. Each parenteral antimicrobial dose administered was characterized as indicated or not indicated based on national guidelines. Patient factors associated with receipt of antimicrobials and receipt of ≥1 inappropriate antimicrobial dose were analyzed.

Results—A total of 89 of 278 CHD patients (32%) received ≥1 antimicrobial doses and 52 (58%) received ≥1 inappropriately indicated dose. Patients with tunneled catheter access, a history of colonization or infection with a multidrug-resistant organism, and receiving CHD sessions during daytime shifts were more likely to receive antimicrobials (odds ratio [OR], 5.16; 95% confidence interval [CI], 2.72–9.80; OR, 5.43; 95% CI, 1.84–16.06; OR, 4.59; 95% CI, 1.20–17.52, respectively). Patients with tunneled catheter access, receiving CHD at dialysis unit B, and with a longer duration of CHD prior to enrollment were at higher risk of receiving an inappropriately indicated antimicrobial dose (incidence rate ratio, 2.23; 95% CI, 1.16–4.29; incidence rate ratio, 2.67; 95% CI, 1.34–5.35; incidence rate ratio, 1.11; 95% CI, 1.01–1.23, respectively).

[*]Address correspondence to Graham M. Snyder, MD, SM, Division of Infectious Diseases, Beth Israel Deaconess Medical Center, 330 Brookline Ave, Mailstop SL-435, Boston, MA 02215. gsnyder@bidmc.harvard.edu (G.M. Snyder).

Conflicts of Interest: None to report.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Conclusions—This study of all types of antimicrobials administered in 2 outpatient dialysis units identified several important factors to consider when developing antimicrobial stewardship programs in this health care setting.

Keywords

Hemodialysis; antimicrobial stewardship; multidrug-resistant organism

The outpatient hemodialysis unit is a high-risk setting for the acquisition of multidrug resistant organisms (MDRO).[1] A contributing factor is the substantial exposure to antimicrobials among patients requiring chronic hemodialysis (CHD).[2] At least 40% of patients on CHD receive ≥1 antimicrobial course each year, a frequency that exceeds the use of antimicrobials in nursing home populations, another patient population with high rates of MDRO.[3–5]

Studies focusing on antimicrobial use in the CHD population, including reasons for inappropriate administration, are limited.[6–8] We have previously published a prospective 12-month cohort study in 2 outpatient dialysis units characterizing antimicrobial use and reasons for inappropriate prescribing. In that study, over one-third of CHD patients received at least 1 antimicrobial course in the 12-month study period, and among all antimicrobials prescribed, one-third were classified as inappropriately indicated, based on national guidelines.[6,9–19] Vancomycin and third- and fourth-generation cephalosporins were the most common antimicrobials prescribed inappropriately. The 3 main reasons for inappropriate prescribing were (1) criteria for infection were not met based on national guidelines, (2) failure to choose a more narrow-spectrum antimicrobial, and (3) criteria for surgical prophylaxis were not met.[6]

To this evidence, which describes how antimicrobials are inappropriately prescribed, we present here additional data describing the characteristics of patients at higher risk of receiving antimicrobials, including those who received antimicrobials inappropriately, based on national guidelines. This information is integral to developing effective stewardship efforts with the goal of improving prescribing practices.

MATERIALS AND METHODS

Dialysis units

The study was conducted in 2 outpatient CHD units in Boston, Massachusetts. Each unit has an approximate point census of 100 patients and is affiliated with a community-based academic medical center. The study population has been previously described, including clinical characteristics of patients, antimicrobial use rates, and appropriateness of indication for antimicrobial receipt.[6] Study data were collected by a study investigator, and unit clinicians were blinded to study methodology. The conduct of this study was approved by the institutional review board at the investigator and participating medical center institutions.

Study population and data collection

Patients were included in the study if they were registered patients of the CHD unit and received at least 1 hemodialysis session for end-stage renal disease during the study period (August 2010–July 2011). Patients on peritoneal dialysis who received exclusively a backup session of dialysis while remaining on peritoneal dialysis and nonresidents receiving CHD while traveling were excluded. Demographic data were collected for each study patient at the time of enrollment, including age, sex, pertinent medical conditions and comorbidities, and CHD-related factors. The Charlson Comorbidity Index score, which has been validated in the CHD population, was used as a composite score of comorbidities.[20,21] MDROs included methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococci, and multidrug-resistant gram-negative bacteria. For each antimicrobial dose, comprehensive data supporting the indication for use were collected from available documentation in the unit and affiliated medical center electronic medical records.

