MAJOR ARTICLE

Infectious Diseases Specialty Intervention Is Associated With Decreased Mortality and Lower Healthcare Costs

Steven Schmitt,[1] Daniel P. McQuillen,[2] Ronald Nahass,[3] Lawrence Martinelli,[4] Michael Rubin,[5] Kay Schwebke,[6] Russell Petrak,[7] J. Trees Ritter,[8] David Chansolme,[9] Thomas Slama,[10] Edward M. Drozd,[11] Shamonda F. Braithwaite,[11] Michael Johnsrud,[12] and Eric Hammelman[11]

[1]Department of Infectious Diseases, Medicine Institute, Cleveland Clinic, Ohio; [2]Center for Infectious Diseases and Prevention, Lahey Hospital & Medical Center, Tufts University School of Medicine, Burlington, Massachusetts; [3]ID Care, Hillsborough, New Jersey; [4]Covenant Health, Lubbock, Texas; [5]Divisions of Clinical Epidemiology and Infectious Diseases, University of Utah School of Medicine, Salt Lake City; [6]OptumInsight, Eden Prairie, Minnesota; [7]Metro ID Consultants, LLC, Burr Ridge, Illinois; [8]French Hospital Medical Center, San Luis Obispo, California; [9]Infectious Disease Consultants of Oklahoma City, Oklahoma; [10]Indiana University School of Medicine, Indianapolis, Indiana; [11]Data Analytics, and [12]Health Economics and Outcomes Research, Avalere Health, Washington, D.C.

(See the Editorial Commentary by Bouza on pages 29–31.)

Background. Previous studies, largely based on chart reviews with small sample sizes, have demonstrated that infectious diseases (ID) specialists positively impact patient outcomes. We investigated how ID specialists impact mortality, utilization, and costs using a large claims dataset.

Methods. We used administrative fee-for-service Medicare claims to identify beneficiaries hospitalized from 2008 to 2009 with at least 1 of 11 infections. There were 101 991 stays with and 170 336 stays without ID interventions. Cohorts were propensity score matched for patient demographics, comorbidities, and hospital characteristics. Regression models compared ID versus non-ID intervention and early versus late ID intervention. Risk-adjusted outcomes included hospital and intensive care unit (ICU) length of stay (LOS), mortality, readmissions, hospital charges, and Medicare payments.

Results. The ID intervention cohort demonstrated significantly lower mortality (odds ratio [OR], 0.87; 95% confidence interval [CI], .83 to .91) and readmissions (OR, 0.96; 95% CI, .93 to .99) than the non-ID intervention cohort. Medicare charges and payments were not significantly different; the ID intervention cohort ICU LOS was 3.7% shorter (95% CI, −5.5% to −1.9%). Patients receiving ID intervention within 2 days of admission had significantly lower 30-day mortality and readmission, hospital and ICU length of stay, and Medicare charges and payments compared with patients receiving later ID interventions.

Conclusions. ID interventions are associated with improved patient outcomes. Early ID interventions are also associated with reduced costs for Medicare beneficiaries with select infections.

Keywords. infectious diseases; ID specialists; costs; utilization; patient outcomes.

In an inpatient hospital setting, cognitive specialists often consult with the primary physician on treatment of patients with complex conditions, offering evidence-based recommendations on diagnosis and management. Cognitive specialists play a key role in inpatient to outpatient care transitions and provide follow-up in an effort to avoid re-admissions. Specifically, infectious diseases (ID) specialists provide consultation on treatment of patients who may have 1 or more infectious conditions, which are often severe and require intensive monitoring to appropriately diagnose and manage. ID specialists optimize treatment in the inpatient setting

Received 16 January 2013; accepted 26 July 2013; electronically published 25 September 2013.

Correspondence: Steven Schmitt, MD, 9500 Euclid Ave., Desk G-21, Cleveland, OH 44195, USA (schmits@ccf.org).

Clinical Infectious Diseases 2014;58(1):22–8

© The Author 2013. Published by Oxford University Press on behalf of the Infectious Diseases Society of America. All rights reserved. For Permissions, please e-mail: journals.permissions@oup.com.

