


Original Article

Total duration of antimicrobial therapy resulting from inpatient hospitalization

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Abstract

Objective: To assess the feasibility of electronic data capture of postdischarge durations and evaluate total durations of antimicrobial exposure related to inpatient hospital stays.

Design: Multicenter, retrospective cohort study.

Setting: Two community hospitals and 1 academic medical center.

Patients: Hospitalized patients who received ≥ 1 dose of a systemic antimicrobial agent.

Methods: We collected and reviewed electronic data on inpatient and discharge antimicrobial prescribing from April to September 2016 in 3 pilot hospitals. Inpatient antimicrobial use was obtained from electronic medication administration records. Postdischarge antimicrobial use was calculated from electronic discharge prescriptions. We completed a manual validation to evaluate the ability of electronic prescriptions to capture intended postdischarge antibiotics. Inpatient, postdischarge, and total lengths of therapy (LOT) per admission were calculated to assess durations of antimicrobial therapy attributed to hospitalization.

Results: A total of 45,693 inpatient admissions were evaluated. Antimicrobials were given during 23,447 admissions (51%), and electronic discharge prescriptions were captured in 7,442 admissions (16%). Manual validation revealed incomplete data capture in scenarios in which prescribers avoided the electronic system. The postdischarge LOT among admissions with discharge antimicrobials was median 8 days (range, 1–360) with peaks at 5, 7, 10, and 14 days. Postdischarge days accounted for 38% of antimicrobial exposure days.

Conclusion: Discharge antimicrobial therapy accounted for a large portion of antimicrobial exposure related to inpatient hospital stays. Discharge prescription data can feasibly be captured through electronic prescribing records and may aid in designing stewardship interventions at transitions of care.

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Acute-care hospital antibiotic stewardship programs (ASPs) promote appropriate durations of therapy for patients cared for during their hospital stay. The Centers for Disease Control and Prevention (CDC) Core Elements advise hospitals to develop and implement facility-specific treatment recommendations to optimize antibiotic selection and duration as well as track the impact of their ASP.¹ In-hospital antimicrobial durations, however, only capture a portion of the total antimicrobial exposure attributable to

hospitalization. In fact, the majority of the antibiotic course may be completed postdischarge for many common infections.^{2,3}

Promoting shorter durations has become a goal for many ASPs, as data are emerging on successful short course therapy for common infectious syndromes, such as community-acquired pneumonia, urinary tract infection, intra-abdominal infections, and skin and soft-tissue infections.^{4,5} Hospitals that only assess inpatient days of antibiotics are not able to demonstrate the full impact of duration-focused interventions that affect both inpatient and postdischarge days of antibiotics. Assessing total duration of therapy could allow better understanding of duration-focused stewardship interventions and identify opportunities to optimize antibiotic use at transitions of care.

This study was part of a larger project entitled, “Developing Patient Safety Outcome Measures and Measurement Tools for

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Antibiotic Stewardship Programs,” that aimed to identify metrics that reflect the impact of the ASP on patient safety and quality of care.⁶ A metric of total duration was deemed useful in demonstrating ASP impact by the Structured Task Force of Experts Working at Reliable Standards for Stewardship (STEWARDS) panel, but the panel was uncertain of feasibility of data collection and analysis in hospitals utilizing electronic health records (EHRs). To our knowledge, most prior studies reporting total duration have used chart review and manual extraction to quantify the intended postdischarge days of antibiotic therapy.^{2,3,7-9} Historically, total duration has been difficult to capture electronically because inpatient and outpatient data were housed in different electronic systems or discharge prescriptions were hand written. Electronic capture could allow stewards to analyze prescribing durations without performing labor-intensive chart reviews.

In this study, we aimed to determine the feasibility of capturing electronic discharge prescription information in addition to inpatient antimicrobial use to calculate total duration of antimicrobials. The secondary aim was to quantify total antimicrobial durations attributable to inpatient hospital stays and the proportion contributed by postdischarge days.

Methods

We performed a retrospective cohort study of inpatient and discharge antimicrobial use data from April to September 2016 at 1 large, academic medical center and 2 community teaching hospitals (each with 300+ beds) located in the southeastern United States. The electronic health systems in use were Epic (2015 Upgrade, Verona, WI; www.epic.com) for 2 hospitals and McKesson (version 10.1.4.3, build 5, San Francisco, CA; www.mckesson.com) for the third. Electronic medication administration records were used to calculate inpatient antimicrobial days. Electronic discharge prescriptions (“e-scripts”) data were accessed to capture intended postdischarge antimicrobial days.