Antimicrobial characterization

Only parenteral antimicrobial doses administered in the hemodialysis unit were evaluated. Each administered dose was categorized as having an appropriate or inappropriate indication; any dose for which there was inadequate or unavailable documentation in support of appropriate criteria was classified as unknown appropriateness. Criteria for the appropriateness of indication were defined a priori using published guidelines for each site of suspected infection.[6,9–19,22] The appropriateness of each dose was characterized based on the clinical data available to the prescribing clinician at the time the dose was administered. Doses characterized as inappropriate included antimicrobials prescribed empirically without guideline-based minimum criteria to define infection being met; antimicrobials prescribed for treatment (ie, in the setting of a positive culture) when a more narrow-spectrum agent could have been considered; and those used for an indication of surgical prophylaxis in the absence of infection when antimicrobials were not indicated for the procedure (eg, tunneled catheter placement), or if indicated, prescribed for a duration >24 hours postprocedure.[6] The following modifications from published guidelines were made. First, we considered antibiotic administration appropriate if coagulase-negative *Staphylococcus* was cultured from ≥1 blood culture (as opposed to ≥2 blood cultures) in the setting of fever, chills, or hypotension, given the high prevalence of bacteremia caused by this pathogen in the dialysis population. Second, we defined fever as a temperature >100°F, as opposed to the standard >100.4°F, because of the immunosuppressive state of CHD patients.[6] Medication allergies and drug-drug interactions were considered when assessing appropriateness. The appropriateness of the duration of therapy was not assessed.

Statistical analyses

Two analyses were performed: the first analysis characterized variables associated with antimicrobial receipt, and the second analysis characterized variables associated with inappropriately indicated antimicrobial doses. Nominal and ordinal variables were dichotomized or categorized in a clinically relevant manner. The number of hospitalizations in the preceding 12 months was categorized into no hospitalizations, 1–2 hospitalizations, or ≥3 hospitalizations based on the pattern of inpatient hospital use seen in clinical practice.

Charlson Comorbidity Index score, a non-normally distributed continuous variable with a small range of values, was dichotomized around the median value.

In the first analysis, all patients who received at least 1 session of CHD during the study period were stratified into those receiving ≥1 parenteral antimicrobials and those who received no parenteral antimicrobials. Modeling was performed using multivariable logistic regression. Bivariate analyses of predictor variables potentially associated with antimicrobial receipt were performed using Fisher exact test for binary predictors, Pearson χ^2 test for nominal categorical predictors, and *t* test or Wilcoxon rank-sum test for continuous predictors. Variables with a 2-sided *P* value ≤ .20 were considered for the multivariable regression model. Nominal categorical variables were considered significant if ≥1 of the dummy-coded variables demonstrated significance ($P \leq .20$). A forward stepwise selection procedure was used to select variables for the final model. Statistical significance in the final model was defined as $P \leq .05$. Variables with a *P* value ≤.20 on bivariate analysis but not included in the stepwise selection model were added back to the model serially to assess for confounding. A variable was considered a confounder and included in the model if the β coefficient of any of the model variables changed by ≥20% with the addition of the confounding variable. Collinearity was assessed by removing the model variables serially, and each variable was considered for exclusion if the SEM of the effect estimates of the remaining model variables decreased by ≥20%. Effect modification was explored among clinically relevant variables through the use of interaction terms.

For the second analysis, the number of inappropriately indicated doses and observation time were tallied for each patient. Because the outcome for this analysis is overdispersed count data (inappropriately indicated antimicrobial doses received among study patients), modeling was performed using negative binomial regression. Bivariate analyses were conducted in the same manner as described for the first analysis. Variables with a *P* value ≤. 20 on bivariate analysis were included in the final multivariable model without further selection procedures.

All data were collected and tabulated with a relational database (Microsoft Access 2003; Microsoft, Redmond, WA). Statistical analyses were performed using STATA software (version 10.0; StataCorp, College Station, TX).