DOI: 10.1093/cid/cit610

by recommending appropriate antibiotic choices, duration of therapy, and route of delivery and by monitoring to minimize adverse drug reactions [1, 2]. Furthermore, ID specialists facilitate care transitions from the inpatient setting through outpatient parenteral antibiotic therapy programs and provision of care management oversight. Existing evidence suggests that when an ID specialist is involved in a patient's care and the physician in charge follows ID recommendations, patients are more often correctly diagnosed [3, 4], have shorter lengths of stay [5], receive more appropriate therapies [6, 7], have fewer complications [7], and may use fewer antibiotics overall [8]. ID interventions have been associated with reduced hospital mortality rates in patients with *Staphylococcus aureus* bacteremia (SAB) [9, 10]. ID specialists have been shown to have a positive impact on the appropriate use of antibiotic therapy in patients with trauma, bacteremia, and skin and soft tissue infections [8]. Data regarding the impact of ID specialists on hospital length of stay and costs have been mixed, with both positive and negative effects seen [5, 8, 11]. Most existing studies regarding the impact of ID specialty care are constrained by small sample size and chart review methodology, which limit the ability to generalize their conclusions. A prior metaanalysis of studies of specialist versus generalist care for individual conditions highlighted several potential methodological pitfalls, including selection bias [12]. As a consequence, it has been difficult for payers, hospitals, and consumers to draw meaningful conclusions about the value of ID specialty interventions. The objective of this study was to generate robust data regarding the impact of ID consultation on spending and outcomes using a national claims database.

METHODS

Study Population

The study population consists of Medicare fee-for-service (FFS) patients who were hospitalized in an acute care hospital (ACH) between 1 January 2008 and 30 November 2009 with a primary or secondary diagnosis of 1 or more of 11 infections: bacteremia, *Clostridium difficile* infection (CDI), central line–associated bloodstream infections, bacterial endocarditis, human immunodeficiency virus/opportunistic infections, meningitis, osteomyelitis, prosthetic joint infections, septic arthritis, septic shock, and vascular device infections. The data source was claims data from Medicare research identifiable files (RIFs).

We required beneficiaries to be enrolled in Medicare parts A and B for the full calendar year prior to and the calendar year of the index hospitalization. We excluded stays if the same patient had an ACH hospitalization for any cause within 30 days prior to the index stay or an ACH hospitalization in the past year for a condition of interest. We further excluded any transfer stay from different ACHs or stays where Medicare FFS was not the primary payer.

For the primary analysis, we created 2 cohorts, defined by the presence of at least 1 ID intervention during the index stay. ID intervention was defined as 1 or more physician claims from an ID specialist with an inpatient hospital place of service from 2 days prior to the admission date through 2 days after the discharge date. We allowed for a 2-day range to account for variation in physician billing.

For the secondary analysis, we limited the study population to only stays with ID involvement. We compared stays with initial ID involvement within the first 2 days of the ACH admission with those with initial ID involvement after the first 2 days. We required all stays in this secondary analysis to be longer than the geometric mean length of stay (GMLOS) for the specific Medicare severity-diagnosis related group in order to identify patients whose severity was great enough to warrant a relatively long inpatient stay.

Outcomes of Interest

Information regarding hospital mortality and length of stay was collected from inpatient claims. Readmission rates were assessed by evaluating inpatient claims for any subsequent admission to an ACH within 30 days following discharge from the index hospitalization. Similar to the readmission measure process used by the Centers for Medicare & Medicaid Services, patients discharged alive but expiring within 30 days were retained in the stays at risk for 30-day readmission. ACH charges, Medicare payments to the ACH for the index stay, Medicare payments to all providers during the index stay, and total Medicare payments for the 30 days post discharge were extracted from the RIFs. All payments were adjusted to 2009 dollars using the Medicare hospital market basket price index.

Statistical Analysis

We used a 2-step process to address potential selection bias. First we used a propensity score matching (PSM) method, wherein we established similar groups of patients based on identifiable risk factors. We then used a multivariate regression to control for expected differences caused by variables that have been shown to influence outcomes unrelated to physician specialty. The combined effect of these 2 steps provided us with a set of hospital stays that we used to measure the effect of ID involvement.

First we applied the PSM method. We used logistic regression using Stata 12 (StataCorp. College Station, TX), with an indicator of ID involvement as the dependent variable and patient and hospital variables as explanatory variables to estimate a propensity score for each patient (Table 1). The C-statistics for the propensity score models ranged from 0.83 to 0.85 (separate propensity scores were created for all admissions, admissions with 1 or more intensive care unit [ICU] days, and admissions with a live discharge).