E-script data files were requested from the 3 pilot sites for the 6-month period. Two hospitals had a previously prepared data extraction file used by their outpatient pharmacy for administrative purposes. The third hospital employed a local analyst to create a new extract file for the purpose of the study. Fields in the data file included patient and admission/encounter identifiers, drug name, instructions for medication administration (sig), frequency, dispense number (quantity), duration (in days), and order date. Data files for electronic discharge prescriptions from the 2 sites using an existing data report did not include a discrete field for days duration, so we calculated duration using sig and quantity fields. E-scripts were linked to admission identifiers using dates of discharge prescription orders matched to hospitalization dates.

A 200-patient validation was performed at 1 site (hospital B) to ensure that electronic data were being captured appropriately. The validation included 2 random samples of patient admissions that were pulled from the primary EHR and compared to the e-script data extract: 100 patients discharged with e-scripts captured in the extract file and 100 patients with no e-script in the extract file. Reviewers manually analyzed the data captured in data extract files compared to documentation in the EHR.

For the analysis of total duration, adult or pediatric patients who received at least 1 day of antimicrobial therapy on an inpatient unit were included. Antimicrobial therapy received in outpatient units (eg, emergency departments) and procedural areas (eg, cardiac catheterization lab, operating room) were excluded. Antimicrobial agents were limited to those in the National

Healthcare Safety Network Antimicrobial Use module, since most other agents would not be used for acute illnesses (eg, HIV medications).¹⁰ Agents administered systemically (eg, intravenous, oral, and intramuscular) were included; topical (eg, creams, drops) and inhaled agents were excluded. Definitions of days of therapy and length of therapy (LOT) were taken from Polk et al.^{1,11,12} The primary metric of total duration was defined as the inpatient LOT plus postdischarge LOT, the count of calendar days when antimicrobials were received irrespective of the number of agents or doses on each calendar day. Postdischarge prescription durations were calculated based on orders and not administrations because patient adherence with ordered durations could not be measured. Descriptive statistics were used to describe (1) admissions with inpatient antimicrobials only versus admissions with both inpatient and postdischarge antimicrobials, (2) the distributions of total and postdischarge durations, and (3) the total duration among admissions with syndrome diagnoses. Syndrome diagnoses were defined using the Agency for Healthcare Research and Quality Clinical classifications software categories for pneumonia (122), urinary tract infection (159), skin and soft-tissue infection (197), and intra-abdominal infections (142, 146, 148, 149) based on *International Classification of Disease, Tenth Revision* (ICD-10) diagnosis codes associated with each admission.¹³

Data were analyzed using SAS version 9.4 software (SAS Institute, Cary, NC). The study was deemed exempt research by the institutional review boards at Duke University and Southeastern Regional Medical Center.

Results

Feasibility and validation

For 2 pilot sites, analysts calculated days duration for the electronic prescriptions from text in the sig and quantity fields. Due to inconsistencies in the text of sig fields, 437 e-scripts (5%) had durations that could not be calculated. This occurred most commonly for oral solutions and intravenous antibiotic orders. A metrics guide is available on our website that describes the structure of the data extracts from the 2 EHR systems in detail.⁶ This guide also includes detailed description of data cleaning steps required to match discharge prescriptions to inpatient admissions and to quantify days duration from sig and quantity fields.⁶

The manual validation steps taken at hospital B included 200 patients: 100 patients discharged with e-scripts captured in the extract file and 100 patients with no e-script in the extract file. Patients from the first sample had 100% accurate capture of e-scripts data, including dose and days duration, in extract files. In the other sample, validators found inconsistencies in clinicians’ use of e-scripts. Clinicians used written prescriptions or documented intent to prescribe antimicrobials without inputting e-scripts in 23 patients (23%). Clinical scenarios in which written or verbal order prescriptions were utilized instead of e-scripts included patients discharged to and receiving antimicrobials in long-term care facilities or dialysis centers.

Analysis of total duration

A total of 45,693 inpatient admissions were analyzed during the 6-month study period: 23,447 admissions (51%) received inpatient antimicrobials and 7,442 admissions (16%) received e-scripts at discharge. E-scripts were prescribed for 348 (5%) admissions who had not received antimicrobials as an inpatient. Patients most

Table 1. Number of Electronic Discharge Prescriptions by Antimicrobial Class, Agent, and Discharge Unit Type