RESULTS

Study demographics

During the 12-month prospective study period, 278 patients received at least one chronic outpatient dialysis session, including 129 (46.4%) patients in unit A and 149 (53.6%) patients in unit B. Details of the study population, classes of antimicrobials administered in the 2 units, and appropriateness of the indication for antimicrobials are summarized in the introduction and have been previously published.[6] Patient characteristics are presented in Table 1. A total of 89 (32.0%) patients received ≥1 parenteral antimicrobial dose, including 37 of 129 patients (28.7%) in unit A and 52 of 149 patients (34.9%) in unit B. The overall incidence rate of antimicrobial receipt was 40.7 doses per 100 patient months.

Variables associated with antimicrobial receipt

The results of the bivariate and multivariable analyses of predictor variables associated with the receipt of any antimicrobials are presented in Table 2. On multivariable analysis, patients were at significantly higher odds of receiving an antimicrobial during the follow-up period if they had a tunneled catheter for CHD access at baseline (vs arteriovenous access), a history of colonization or infection with an MDRO in the 1 year preceding enrollment, or received CHD sessions during daytime shifts (c statistic, 0.78) (Table 2). Additionally, each additional month of observation during the study period was associated with 1.27 times higher odds of antimicrobial receipt (Table 2).

We identified no significant confounder variables or collinearity. However, there was evidence of effect modification by dialysis access type on the relationship between duration of observation and receipt of any antimicrobials, and by MDRO history on the relationship between duration of observation and receipt of any antimicrobials. Therefore, regression analysis was additionally performed sequentially by stratifying on dialysis access and then MDRO history (because of small cell sizes, the regression could not be performed in MDRO-positive patients). Among the 92 patients (33.1%) with a tunneled catheter at baseline, the duration of study observation remained significantly associated with antimicrobial receipt (odds ratio [OR], 1.39; 95% confidence interval [CI], 1.21–1.60); daytime shift and history of MDRO were no longer significantly associated with antimicrobial receipt (OR, 5.82; 95% CI, 0.51–66.70 and OR, 2.07; 95% CI, 0.39–11.08, respectively). Among the 186 patients (66.9%) with arteriovenous access at baseline, duration of study participation (OR, 1.14; 95% CI, 1.01–1.29) and history of MDRO (OR, 12.53; 95% CI, 2.72–57.78) remained statistically significant; however, daytime shift did not (OR, 4.51; 95% CI, 0.77–26.34). When the analysis was stratified by MDRO history, among the 256 patients (92.1%) without a preceding recent history of MDRO, daytime shift was nonsignificant (OR, 4.48; 95% CI, 0.95–21.06), but duration of study observation and tunneled catheter access both remained statistically significant (OR, 1.21; 95% CI, 1.10–1.33 and OR, 5.43; 95% CI, 2.84–10.39, respectively). Because of small cell sizes, the stratified regression could not be performed for the 22 MDRO-positive patients (7.9%).

Variables associated with inappropriately indicated antimicrobials

Among the 89 patients who received ≥1 dose of parenteral antimicrobials, 52 (58.4%) received ≥1 inappropriately indicated dose. The incidence rate of inappropriately prescribed antimicrobials was 11.3 doses per 100 patient months. There were a total of 278 inappropriately indicated doses received by the 52 patients who received any inappropriately indicated antimicrobial, with a range of 1–28 inappropriate doses received per patient (median, 4 doses).

Results of the bivariate and multivariable analysis of potential predictors of receiving at least 1 dose of inappropriately indicated parenteral antimicrobials per patient are presented in Table 3. Patients with tunneled catheter (vs arteriovenous) access at baseline, receiving CHD at study unit B (vs unit A), and with a longer duration of CHD at baseline had a statistically significant higher incidence rate of receiving an inappropriately indicated antimicrobial dose (Table 3).

DISCUSSION

This study characterized variables associated with receipt of antimicrobials and the receipt of inappropriately indicated antimicrobials among patients receiving hemodialysis in outpatient units. The analyses presented here continue our comprehensive assessment of parenteral antimicrobial use in the outpatient hemodialysis setting: patients with tunneled catheter (vs arteriovenous) access at baseline, a history of colonization or infection with an MDRO in the 1 year preceding enrollment, and receiving CHD sessions during daytime shifts had a higher odds of receiving antimicrobials.