Table 1. Propensity Score Match and Regression Model Variables

Propensity Score Match Variables	Regression Variables
Patient Variables	Patient Variables
Charlson comorbidity index from prior 12 mo	Charlson comorbidity index from prior 12 mo
Charlson comorbidity index based on index stay	Charlson comorbidity index based on index stay
Elixhauser score	Elixhauser score
Patient HCC risk score based on prior 12 mo	Patient HCC risk score deciles
Index stay number of physician visits per day	Patient age
Patient age	Patient gender
Patient gender	Patient race
Patient race	Patient dual-eligible status
Patient dual-eligible status	Patient reason for Medicare entitlement
Patient reason for Medicare entitlement	Index stay source of admission
Index stay source of admission	Index stay type of stay (medical vs surgical)
Index stay type of stay (medical vs surgical)	Index stay major diagnosis category
Index stay major diagnosis category	
Index stay indicator for all days Medicare covered	
Hospital variables	Hospital variables
Hospital census division	Hospital census division
Hospital urban/rural location	Hospital urban/rural location
Hospital bed size	Hospital bed size
Hospital teaching status	Hospital teaching status
Hospital Medicaid percentage	Hospital Medicaid percentage
Hospital Medicare SSI percentage	Hospital Medicare SSI percentage
Hospital Medicare case mix index	Hospital Medicare case mix index

Abbreviations: HCC, hierarchical condition categories; SSI, Social Security index.

Using nearest-neighbor matching, we constructed a matched sample of ID and no-ID cohorts. We used a 1:1 matching strategy without replacement with a caliper (maximum propensity score distance) of 0.03. Only intervention and comparison stays on common support (ie, stays with matching risk factors) were retained. For each of the 3 propensity score models, approximately 40% of the prematch ID cohort was dropped for having very large propensity scores that could not be matched, and approximately 55% of the prematch no-ID cohort was dropped for having very small propensity scores.

Beneficiary and hospital-related characteristics were compared between the 2 study cohorts using χ^2 and t tests, as appropriate. Prior to PSM, most characteristics exhibited statistically significant differences between the 2 cohorts. After PSM, there was only 1 statistically significant difference: number of physician visits per day. Comparisons of pre- and postmatch outcomes and covariates are available in the Supplementary Materials.

Table 2. Summary Statistics of Patient Condition

	No ID Intervention		ID Intervention	
Condition	Number	Percent	Number	Percent
Bacteremia	20 377	12.0	14 066	13.8
Clostridium difficile infection	31 853	18.7	13 681	13.4
Central line infections	3308	1.9	3980	3.9
Endocarditis	8585	5.0	5773	5.7
HIV/opportunistic infections	24 087	14.1	9648	9.5
Meningitis	279	0.2	644	0.6
Osteomyelitis	16 754	9.8	19 959	19.6
Prosthetic joint infections	30 608	18.0	21 957	21.5
Septic arthritis	3215	1.9	4809	4.7
Septic shock	35 659	20.9	19 975	19.6
Vascular device infections	8232	4.8	6885	6.8
Total unique stays	**170 366**		**101 991**	

Many patients had more than 1 condition during an index stay.

Abbreviations: HIV, human immunodeficiency virus; ID, infectious diseases.

To account for remaining between-cohort differences, we estimated separate regression models using PSM-matched cohorts for each of the outcomes of interest: index stay length of stay (LOS) and index stay ICU days (negative binomial regression); inpatient mortality, 30-day postdischarge mortality, and 30-day readmission rate (logistic regression); and ACH charges for index stay, ACH index stay Medicare payments, all-provider index stay Medicare payments, and all-provider 30-day postdischarge Medicare payments (generalized linear model with log link and gamma distribution).

All multivariate regression models shared a common set of explanatory hospital and patient variables. The main explanatory variable was ID involvement. Other covariates included many of the same variables used in the PSM model, with a few modifications (Table 1).

Estimated odds ratios (ORs) or estimated percent change derived from exponentiated regression coefficients and the associated 95% confidence intervals (CIs) were reported for all model coefficients. Risk-standardized levels of each outcome for the 2 cohorts were computed at the means of all variables other than the ID indicator.