Variable	No. of Discharge Prescriptions (N=9,264)	%	Postdischarge Duration, median d (IQR)
Top 5 antimicrobial classes			
Fluoroquinolones	2,318	25	7 (5–10)
Cephalosporins	1,526	17	7 (5–10)
First generation	687	7	9 (6–11)
Second generation	373	4	6 (4–10)
Third generation	425	5	7 (5–10)
β-lactam/β-lactamase inhibitors	1,014	11	8 (5–10)
Folate pathway inhibitors	689	7	10 (7–14)
Tetracyclines	617	7	7 (5–10)
Top 10 antimicrobial agents			
Ciprofloxacin	1,242	14	8 (5–11)
Amoxicillin/clavulanate	980	11	8 (5–10)
Levofloxacin	716	8	7 (5–10)
Trimethoprim/sulfamethoxazole	689	7	10 (7–14)
Metronidazole	599	7	10 (7–11)
Cephalexin	593	7	7 (6–10)
Doxycycline	585	7	7 (5–10)
Clindamycin	467	5	8 (6–10)
Fluconazole	369	4	9 (5–14)
Cefuroxime	367	4	6 (4–10)
Discharge unit type			
Medical ward	3,434	37.1	7 (5–10)
Surgical ward	1,446	15.6	10 (7–13)
Hematology/oncology ward	1,344	14.5	10 (5–13)
Medical/surgical ward	706	7.6	7 (5–10)
Other ^a	512	25.2	...

Note. IQR, interquartile range.

^aIncludes specialty wards (eg, pulmonary or orthopedic wards), labor and delivery wards, pediatric wards, and critical care units.

commonly received e-scripts for 1 antimicrobial agent on discharge (82%) or 2 antimicrobial agents on discharge (16%). The most common e-scripts were for fluoroquinolones, cephalosporins, and β-lactam/β-lactamase inhibitor combination antibiotics (Table 1). For all 3 hospitals, fluoroquinolones were the most common class; the most common agent was ciprofloxacin. Approximately 75% of discharge e-scripts were written on medical, surgical, and hematology/oncology wards. Durations of e-scripts were longer for surgical and hematology/oncology wards.

E-scripts accounted for 38% of the overall duration of therapy for patients (Table 2). Postdischarge duration among all discharge e-scripts was a median of 8 days (range, 1–360). The most common postdischarge durations were 3, 5, 7, and 10 days (Fig. 1B). There were also increased frequencies of e-scripts with 14- and 30-day durations. Also, 14 patients had discharge durations that exceeded 100 days of therapy. Drugs with median LOTs of ≥30 days included drugs used in outpatient parenteral antimicrobial therapy (OPAT) (eg, ceftazolin, penicillin V), oral anti-fungals for mold treatment and prophylaxis (eg, posaconazole, voriconazole), and agents for treatment of nontuberculous mycobacteria (eg, amikacin, tedizolid, cefoxitin). Patients with inpatient plus discharge antimicrobial e-scripts were older, more likely to be male, and

had higher Elixhauser comorbidity scores, but these patients had a shorter mean length of stay compared to admissions with inpatient antimicrobials only (Table 3).

Patients with an ICD-10 diagnosis for pneumonia, urinary tract infections, skin and soft-tissue infection, or intra-abdominal infection were often discharged on antibiotic therapy (Table 4). Using a 7-day duration as a recommended typical course for most uncomplicated infections, most patients (78%) who received e-scripts exceeded this duration compared to 16% of patients who had inpatient antimicrobials only. Among patients with a diagnosis of these infectious syndromes, total durations for patients who received discharge e-scripts exceeded those for patients without discharge prescriptions despite having shorter lengths of stay. The difference in total duration was most pronounced among those with a diagnosis of intra-abdominal infection.

Discussion

ASPs must target decisions occurring at transitions of care and processes for discharge antimicrobial prescriptions to improve patient safety. Our study indicates that more than one-third of

Table 2. Percentage of Postdischarge and Total Durations of Therapy

Variable	Hospital A	Hospital B	Hospital C	All Hospitals
No. admissions with antibiotics	4,534	4,615	14,646	23,795
Antibiotic admissions with electronic discharge prescriptions, no. (%)	1,571 (35)	1,344 (29)	4,527 (31)	7,442 (31)
Days Duration, Median (IQR)				
Inpatient	0 (0–2)	1 (0–3)	1 (0–3)	3 (2–5)
Postdischarge	0 (0–5)	0 (0–4)	0 (0–4)	0 (0–4)
Total duration	4 (2–10)	4 (2–9)	4 (2–12)	4 (2–10)
Postdischarge length of therapy, d (% of total duration)	12,710 (41)	9,774 (34)	51,128 (38)	73, 612 (38)