Data collected through the 2008 National Healthcare Safety Network demonstrate significantly higher rates of vascular access–related infections and antimicrobial starts among patients who use a tunneled catheter for access than those with an arteriovenous graft or fistula.[23] These data support our findings of greater antimicrobial exposure among CHD patients with tunneled catheters because it is likely that prescribing health care workers would have a lower threshold to start antimicrobials when an infection was suspected. Additionally, the finding that patients with a history of MDRO colonization or infection are more likely to receive antimicrobials is not unexpected. Prior studies have demonstrated that for MDROs, colonization precedes infection, and antimicrobial use is higher among patients colonized with MDROs.[24,25] Importantly, our stratified analyses demonstrated consistent relationships between exposures and risk of antimicrobial receipt, including in the presumptively lower-risk strata: in the stratum of patients who were MDRO negative at baseline, tunneled catheter for CHD access still conferred a higher odds of antimicrobial receipt than arteriovenous access; and in the stratum of patients with arteriovenous access at baseline, MDRO positivity at baseline was associated with a higher odds of antimicrobial receipt. One likely interpretation of this finding is that the increased risk of antimicrobial receipt may be independent of MDRO status in patients with a tunneled catheter because of the significantly higher risk of infection with any pathogen among patients with tunneled catheter. These findings support the robustness of tunneled catheter and MDRO positivity as risk factors for infection and therefore antimicrobial receipt.

An unexpected and novel risk factor for antimicrobial receipt included dialysis during daytime shift. Although we do not have detailed data on the temporal relationship between hospitalization or emergency department visit and antimicrobial receipt, we hypothesize that patients dialyzed during the evening shift may be less likely to receive empirical antimicrobial therapy and instead have evaluation deferred to the emergency department or hospitalization.

In our second analysis, patients with tunneled catheter access at baseline, receiving CHD at study unit B, and with a longer duration of years on CHD at enrollment were at higher risk of receiving an inappropriately indicated antimicrobial dose. Importantly, tunneled catheter access was associated with both an increased risk of receiving antimicrobials and consequently having a higher risk of receiving them inappropriately. This finding further emphasizes the importance of avoiding catheters, when possible.[26–29] The identification of one unit having a higher risk of inappropriate antimicrobial administration implies that there are unit-specific factors that require further investigation. Finally, it is unclear why a longer

duration of years on CHD would be associated with receipt of inappropriate antimicrobials. A potential hypothesis is that providers practiced more cautious care and liberalized treatment of potential infections in patients with limited dialysis access, a characteristic more typical of patients with a long history of CHD.[30]

The findings of this study provide important data that might help target antimicrobial stewardship efforts in outpatient dialysis settings. Unit-based interventions might include enhanced review of antimicrobial treatment for patients with tunneled catheters and MDRO-positive history at the time of first antimicrobial prescribing, through educational efforts and protocols.[10] Stewardship interventions may also benefit from continuing to address basic infection prevention, including promoting the ongoing effort to minimize the use of tunneled central venous catheters for hemodialysis access.

There are several limitations to be addressed in this study. The study population was derived from 2 dialysis units with a consistent nephrology team (6 physicians in unit A and 10 physicians in unit B). Therefore, the prescribing patterns and variables associated with antimicrobial use may not be generalizable to all populations Even though overall prescribing practices were similar between the 2 study units,[6] it is evident from our second analysis that there was a difference in inappropriate prescribing patterns. This difference may be largely accounted for by differences in prescribing for surgical prophylaxis, which was noted to occur more frequently in unit B in our previous study.[6] We have only characterized parenteral antimicrobial use for several reasons based on expert opinion given the paucity of published research: oral antimicrobials prescribed by non-nephrology providers may be unreliably captured; nearly all antimicrobial prescribing by nephrology providers is parenteral and documented within the unit; and for convenience (and because use of additional peripherally inserted central venous catheters is discouraged[10]) parenteral antimicrobials are generally prescribed at 3 times weekly dosing intervals to coincide administration with hemodialysis. In national aggregate data, oral antimicrobials are significantly less commonly prescribed than parenteral agents.[3] Furthermore, we did not evaluate whether parenteral therapy could be transitioned to an oral antimicrobial with lower risk profile and cost, an important additional antimicrobial stewardship intervention.[31] Therefore, associations with prescribing practices for oral antimicrobials may be different than those described here. Finally, while incomplete or unavailable documentation may have led to misclassification of appropriateness (underestimating the frequency of appropriate doses), this issue in itself may be a hazard for inappropriate prescribing. The magnitude of this effect will be challenging to quantify. Inter-rater reliability was not assessed; however, published criteria for use were stringently applied, and antimicrobials of uncertain appropriateness were reviewed by a second expert.[32]