RESULTS

Sample Descriptive Statistics

The pre-PSM sample included 101 991 stays with and 170 366 stays without ID involvement. In general, patients with ID

Table 3. Patient and Index Stay Characteristics

	No ID Intervention		ID Intervention	
Category	Number	Percent	Number	Percent
% Male	75 992	46.8	50 012	51.2
% Female	86 473	53.2	47 663	48.8
% Aged <65 y	37 007	22.8	26 326	27.0
% Aged 65–74 y	39 419	24.3	25 574	26.2
% Aged 75–84 y	50 506	31.1	29 080	29.8
% Aged 85+ y	35 533	21.9	16 704	17.1
% Index stays at teaching hospital	83 517	49.0	59 746	58.6
% Index stays with ICU days	41 916	24.6	28 359	27.8

Percentages of cases in the age and gender groups excluded from the denominator 7901 non-ID consult and 4307 ID consult cases where the age and gender of the patient are missing.

Abbreviations: ICU, intensive care unit; ID, infectious diseases.

involvement were more likely to have more than 1 of the listed infections during their hospital admission (Table 2). Patients with ID involvement were also younger, more likely to be male, and more likely to have been admitted to a teaching hospital and to an intensive care unit (Table 3).

The matched sample was composed of 61 680 ID and 65 192 non-ID cases. The number of non-ID cases is somewhat larger because of cases with identical propensity scores. Compared with the ID intervention cases included in the analysis, the excluded ID intervention cases were more likely to be treated in large hospitals, more likely to be younger and male, less likely to have a respiratory primary diagnosis, more likely to have an orthopedic infection primary diagnosis, and more likely to have had surgery. Supplementary Table 1 presents means of the matching characteristics plus additional geographic indicators not used for matching for the full and matched sample cohorts.

Outcomes

Prior to applying risk controls, ID intervention stays were associated with longer lengths of index stay, more ICU days, higher 30-day mortality, readmission rates, Medicare charges and payments, and significantly lower index stay mortality. After adjustment, stays with ID involvement were associated with significantly lower rates of index stay mortality (OR, 0.87), 30-day mortality (OR, 0.86), and 30-day readmission rates (OR, 0.96). There were highly statistically significant differences in risk-adjusted lengths of stay, ICU days, and Medicare charges and payments between the 2 groups, although the absolute differences were fairly minor (Table 4).

Among stays with only ID involvement, early ID involvement was associated with improved outcomes. Stays with early ID involvement had significantly lower 30-day mortality (OR, 0.87) as well as readmission rates (OR, 0.92). In addition, stays with early ID involvement had 3.8% shorter overall index stays, 5.1% shorter ICU stays, 2.9% lower ACH charges for the index stay, 3.3% lower Medicare payments to the ACH for the index stay, 3.4% lower Medicare payments to all providers for the index stay, and 6.2% lower Medicare payments to all providers for the 30 days post index stay discharge (Table 5).

As a sensitivity test on the early versus late ID results, we required the claim for the index stay to include the present-on-admission indicator for at least 1 of the infections of interest. We applied this restriction to remove the potential confounder

Table 4. Unadjusted and Risk-Adjusted Outcomes for Stays With and Without Infectious Diseases Interventions

	Unadjusted Outcomes			Risk-Adjusted Outcomes			
Outcome	No ID	ID	OR/%Δ (95% CI)	No ID	ID	*P* Value	OR/%Δ (95% CI)
Index stay length of stay	7.3	11.5	+56.1% (+54.9% to +57.3%)	9.5	9.6	.001	1.3% (+.5% to +2.1%)
Index stay ICU days[a]	5.2	7.9	+54.2% (+51.4% to +57.1%)	6.7	6.4	<.001	−3.7% (−5.5% to −1.9%)
Index stay mortality (%)	10.1	9.7	0.95 (.93 to .98)	10.7	9.8	<.001	0.87 (.83 to .91)
30-day mortality (%)[b]	8.0	8.1	1.02 (.99 to 1.05)	8.7	7.7	<.001	0.86 (.82 to .90)
30-day readmission rate (%)[b]	20.8	23.4	1.17 (1.15 to 1.19)	22.7	22.1	.009	0.96 (.93 to .99)
ACH charges for index stay	$46 974	$86 117	+83.3% (+81.3% to +85.4%)	$65 570	$66 811	<.001	+1.9% (+.9% to +2.8%)
Medicare payments to ACH for index stay	$12 699	$18 802	+48.1% (+46.5% to +50.0%)	$15 850	$15 799	.435	−0.3% (−1.1% to +.5%)
Medicare payments for index stay	$14 188	$21 837	+53.9% (+52.4% to +55.4%)	$18 017	$18 076	.397	+0.3% (−.4% to +1.1%)
Medicare payments for 30-day episode[b]	$6460	$8512	+31.8% (+29.8% to +33.7%)	$7706	$7858	.069	+2.0% (−.2% to +4.1%)

Abbreviations: ACH, acute care hospital; CI, confidence interval; ICU, intensive care unit; ID, infectious diseases; OR, odds ratio; %Δ, percent difference.