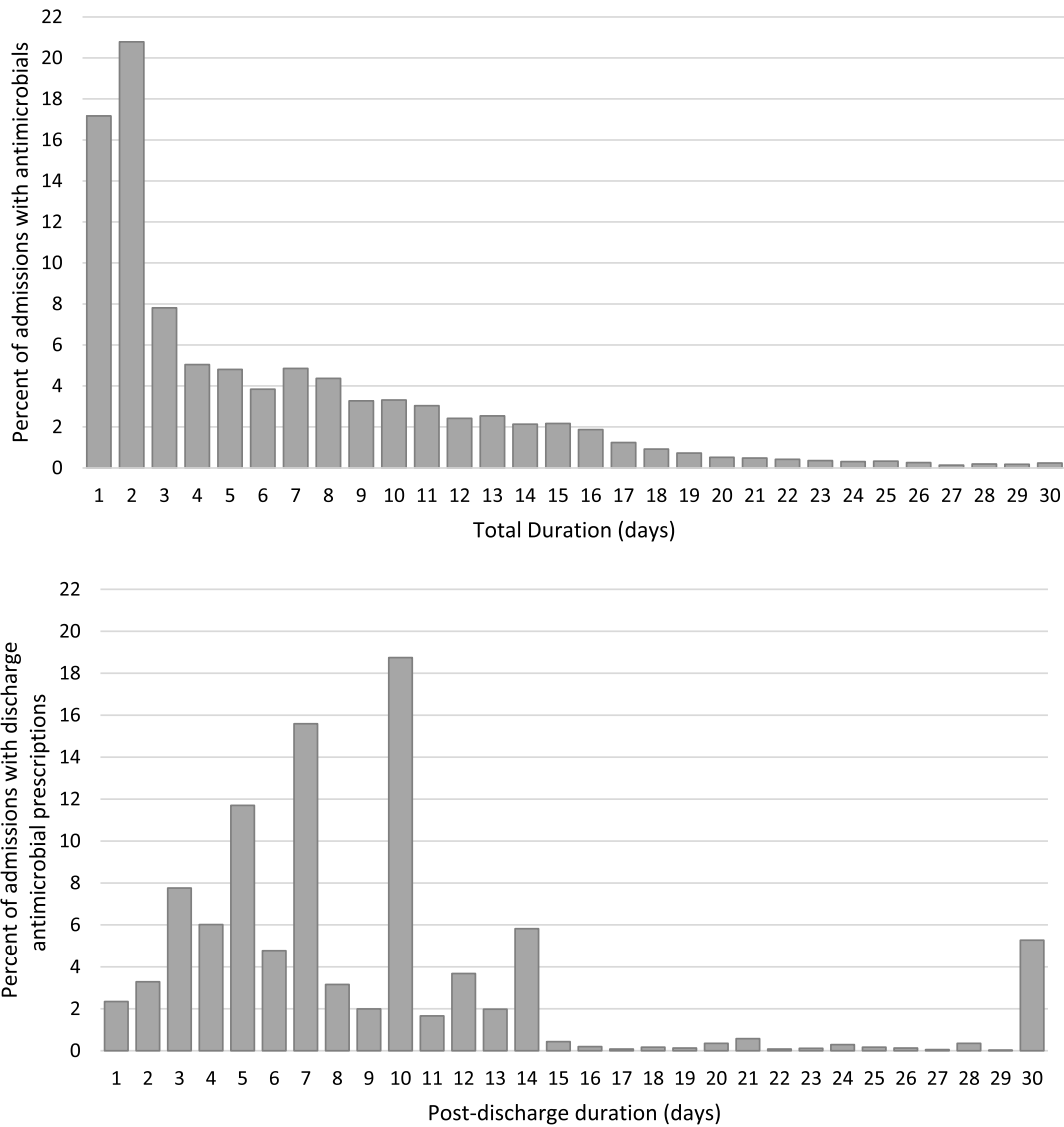


Fig. 1. Distribution of total duration and postdischarge durations for all hospitals. The graphs were limited to durations of ≤ 30 days. Total durations ranged from 1 to 367 days, and 4.2% of durations were > 30 days. Postdischarge durations ranged from 1 to 360 days, and 3% of these were > 30 days.

hospital-related antimicrobial exposure occurred after the patient was discharged. More than three-quarters of patients given e-scripts received a total antibiotic course that exceeded 7 days. In addition, our study highlights the complexity of the task of

electronic data collection and analysis from EHRs. Our estimates of postdischarge antimicrobial days were subject to missing data based on clinician work flow and avoidance of the electronic system in certain clinical scenarios. Thus, the estimates of total

Table 3. Characteristics of Patient Admissions by Receipt of Inpatient Only or Inpatient Plus Postdischarge Antimicrobials