CONCLUSIONS

Substantial inappropriate antimicrobial prescribing likely exists in outpatient hemodialysis centers. Future antimicrobial stewardship interventions may benefit from targeting antimicrobial use among patients with catheter access and could be informed by a patient's history of health care exposure, including colonization or infection with MDROs and unit-specific practices.

Acknowledgments

Funding/Support: Supported by the Centers for Disease Control and Prevention Division of Healthcare Quality Promotion (intergovernmental personnel agreement no. 10IPA1004108) and the Agency for Healthcare Research and Quality (grant no. R18HS021666 to E.M.C.D.).

References

1. Snyder GM, D'Agata EM. Novel antimicrobial-resistant bacteria among patients requiring chronic hemodialysis. Curr Opin Nephrol Hypertens. 2012; 21:211–5. [PubMed: 22240441]
2. Pop-Vicas A, Strom J, Stanley K, D'Agata EM. Multidrug-resistant gram-negative bacteria among patients who require chronic hemodialysis. Clin J Am Soc Nephrol. 2008; 3:752–8. [PubMed: 18322047]
3. U.S. Renal Data System. USRDS 2010 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States. Bethesda, MD: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 2010.
4. Pakyz AL, Dwyer LL. Prevalence of antimicrobial use among United States nursing home residents: results from a national survey. Infect Control Hosp Epidemiol. 2010; 31:661–2. [PubMed: 20426578]
5. O'Fallon E, Schreiber R, Kandel R, D'Agata EM. Multidrug-resistant gram-negative bacteria at a long-term care facility: assessment of residents, healthcare workers, and inanimate surfaces. Infect Control Hosp Epidemiol. 2009; 30:1172–9. [PubMed: 19835474]
6. Snyder GM, Patel PR, Kallen AJ, Strom JA, Tucker JK, D'Agata EM. Antimicrobial use in outpatient hemodialysis units. Infect Control Hosp Epidemiol. 2013; 34:349–57. [PubMed: 23466906]
7. Green K, Schulman G, Haas DW, Schaffner W, D'Agata EM. Vancomycin prescribing practices in hospitalized chronic hemodialysis patients. Am J Kidney Dis. 2000; 35:64–8. [PubMed: 10620546]
8. Zvonar R, Natarajan S, Edwards C, Roth V. Assessment of vancomycin use in chronic haemodialysis patients: room for improvement. Nephrol Dial Transplant. 2008; 23:3690–5. [PubMed: 18565979]
9. Recommendations for preventing the spread of vancomycin resistance. Recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC). MMWR Recomm Rep. 1995; 44:1–13.
10. Vascular Access 2006 Work Group. Clinical practice guidelines for vascular access. Am J Kidney Dis. 2006; 48(Suppl):S176–247. [PubMed: 16813989]
11. Vascular Access Work Group. Clinical practice guidelines for vascular access. Am J Kidney Dis. 2006; 48(Suppl):S248–73. [PubMed: 16813991]
12. Anderson, DJ.Sexton, DJ., Harris, A., editors. Overview of control measures to prevent surgical site infection. Waltham (MA): UpToDate; 2012.
13. Dellinger EP, Gross PA, Barrett TL, Krause PJ, Martone WJ, McGowan JE Jr, et al. Quality standard for antimicrobial prophylaxis in surgical procedures. Infectious Diseases Society of America. Clin Infect Dis. 1994; 18:422–7. [PubMed: 8011827]
14. High KP, Bradley SF, Gravenstein S, Mehr DR, Quagliarello VJ, Richards C, et al. Clinical practice guideline for the evaluation of fever and infection in older adult residents of long-term care facilities: 2008 update by the Infectious Diseases Society of America. Clin Infect Dis. 2009; 48:149–71. [PubMed: 19072244]
15. Mackowiak PA, Wasserman SS, Levine MM. A critical appraisal of 98.6 degrees F, the upper limit of the normal body temperature, and other legacies of Carl Reinhold August Wunderlich. JAMA. 1992; 268:1578–80. [PubMed: 1302471]
16. Mandell LA, Wunderink RG, Anzueto A, Bartlett JG, Campbell GD, Dean NC, et al. Infectious Diseases Society of America/American Thoracic Society consensus guidelines on the management of community-acquired pneumonia in adults. Clin Infect Dis. 2007; 44(Suppl):S27–72. [PubMed: 17278083]