[a] Only patients with 1 or more ICU days.

[b] Excludes patients expiring in the hospital.

Table 5. Risk-Adjusted Outcomes for Stays Receiving Early Versus Late Infectious Diseases Interventions

Outcome	Early ID (within 2 d)	Late ID	*P* Value	OR/%Δ (95% CI)
Index stay length of stay	13.2	13.8	<.001	−3.8% (−4.8% to −2.9%)
Index stay ICU days[a]	7.6	8.1	<.001	−5.1% (−7.7% to −2.4%)
Index stay mortality (%)	7.1	7.5	.122	0.94 (.88 to 1.02)
30-day mortality (%)[b]	8.6	9.6	<.001	0.87 (.82 to .93)
30-day readmission rate (%)[b]	24.6	26.1	<.001	0.92 (.89 to .96)
ACH charges for index stay	$95 135	$98 015	<.001	−2.9% (−4.1% to −1.7%)
Medicare payments to ACH for index stay	$18 111	$18 728	<.001	−3.3% (−4.3% to −2.3%)
Medicare payments for index stay	$21 453	$22 207	<.001	−3.4% (−4.3% to −2.5%)
Medicare payments for 30-day episode[b]	$8739	$9318	<.001	−6.2% (−8.8% to −3.5%)

Abbreviations: ACH, acute care hospital; CI, confidence interval; ICU, intensive care unit; ID, infectious diseases; OR, odds ratio; %Δ, percent difference.

[a] Only patients with 1 or more ICU days.

[b] Excludes patients expiring in the hospital.

of late ID involvement occurring due to development of an infection during the stay. Results of this sensitivity test showed similar results as the overall early versus late ID analysis (not shown).

DISCUSSION

Given an increasingly medically complex aging population and growth in medical knowledge, primary care physicians often call upon specialists to assist in patient care. It is common to ask a cardiologist to help in the care of acute myocardial infarction, a nephrologist in the care of acute kidney injury, or an ID specialist in the care of acute bacterial meningitis. Despite the intuitive sense that the appropriate standard of care is to ask the assistance of these physicians, evidence from large databases proving the value of specialist interventions is lacking. Possible reasons for this gap in evidence include the significant cost of such studies and challenging study design. As a consequence, there are few studies of claims data that examine specialist intervention and fewer with robust data suggesting a positive effect from specialist involvement. One recent analysis of Medicare claims data showed a 10% lower risk of 30-day mortality and 12% lower risk of rehospitalization for infection and aspiration pneumonia among stroke patients seen by a neurologist [13].

In the current study, unadjusted Medicare data suggest that ID specialists routinely care for a very complex patient population. Notably, on an unadjusted basis, ID intervention was associated with lower index stay mortality. After risk adjustment, ID care of patients with ID diagnoses was associated with better outcomes and lower cost of care. These benefits were greatest when ID specialist involvement started within the first 2 days of hospital admission. Taken as a whole, these data suggest that appropriate inpatient specialty care may generate value for the healthcare system. This impact is seen in both quality and cost of care across a broad range of ID diagnoses. To our knowledge, this is the first time specialty involvement has been demonstrated to have such a strong influence using an administrative claims data source, where even small absolute differences can illuminate highly statistically significant effects. The overall positive impact of early compared with later involvement may reflect decreased morbidity and resource use associated with earlier diagnosis and appropriate treatment, as has been illustrated in the treatment of many infectious diseases [3–7].