Variable	Admissions with Inpatient Antimicrobials Only (N=16,353)	Admissions With Inpatient Plus Postdischarge Antimicrobials (N=7,442)	P Value
Age, mean y \pm standard deviation	51.6 \pm 24.5	54.3 \pm 22.1	<.001
Pediatric admission, no. (%)	1,867 (11)	588 (8)	<.001
Male gender, no. (%)	7,114 (44)	3,593 (49)	<.001
Elixhauser score	2.7 \pm 2.3	2.9 \pm 2.2	<.001
Length of stay, d	8.8 \pm 14.8	7.3 \pm 11.1	<.001
Race, no. (%)			
White/Caucasian	9,159 (57)	4,175 (56)	.02
Black/African American	4,707 (29)	2,353 (32)	
American Indian/Alaskan Native	1,073 (7)	435 (6)	
Other	609 (4)	233 (3)	
Unknown	344 (2)	108 (1)	
Asian	230 (1)	88 (1)	
Native Hawaiian/Other Pacific Islander	12 (<1)	4 (<1)	
Hispanic or Latino	3 (<1)	2 (<1)	
Hospital, no. (%)			
Hospital A (n=4,534)	2,963 (18)	1,571 (21)	.10
Hospital B (n=4,615)	3,271 (20)	1,344 (18)	
Hospital C (n=14,696)	10,119 (62)	4,529 (61)	

Note. For all hospitals, 349 (1%) patients had an electronic discharge prescription for an antimicrobial without receiving a prescription for inpatient antimicrobials. Missing data were not included in above percent calculations and represented <1% for any single characteristic. Pediatric admission was defined as age at admission 0–17 years.

antibiotic exposure attributed to postdischarge prescriptions in this study were likely underestimates of the intended antibiotic duration.

Several potential causes of excessive antimicrobial durations at hospital discharge are possible. Errors in the ordering process or electronic system “defaults” for outpatient prescriptions may result in longer durations than intended. Extended durations may be prescribed due to lack of knowledge, uncertainty about the patient’s diagnosis or readiness for discharge, or inadequate attention to the task of defining the start and stop dates to meet the intended total duration of treatment. Growing administrative pressure to shorten hospital lengths of stay and perform discharges earlier in the day might lead clinical teams to rush the discharge process. Antimicrobial stewardship and appropriate antimicrobial durations should be included in efforts to improve patient safety and to prevent negative consequences that could be attributed to hospital discharges. Discharge processes are a key area in which ASPs need to engage other healthcare professionals, such as hospitalists, nurses, and clinical pharmacists to improve patient safety.

Previous investigation of discharge prescriptions has indicated that when discharge durations are factored into prescribing, 55% of patients receive a course of antibiotics that is too long and, on average, patients receive 3.8 days of unnecessary antibiotic therapy.¹⁵ For many common infections, short-course therapy is equivalent to longer durations of therapy.⁴ In controlled clinical trials, uncomplicated community acquired pneumonia can be treated in as few

as 5 days; hospital-acquired or ventilator-associated pneumonia, ≤ 7 –8 days; pyelonephritis, 5–7 days; cellulitis, 5 days; and intra-abdominal infection, 4–7 days.^{16–23} The most common post-discharge durations in our study were 5, 7, and 10 days, with additional spikes at 14 and 30 days. Since each of these are common durations for full antimicrobial treatment courses, this finding may indicate that clinicians did not factor in the patient’s inpatient LOT when selecting outpatient antibiotic duration or may have relied on electronic defaults within the prescribing system. Frequency of discharge prescribing by agent and drug class revealed that 25% of all discharge antimicrobial prescriptions were fluoroquinolones. Our data are consistent with those of Scarpato et al,¹⁵ who noted a similar fluoroquinolone prescribing rate of 23.5% when evaluating discharge prescriptions from the Hospital of the University of Pennsylvania. Our fluoroquinolone prescribing rate was lower than the 40% rate described by Yogo et al⁸ for discharge prescriptions filled within 7 days posthospitalization, lower than the 47%–49% rate of outpatient prescribing noted in a study of community acquired pneumonia by Yi et al,²⁴ and lower than the 30.5% rate cited by Vaughn et al²⁵ from patients diagnosed with urinary tract infection or community-acquired pneumonia in 48 hospitals in the Michigan Hospital Medicine Safety Consortium.^{1,8,24,25} The inpatient stewardship programs at all 3 study hospitals were actively engaged in initiatives to decrease inpatient fluoroquinolone prescribing due to resistance of common pathogens to these agents and the increased risk *Clostridioides difficile* infections.^{26,27} Based on this growing body of literature