17. Nicolle LE, Bradley S, Colgan R, Rice JC, Schaeffer A, Hooton TM. Infectious Diseases Society of America guidelines for the diagnosis and treatment of asymptomatic bacteriuria in adults. Clin Infect Dis. 2005; 40:643–54. [PubMed: 15714408]

18. Solomkin JS, Mazuski JE, Bradley JS, Rodvold KA, Goldstein EJ, Baron EJ, et al. Diagnosis and management of complicated intra-abdominal infection in adults and children: guidelines by the Surgical Infection Society and the Infectious Diseases Society of America. Surg Infect (Larchmt). 2010; 11:79–109. [PubMed: 20163262]

19. Stevens DL, Bisno AL, Chambers HF, Everett ED, Dellinger P, Goldstein EJ, et al. Practice guidelines for the diagnosis and management of skin and soft-tissue infections. Clin Infect Dis. 2005; 41:1373–406. [PubMed: 16231249]

20. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987; 40:373–83. [PubMed: 3558716]

21. Beddhu S, Zeidel ML, Saul M, Seddon P, Samore MH, Stoddard GJ, et al. The effects of comorbid conditions on the outcomes of patients undergoing peritoneal dialysis. Am J Med. 2002; 112:696–701. [PubMed: 12079709]

22. Centers for Disease Control and Prevention. Central line-associated bloodstream infection (CLABSI) event. 2012. Available from: www.cdc.gov/nhsn/pdfs/pscmanual/4psc_clabscurrent.pdf. Accessed May 2, 2016

23. Klevens RM, Edwards JR, Andrus ML, Peterson KD, Dudeck MA, Horan TC. Dialysis surveillance report: National Healthcare Safety Network (NHSN)-data summary for 2006. Semin Dial. 2008; 21:24–8. [PubMed: 18251954]

24. Galoisy-Guibal L, Soubirou JL, Desjeux G, Dusseau JY, Eve O, Escarment J, et al. Screening for multidrug-resistant bacteria as a predictive test for subsequent onset of nosocomial infection. Infect Control Hosp Epidemiol. 2006; 27:1233–41. [PubMed: 17080382]

25. Pacio GA, Visintainer P, Maguire G, Wormser GP, Raffalli J, Montecalvo MA. Natural history of colonization with vancomycin-resistant enterococci, methicillin-resistant Staphylococcus aureus, and resistant gram-negative bacilli among long-term-care facility residents. Infect Control Hosp Epidemiol. 2003; 24:246–50. [PubMed: 12725352]

26. Rayner HC, Besarab A, Brown WW, Disney A, Saito A, Pisoni RL. Vascular access results from the Dialysis Outcomes and Practice Patterns Study (DOPPS): performance against Kidney Disease Outcomes Quality Initiative (K/DOQI) Clinical Practice Guidelines. Am J Kidney Dis. 2004; 44:22–6. [PubMed: 15486870]

27. Allon M, Daugirdas J, Depner TA, Greene T, Ornt D, Schwab SJ. Effect of change in vascular access on patient mortality in hemodialysis patients. Am J Kidney Dis. 2006; 47:469–77. [PubMed: 16490626]

28. Lacson E Jr, Wang W, Lazarus JM, Hakim RM. Change in vascular access and mortality in maintenance hemodialysis patients. Am J Kidney Dis. 2009; 54:912–21. [PubMed: 19748717]

29. Asif A, Cherla G, Merrill D, Cipleu CD, Briones P, Pennell P. Conversion of tunneled hemodialysis catheter-consigned patients to arteriovenous fistula. Kidney Int. 2005; 67:2399–406. [PubMed: 15882285]