Prior studies on the impact of ID specialists have shown mixed results, in part, due to reliance on chart review methodology. The positive impact of ID specialty intervention has been most conclusively shown for SAB. A retrospective cohort study of 9 closely matched pairs showed that the excess cost per life saved was $18 000 and those with ID intervention were significantly more likely to receive longer courses of antibiotics [14]. Implementation of routine mandatory ID consultation for SAB increased use of echocardiography ($P < .04$), detection of endocarditis and metastatic infection ($P < .04$), and adherence to standards of care ($P < .01$) [4]. A 2-year prospective study of 341 patients with SAB showed a 56% reduction in 28-day mortality with ID consultation ($P = .022$) [15]. A 6-year cohort study in a large hospital showed that ID specialty intervention decreased mortality (OR, 0.6; CI, .4–1.0) in SAB [16]. A recent retrospective analysis of 599 SAB cases showed that ID consultation was associated with lower 7-day, 30-day, and 1-year mortality ($P < .001$); multivariate analysis showed that effective initial therapy was the only variable associated with the protective effect of ID consultation [17]. The common theme of these single-institution studies is that all focus on a single diagnosis that has considerable morbidity and mortality. In contrast, our study attempts to create an evidence base that is more generally applicable by use of a large national dataset of Medicare patients with several types of common, severe infections.

Several limitations of this study deserve comment. First, limited clinical information can be derived from administrative claims databases such as Medicare RIFs. With these limitations, it is challenging to control for clinical differences between patients and to detect referring physician adherence to ID recommendations. Unobserved reasons for the presence or absence of an ID intervention during the hospital stay, such as receipt of palliative care, may remain. A comparison of the average LOS of patients who died during their index stay did show a significant difference between the matched ID and non-ID cohorts (11.9 days versus 10.5 days, respectively). Conversely, variation in coding (eg, leukocytosis coded as the primary diagnosis in a case of sepsis) may preclude detection of a severe illness that prompts ID intervention. The identification of an ID specialist in our study is based on Medicare administrative claims physician specialty codes. Many physicians list multiple specialties at enrollment, and a physician acting as an ID specialist may be reported as a different specialty. In addition, a higher percentage of ID interventions than non-ID interventions occurred in academic medical centers. Unobserved characteristics about the healthcare setting in which the ID specialist operates, including the availability of key information or medical technology and care management programs, and variability in medical practice of ID or non-ID physicians could impact outcomes [12].

The PSM methodology excludes from our analysis a portion of the sickest people in the ID intervention group because there were no available matches in the non-ID intervention group. Since PSM is intended to compare "like" patients, patients who are too dissimilar are not included. Our results may therefore underestimate the impact of ID interventions on some of the most acutely ill patients. Notwithstanding, even small improvements in mortality and costs can have a significant impact on the aggregate and over time when extended to the entire Medicare population.

The secondary analysis of early versus late ID involvement also has limitations. Cases were restricted to those above the DRG-specific GMLOS to exclude less complex cases. However, there may be cases where patients acquired an infection late in their stay, which may make patients who had early ID intervention appear to have better outcomes. Conversely, some cases with late ID intervention may have acquired their infections late in the stay, offering less opportunity for positive ID specialist impact. Fully controlling for the complexity of an infection is beyond the capabilities of a claims-based analysis.

It must be noted as well that this study addresses a select group of infections, chosen for their frequent incidence and clinical significance, which still represent only a subset of ID care. Additionally, measuring all-cause mortality, instead of the mortality specifically related to targeted infectious diseases, may overstate the impact of ID involvement on mortality. Additional investigation is needed to address these questions.

To put these data in perspective, ours is a rapidly evolving healthcare environment in which patient outcomes increasingly influence payment and physicians must demonstrate the value of their services [18]. Recent reform elements, including bundled payments and accountable care organizations, encourage management strategies with the best possible outcomes for the lowest possible cost. This study suggests an association between ID involvement and improved patient outcomes during and subsequent to an inpatient hospital stay. Furthermore, the data suggest an even greater "bending of the cost curve" when an ID intervention is received early, with both improved outcomes and reduced costs of care for Medicare recipients with selected common, severe infections. The association of ID involvement with reduced readmission rates suggests an important role for ID specialists in transitions of care from the ACH to the outpatient setting, which has been identified as a critical opportunity for improvement in the healthcare system. Further study is warranted to measure the effect of ID specialty involvement in systems-level measures and targeted infectious processes, including those managed predominately in an outpatient setting, to provide more insight into the ID specialist's role in outcomes improvement and cost reduction and to elucidate opportunities for further improvement in care and prevention of all infections. Data of this kind, applied to other specialties and clinical syndromes, may help guide resource allocation and provide a more complete view of the relative value of the "moving parts" of patient care and healthcare systems.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online (http://cid.oxfordjournals.org). Supplementary materials consist of data provided by the author that are published to benefit the reader. The posted materials are not copyedited. The contents of all supplementary data are the sole responsibility of the authors. Questions or messages regarding errors should be addressed to the author.