Table 4. Length of Stay and Total Duration by Syndrome Diagnosis

Variable	Admissions With Inpatient Antimicrobials Only	Admissions With Inpatient Plus Postdischarge Antimicrobials	Total
All antibiotic admissions, no. (%)	16,353 (69)	7,442 (31)	23,795
Length of stay, median d (IQR)	5 (3–9)	5 (3–7)	5 (3–8)
Total duration, median d (IQR)	2 (2–5)	12 (8–16)	4 (2–10)
Admissions with durations >7 days, no. (% of column)	2,555 (16)	5,817 (78)	8,372 (35)
Pneumonia, no. (%)	1,096 (52)	998 (48)	2,094
Length of stay, median d (IQR)	10 (6–18)	5 (4–8)	7 (4–13)
Total duration, median d (IQR)	7 (4–12)	10 (8–15)	9 (6–14)
Admissions with durations >7 d, no. (% of column)	537 (49)	761 (76)	1,298 (62)
Urinary tract infection, no. (%)	2,071 (55)	1,667 (45)	3,738
Length of stay, median d (IQR)	8 (5–14)	5 (3–8)	6 (4–11)
Total duration, median d (IQR)	5 (3–8)	11 (8–15)	8 (4–13)
Admissions with durations >7 d, no. (% of column)	623 (30)	1,324 (79)	1,947 (52)
Intra-abdominal infection, no. (%)	1,006 (60)	663 (40)	1,669
Length of stay, median d (IQR)	6 (3–11)	5 (4–9)	6 (3–10)
Total duration, median d (IQR)	3 (2–8)	13 (10–18)	8 (2–14)
Admissions with durations >7 d, no. (% of column)	253 (25)	594 (89)	847 (51)
Skin and soft-tissue infection, no (%)	701 (43)	925 (57)	1,626
Length of stay, median d (IQR)	8 (5–15)	5 (3–8)	6 (4–10)
Total duration, median d (IQR)	6 (3–11)	13 (10–17)	11 (6–15)
Admissions with durations >7 d, No. (% of column)	268 (38)	828 (90)	1,096 (68)

Note. IQR, interquartile range.

incorporating postdischarge antibiotics, ASPs should focus on discharge processes as a key area to promote avoidance of fluoroquinolones and shorter, syndrome-based durations.²⁵

Syndrome-focused antimicrobial stewardship has been identified as a strategy to better engage with clinicians. Institution-specific syndromic guidelines and order sets, however, often focus on empiric therapy and do not address decisions after the time of antibiotic initiation. Thus, antibiotic de-escalation and duration may not be included in syndrome-specific antimicrobial stewardship initiatives. We did not specifically evaluate indication with in-depth chart review, but we attempted to understand indication by looking at ICD-10 diagnosis codes for the major infectious clinical syndromes. Although not specifically investigated in this study, we suspect that use of indications documented by prescribers at the time of order entry may be more accurate than ICD-10 codes assigned at discharge, as large proportions of antibiotic-associated encounters have no associated infection diagnosis codes.²⁹ We observed that in pneumonia, patients received a median of 10 days of treatment when they received a e-scripts and a median of 7 days when they completed therapy as an inpatient. This finding is consistent with other estimates of median of 10 days duration for community-acquired pneumonia.²⁴ In a single-center study, direct prescriber feedback, coupled with education, decreased the median total antimicrobial durations for community-acquired pneumonia


from 10 days to 7 days and led to a 61% reduction in overall antibiotic durations.²⁸ These data indicate that stewardship strategies targeting durations for specific indications can have an impact.

Moreover, 78% of patients with discharge e-scripts received a total duration of therapy in excess of 7 days. We observed that patients with diagnoses for infectious syndromes who completed their course of antibiotics while they were inpatients had longer mean hospital stays but received shorter total durations of antibiotic therapy. Presumably, patients who remain hospitalized have more complex clinical management for infections than those discharged sooner. Thus, the finding of longer durations in those discharged earlier is not consistent with the expected clinical status and requires further exploration to better elucidate the clinical rationales for long durations. Notably, few patients in the inpatient only group suffered in-hospital death ($n = 689$, 4%); thus, death is unlikely to explain the difference in antimicrobial durations between the 2 groups.

Our study had both strengths and limitations. We evaluated >45,000 patients and reviewed data from both community hospitals and an academic medical center. We assessed the feasibility of e-script data capture and its validity from the EHR. Our electronic data extraction method had feasibility barriers that required extra analysis time before proceeding with analyses of total duration. In addition, we discovered there was a missing data bias in the