30. Bradbury BD, Chen F, Furniss A, Pisoni RL, Keen M, Mapes D, et al. Conversion of vascular access type among incident hemodialysis patients: description and association with mortality. Am J Kidney Dis. 2009; 53:804–14. [PubMed: 19268411]

31. Dellit TH, Owens RC, McGowan JE Jr, Gerding DN, Weinstein RA, Burke JP, et al. Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. Clin Infect Dis. 2007; 44:159–77. [PubMed: 17173212]

32. Schwartz DN, Wu US, Lyles RD, Xiang Y, Kieszkowski P, Hota B, et al. Lost in translation? Reliability of assessing inpatient antimicrobial appropriateness with use of computerized case vignettes. Infect Control Hosp Epidemiol. 2009; 30:163–71. [PubMed: 19090769]

Table 1

Characteristics of patients receiving chronic hemodialysis in the study population by antimicrobial receipt

Variable	Total study sample (N = 278)	Patients who received no antimicrobials (n = 189)	Patients who received ≥1 antimicrobials (n = 89)
Age, mean ± SD, y	66.7 ± 15.5	66.8 ± 15.7	66.4 ± 15.1
Male sex	144 (51.8)	106 (56.1)	38 (42.7)
Race-ethnicity			
White	145 (52.2)	105 (55.6)	40 (44.9)
Black	93 (33.5)	62 (32.8)	31 (34.8)
Other or unknown	40 (13.4)	22 (11.6)	18 (20.2)
Primary indication for hemodialysis, diabetes mellitus	124 (44.6)	81 (42.9)	43 (48.3)
Hemodialysis access type at time of enrollment			
Arteriovenous fistula-graft	186 (66.9)	143 (75.7)	43 (48.3)
Tunneled catheter	92 (33.1)	46 (24.3)	46 (51.7)
Unit B	149 (53.6)	97 (51.3)	52 (58.4)
Time of day patient regularly receives hemodialysis			
Daytime shift	255 (91.7)	169 (89.4)	86 (96.6)
Evening shift	23 (8.3)	20 (10.6)	3 (3.6)
Median duration of study participation, mo (IQR)	11.7 (6.0–12.0)	10.6 (4.2–11.9)	11.9 (9.1–12.0)
Mean duration of hemodialysis at time of enrollment ± SD, y	2.80 ± 3.19	2.65 ± 3.10	3.02 ± 3.37
Charlson Comorbidity Index score >4	134 (48.2)	82 (43.4)	52 (58.4)
Requires wheelchair or bedbound	37 (13.3)	20 (10.6)	17 (19.1)
Chronic wound present on enrollment	17 (6.1)	9 (4.8)	8 (9.0)
Immunosuppressive medication at time of enrollment *	25 (9.0)	13 (6.9)	12 (13.5)
History of prior organ transplant	21 (7.6)	14 (7.4)	7 (7.9)
Malignancy	16 (5.8)	10 (5.3)	6 (6.7)
History of ≥1 multidrug-resistant organism in 12 mo preceding enrollment	22 (7.9)	8 (4.2)	14 (15.7)
VRE	10 (3.6)	4 (2.1)	6 (6.7)
MRSA	11 (4.0)	4 (2.1)	7 (7.9)
MDRGN	9 (3.2)	2 (1.1)	7 (7.9)
Hospitalizations in the 12 mo prior to enrollment, median (IQR)	1 (0–3)	1 (0–3)	2 (1–4)

NOTE. Data are n (%), unless indicated otherwise.

IQR, interquartile range; *MDRGN*, multidrug-resistant gram-negative bacteria; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *VRE*, vancomycin-resistant enterococci.

* Immunosuppressive medications include corticosteroids (prednisone dose equivalent of ≥20 mg/d), immunomodulators, and cancer chemotherapeutic treatment.