Notes

Acknowledgments. The authors thank Kristopher Norris for the statistical programming and analysis required for this study. The authors are members of the Value of Infectious Disease Specialists Work Group of the Infectious Diseases Society of America (IDSA) or employees of Avalere Health. This study was commissioned by IDSA and represents a research collaboration with Avalere Health.

Financial support. The IDSA supported this work.

Potential conflicts of interest. All authors: No reported conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed

References

1. Petrak RM, Sexton DJ, Butera ML, et al. The value of an infectious diseases specialist. Clin Infect Dis **2003**; 36:1013–17.

2. McQuillen DP, Petrak RM, Wasserman RB, Nahass RG, Scull JA, Martinelli LP. The value of infectious diseases specialists: non-patient care activities. Clin Infect Dis **2008**; 47:1051–63.
3. Borer A, Gilad J, Meydan N, Schlaeffer P, Riesenberg K, Schlaeffer F. Impact of regular attendance by infectious disease specialists on the management of hospitalized adults with community-acquired febrile syndromes. Clin Microbiol Infect **2004**; 10:911–6.
4. Jenkins TC, Price CS, Sabel AL, Mehler PS, Burman WJ. Impact of routine infectious disease services consultation on the evaluation, management and outcomes of *Staphylococcus aureus* bacteremia. Clin Infect Dis **2008**; 46:1000–8.
5. Eron LJ, Passos S. Early discharge of infected patients through appropriate antibiotic use. Arch Intern Med **2001**; 161:61–5.
6. Gomez J, Conde Covero SJ, Hernandez Cardona JL, et al. The influence of the opinion of an infectious disease consultant on the appropriateness of antibiotic treatment in a general hospital. J Antimicrob Chemother **1996**; 38:309–14.
7. Fluckiger U, Zimmerli W, Sax H, Frei R, Widmer AF. Clinical impact of an infectious disease service on the management of bloodstream infection. Eur J Clin Microbiol Infect Dis **2000**; 19:493–500.
8. Fox BC, Imrey PB, Voights MB, Norwood S. Infectious disease consultation and microbiologic surveillance for intensive care unit trauma patients: a pilot study. Clin Infect Dis **2001**; 33:1981–9.
9. Lahey T, Shah R, Gittzus J, Schwartzman J, Kirkland K. Infectious diseases consultation lowers mortality from *Staphylococcus aureus* bacteremia. Medicine **2009**; 88:263.
10. Kaech C, Elzi L, Sendi P, et al. Course and outcome of *Staphylococcus aureus* bacteraemia: a retrospective analysis of 308 episodes in a Swiss tertiary-care centre. Clin Microbiol Infect **2006**; 12:345–52.
11. Classen DC, Burke JP, Wenzel RP. Infectious diseases consultation: Impact on outcomes for hospitalized patients and results of a preliminary study. Clin Infect Dis **1997**; 24:468–70.
12. Smetana GW, Landon BE, Bindman AB, et al. A comparison of outcomes resulting from generalist vs. specialist care for a single discrete medical condition. Arch Intern Med **2007**; 167:10–20.
13. Smith MA, Liou JI, Frytak JR, Finch MD. 30-day survival and rehospitalization for stroke patients according to physician specialty. Cerebrovasc Dis **2006**; 22:21–6.
14. Lundberg J, Nettleman MD, Costigan M, Bentler S, Dawson J, Wenzel RP. *Staphylococcus aureus* bacteremia: the cost-effectiveness of long-term therapy associated with infectious diseases consultation. Clin Perform Qual Health Care **1998**; 6:9–11.
15. Honda H, Krauss MJ, Jones JC, Olsen MA, Warren DK. The value of infectious diseases consultation in *Staphylococcus aureus* bacteremia. Am J Med **2010**; 123:631–7.
16. Rieg S, Peyerl-Hoffman G, de With K, et al. Mortality of *S. aureus* bacteremia and infectious diseases specialist consultation—a study of 521 patients in Germany. J Infection **2009**; 59:232–9.
17. Robinson JO, Pozzi-Langhi S, Phillips M, et al. Formal infectious diseases consultation is associated with decreased mortality in *Staphyloccus aureus* bacteraemia. Eur J Clin Microbiol Infect Dis **2012**; 31:2421–8.
18. Porter ME. What is value in health care? N Engl J Med **2010**; 363:2477–81.