electronic prescriptions data due to lack of use of the electronic system in certain clinical scenarios. Based on the estimate of 23% of the sampled patients with no e-script data who did have post-discharge antibiotic exposures, we expect that this bias reduced our estimate of postdischarge days and, in particular, missing courses of intravenous antibiotics. Notably, missing e-scripts were common for patients going to skilled nursing facilities and patients receiving antibiotics with hemodialysis. This population would be useful to target both for measurement of postdischarge antibiotic exposure and to capitalize on opportunities to avoid outpatient parenteral antimicrobial therapies.³⁰ Despite the e-scripts data being incomplete, it is still highly useful for hospital ASPs to better target interventions focused at transitions of care to optimize the e-script process. We did not evaluate for appropriateness of antibiotic choice or intended duration; however, prior studies of outpatient prescribing at the time of hospital discharge have found that 53% of discharge prescriptions were inappropriate.⁸ Thus, we believe that there is ample opportunity to investigate the rationales for long durations and promote more appropriate antibiotic durations upon discharge in our study hospitals. Interventions targeted to these rationales could then be tracked using similar electronic data collection methods. Finally, we captured intended discharge durations but did not assess prescription fills or patient adherence with prescribed antimicrobials. The study results raised additional questions for future investigation. We did not specifically compare e-script durations for children to that of adults, and we did not evaluate discharge e-script prescribing patterns for individual prescribers. Outpatient practices and some hospital ASPs use individual prescriber data feedback with peer comparisons of antibiotic use to encourage behavior change.^{31,32} The addition of post-discharge data to inpatient prescriber feedback reports would provide a more comprehensive look at antibiotic use by prescriber, especially in assessments of antibiotic duration attributed to the inpatient stay and specific syndromes. ASPs that do not attempt to measure postdischarge days may underestimate the effects of inpatient stewardship initiatives on antibiotic use, especially for interventions that intend to shorten durations of therapy. Finally, this study only partially touched on the significant challenges faced by inpatient ASPs in accessing electronic, patient-level datasets, developing standard ways to measure outcomes important and meaningful to ASPs, and implementing these measures on a large scale.

Antimicrobial prescriptions written at the time of hospital discharge led to more than one-third of total antimicrobial days attributable to an inpatient hospital stay. Durations in excess of 7 days were common for the major infectious syndromes among those receiving e-scripts. Our findings suggest that prolonged courses of antibiotic therapy are common at discharge and may contribute to unnecessary antimicrobial exposure in patients. ASPs that target discharge prescription duration and appropriateness have an opportunity to reduce unnecessary antimicrobial use and its resultant harms. These activities should be incorporated to hospital quality improvement initiatives focused at improving safety at transitions of care.

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References

- Pollack LA, Srinivasan A. Core elements of hospital antibiotic stewardship programs from the Centers for Disease Control and Prevention. *Clin Infect Dis* 2014;59(Suppl3):S97–S100.
- Jenkins TC, Knepper BC, Sabel AL, *et al.* Decreased antibiotic utilization after implementation of a guideline for inpatient cellulitis and cutaneous abscess. *Arch Intern Med* 2011;171:1072–1079.
- Jenkins TC, Stella SA, Cervantes L, *et al.* Targets for antibiotic and health-care resource stewardship in inpatient community-acquired pneumonia: a comparison of management practices with National Guideline Recommendations. *Infection* 2013;41:135–144.
- Spellberg B. The new antibiotic mantra “shorter is better.” *JAMA Intern Med* 2016;176:1254–1255.
- Hayashi Y, Paterson DL. Strategies for reduction in duration of antibiotic use in hospitalized patients. *Clin Infect Dis*. 2011;52:1232–1240.
- Developing patient safety outcome measures and measurement tools for antibiotic stewardship programs: metrics guide. Duke Antimicrobial Stewardship Outreach Network website. <https://dason.medicine.duke.edu/system/files/page-attachments/704/dason-cdcfinalanalysisistool-r11-21.pdf>. Published 2018. Accessed January 5, 2019.
- Tamma PD, Avdic E, Keenan JF, *et al.* What is the more effective antibiotic stewardship intervention: preprescription authorization or postprescription review with feedback? *Clin Infect Dis* 2017;64:537–543.
- Yogo N, Haas MK, Knepper BC, Burman WJ, Mehler PS, Jenkins TC. Antibiotic prescribing at the transition from hospitalization to discharge: a target for antibiotic stewardship. *Infect Control Hosp Epidemiol* 2015;36:474–478.
- Moehring RW, Anderson DJ, Cochran RL, *et al.* Expert consensus on metrics to assess the impact of patient-level antimicrobial stewardship interventions in acute-care settings. *Clin Infect Dis* 2017;64:377–383.
- National Healthcare Safety Network: antimicrobial use and resistance (AUR) options. Centers for Disease Control and Prevention website. <http://www.cdc.gov/nhsn/acute-care-hospital/aur/index.html>. Published 2018. Accessed August 14, 2018.
- Polk RE, Hohmann SF, Medvedev S, Ibrahim O. Benchmarking risk-adjusted adult antibacterial drug use in 70 US academic medical center hospitals. *Clin Infect Dis* 2011;53:1100–1110.
- Ibrahim OM, Polk RE. Antimicrobial use metrics and benchmarking to improve stewardship outcomes: methodology, opportunities, and challenges. *Infect Dis Clin North Am*. 2014;28:195–214.
- Beta Clinical Classifications Software (CCS) for ICD-10-CM/PCS. Healthcare Cost and Utilization Project (HCUP) website. <https://www.hcup-us.ahrq.gov/toolssoftware/ccs10/ccs10.jsp#overview> Published 2018. Accessed January 5, 2018.
- Osterberg L, Blaschke T. Adherence to medication. *N Engl J Med* 2005;353:487–497.