Table 2

Bivariate and multivariable logistic regression model of variables associated with receipt of ≥1 parenteral antimicrobial dose among patients receiving outpatient chronic hemodialysis

	Bivariate analysis			Multivariable analysis		
Variable	**OR**	**95% CI**	***P* value**	**OR**	**95% CI**	***P* value**
Age, each additional year	1.00	0.98–1.01	.82			
Male sex	0.58	0.35–0.97	.04			
Race-ethnicity						
White	ref	—	—	ref	—	—
Black	1.31	0.75–2.31	.35			
Other	2.15	1.04–4.42	.04	2.72	1.18–6.25	.02
Primary indication for hemodialysis, diabetes mellitus (vs other)	1.25	0.75–2.07	.39			
Tunneled catheter for access (vs arteriovenous access)	3.33	1.95–5.66	<.001	5.76	2.97–11.15	<.001
Unit B	1.33	0.80–2.22	.27			
Daytime shift (vs evening shift)	3.39	0.98–11.73	.05	4.80	1.26–18.25	.02
Duration of study participation, each additional month	1.16	1.08–1.26	<.001	1.26	1.15–1.39	<.001
Duration of hemodialysis at time of enrollment, each additional year	1.04	0.96–1.12	.36			
Charlson Comorbidity Index score >4	1.83	1.10–3.05	.02			
Requires wheelchair or bedbound	2.00	0.99–4.03	.05			
Chronic wound present on enrollment	1.98	0.74–5.30	.18			
Immunosuppressive medication at time of enrollment *	2.11	0.92–4.83	.08			
History of prior organ transplant	1.07	0.41–2.74	.89			
Malignancy	1.29	0.46–3.68	.63			
History of ≥1 multidrug-resistant organism in 12 mo preceding enrollment	4.22	1.70–10.49	.002	5.85	1.96–17.45	.002
Hospitalizations in the 12 mo prior to enrollment			.09			
No hospitalizations	ref	—	—			
1–2 hospitalizations	1.51	0.79–2.90	.21			
≥3 hospitalizations	2.15	1.07–4.29	.03			

CI, confidence interval; *OR*, odds ratio; *ref*, reference.

* Immunosuppressive medications include corticosteroids (prednisone dose equivalent of ≥20 mg/d), immunomodulators, and cancer chemotherapeutic treatment.

Table 3

Bivariate and multivariable negative binomial regression model of variables associated with receipt of at least 1 inappropriate antimicrobial dose among patients receiving antimicrobials in 2 chronic outpatient hemodialysis units

	Bivariate analysis			Multivariable analysis		
Variable	**IRR**	**95% CI**	***P* value**	**IRR**	**95% CI**	***P* value**
Age, each additional year	0.99	0.97–1.02	.58			
Male sex	0.57	0.27–1.21	.14			
Race-ethnicity						
White	ref	—	—			
Black	1.44	0.65–3.18	.37			
Other	1.26	0.56–2.86	.58			
Primary indication for hemodialysis, diabetes mellitus (vs other)	0.80	0.39–1.63	.54			
Tunneled catheter for access (vs arteriovenous access)	1.72	0.87–3.40	.12	2.23	1.16–4.29	.02
Unit B	2.30	1.97–2.63	.03	2.67	1.34–5.35	.005
Daytime shift (vs evening shift)	2.05	0.49–8.49	.32			
Duration of hemodialysis at time of enrollment, each additional year	1.08	0.98–1.20	.13	1.11	1.01–1.23	.03
Charlson Comorbidity Index score >4	1.17	0.58–2.36	.66			
Requires wheelchair or bedbound	0.99	0.45–2.19	.98			
Chronic wound present on enrollment	0.48	0.08–2.79	.42			
Diabetes mellitus, type 1 or 2	1.42	0.73–2.79	.30			
Immunosuppressive medication at time of enrollment *	0.72	0.26–1.99	.53			
History of prior organ transplant	2.85	0.96–8.43	.06			
Malignancy	1.92	0.62–5.98	.26			
History of ≥1 multidrug-resistant organism in 12 mo preceding enrollment	0.78	0.28–2.18	.64			
Hospitalizations in the 12 mo preceding enrollment						
No hospitalizations	ref	—	—			
1–2 hospitalizations	1.04	0.44–2.47	.92			
≥3 hospitalizations	0.87	0.36–2.07	.75			

CI, confidence interval; *IRR*, incident rate ratio; *ref*, reference.

* Immunosuppressive medications include corticosteroids (prednisone dose equivalent of ≥20 mg/d), immunomodulators, and cancer chemotherapeutic treatment.