15. Scarpato SJ, Timko DR, Cluzet VC, *et al*. An evaluation of antibiotic prescribing practices upon hospital discharge. *Infect Control Hosp Epidemiol* 2017;38:353–355.
16. Uranga A, Espana PP, Bilbao A, *et al*. Duration of antibiotic treatment in community-acquired pneumonia: a multicenter randomized clinical trial. *JAMA Intern Med* 2016;176:1257–1265.
17. Chastre J, Wolff M, Fagon JY, *et al*. Comparison of 8 vs 15 days of antibiotic therapy for ventilator-associated pneumonia in adults: a randomized trial. *JAMA* 2003;290:2588–2598.
18. Singh N, Rogers P, Atwood CW, Wagener MM, Yu VL. Short-course empiric antibiotic therapy for patients with pulmonary infiltrates in the intensive care unit. A proposed solution for indiscriminate antibiotic prescription. *Am J Respir Crit Care Med* 2000;162:505–511.
19. El Moussaoui R, de Borgie CA, van den Broek P, *et al*. Effectiveness of discontinuing antibiotic treatment after three days versus eight days in mild to moderate-severe community-acquired pneumonia: randomised, double-blind study. *BMJ* 2006;332(7554):1355.
20. Dunbar LM, Wunderink RG, Habib MP, *et al*. High-dose, short-course levofloxacin for community-acquired pneumonia: a new treatment paradigm. *Clin Infect Dis* 2003;37:752–760.
21. Eliakim-Raz N, Yahav D, Paul M, Leibovici L. Duration of antibiotic treatment for acute pyelonephritis and septic urinary tract infection—7 days or less versus longer treatment: systematic review and meta-analysis of randomized controlled trials. *J Antimicrob Chemother* 2013;68:2183–2191.
22. Sawyer RG, Claridge JA, Nathens AB, *et al*. Trial of short-course antimicrobial therapy for intraabdominal infection. *N Engl J Med* 2015;372:1996–2005.
23. Hepburn MJ, Dooley DP, Skidmore PJ, Ellis MW, Starnes WF, Hasewinkle WC. Comparison of short-course (5 days) and standard (10 days) treatment for uncomplicated cellulitis. *Arch Intern Med* 2004;164:1669–1674.
24. Yi SH, Hatfield KM, Baggs J, *et al*. Duration of antibiotic use among adults with uncomplicated community-acquired pneumonia requiring hospitalization in the United States. *Clin Infect Dis* 2018;66:1333–1341.
25. Vaughn VM, Gandhi T, Conlon A, Chopra V, Malani AN, Flanders SA. The association of antibiotic stewardship with fluoroquinolone prescribing in Michigan hospitals: a multi-hospital cohort study. *Clin Infect Dis* 2019 Feb 13. doi: 10.1093/cid/ciy1102. [Epub ahead of print].
26. Barlam TF, Cosgrove SE, Abbo LM, *et al*. Implementing an antibiotic stewardship program: guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. *Clin Infect Dis* 2016;62(10):e51–e77.
27. Pepin J, Saheb N, Coulombe MA, *et al*. Emergence of fluoroquinolones as the predominant risk factor for *Clostridium difficile*-associated diarrhea: a cohort study during an epidemic in Quebec. *Clin Infect Dis* 2005;41:1254–1260.
28. Avdic E, Cushinotto LA, Hughes AH, *et al*. Impact of an antimicrobial stewardship intervention on shortening the duration of therapy for community-acquired pneumonia. *Clin Infect Dis* 2012;54:1581–1587.
29. Chua KP, Fischer MA, Linder JA. Appropriateness of outpatient antibiotic prescribing among privately insured US patients: ICD-10-CM-based cross-sectional study. *BMJ* 2019;364:k5092.
30. Shrestha N, Bhaskaran A, Scalera NM, *et al*. Antimicrobial stewardship at transition of care from hospital to community. *Infect Cont Hosp Epidemiol* 2012;33:401–404.
31. Meeker D, Linder JA, Fox CR, *et al*. Effect of behavioral interventions on inappropriate antibiotic prescribing among primary care practices: a randomized clinical trial. *JAMA* 2016;315:562–570.
32. Bork JT, Morgan DJ, Heil EL, Pineles L, Kleinberg M. Peer comparison of anti-MRSA agent prescription in the inpatient setting. *Infect Control Hosp Epidemiol* 2017;38:1506–1508.