Impact of Infectious Disease Consultation on *S. aureus* Bacteremia Mortality

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Abstract: Objective: This study evaluated the impact of a hospital policy requiring infectious disease (ID) consultation and follow-up from an antimicrobial stewardship (AMS) pharmacist-driven team on *S. aureus* Bacteremia (SAB) patient mortality and improved clinical outcomes. Methods: This retrospective study included adult inpatients with SAB from 1 August 2016 to 30 May 2018 (pre-policy) and June 1 2018 to 29 February 2020 (post-policy). The primary outcome variable was in-hospital mortality, and secondary outcomes were 30-day readmission rate, acute kidney injury (AKI) at discharge, stay length, and adherence to evidence-based treatment. Results: The final sample included 435 patients for analysis. Management by non-ID physicians was associated with an 8.1 increased likelihood of mortality while hospitalized (CI 95%, 3.701–17.569). Overall mortality was reduced from 11% (n = 25) pre-policy to 6% (n = 13) after policy implementation (p = 0.07). Patients with antibiotics managed by non-ID physicians were 3 times more likely to be readmitted within 30 days. Those with a history of being immunocompromised (64% vs. 36%), or cardiovascular disease (56% vs. 44%), and patients whose providers followed guidelines (23% vs. 7%) were more likely to be discharged with AKI. Policy implementation reduced non-consultant cases from 11% to 0%. Conclusion: A policy of mandatory ID consultation with pharmacist-driven AMS review to ensure compliance can improve patient mortality, 30-day readmission rates, and clinical outcomes.

Keywords: infectious diseases consultation; MRSA; bloodstream infection

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1. Introduction

Staphylococcus aureus (*S. aureus*), a leading cause of community- and hospital-acquired bacteremia, is associated with 30% to 62% one-year mortality due to complications or long-term negative impact on immune systems and organ function [1]. *S. aureus* bacteremia (SAB) is capable of seeding to all body sites and causing complications in up to 53% of cases, which may result in severe disease, significant morbidity, or death [2]. Understanding factors that predict a complicated course of SAB (e.g., community versus hospital acquisition, unapparent source of infection, prolonged positive blood culture (48 to 96 h), suggestive skin findings, and persistent fever for 72 h) can help guide treatment [3].

Best practices for treatment of SAB include identification, elimination, debridement of the primary source and other sites of infection, and removal of infected devices [4–6]. Vancomycin monitoring is necessary for dose optimization and preventing kidney injury, in vitro susceptibility confirmation and documentation must be performed for narrowing antibiotics, and prescribing β-lactam antibiotics for methicillin sensitive *S. aureus* infections in the absence of allergy is strongly advised in addition to follow-up blood cultures for documentation of infection clearance [5] Given the complicated nature of SAB management, infectious disease (ID) specialist involvement can improve the likelihood of patient survival [6].

Institutions where consultation with ID specialists are mandated for patients with SAB show improved adherence to Infectious Disease Society of America (IDSA) guidelines [7–10]. Using evidence-based care practices and ID consultation have been associated with a 57% decrease in mortality over a nine-year period of mandatory consultation patients with SAB [11]. Despite research demonstrating that ID consultation improves all-cause mortality for patients with SAB, US hospitals have not universally adopted mandatory consults. It has been estimated that management of SAB by ID specialists is as low as 27% to 51% [12]. Despite these disparities, studies have been limited to the impact of ID consultation on multiple organisms, were in countries with universal healthcare, or had populations that were not comparable to the general population [8–11,13]. Others have studied mandatory consultations but focused on MRSA bacteremia in a setting where ID physicians are automatically notified of positive results [12].

The extent to which SAB-patient mortality is associated with mandated consultation of ID physicians in the United States for treatment of SAB is unknown. The purpose of this study was to evaluate the impact of a hospital policy requiring ID consultation with chart review during treatment initiation and verbal follow-up from an AMS team on SAB-patient mortality. Secondary outcomes included 30-day readmission, decreased persistence of acute kidney injury (AKI), and adherence to IDSA guidelines.

2. Materials and Methods

The hospital system in this study was a 400-bed, urban tertiary care teaching hospital with cardiac surgery available, served by a single infectious disease consultant group. It not a safety net hospital.

Inclusion Criteria

Patients 18 years or older who had at least one positive blood culture for *S. aureus* during admission to any of our hospitals from 1 August 2016 through 30 May 2018 were included in this retrospective chart review. Providers of SAB patients admitted from 1 August 2016 through 30 May 2018 were not required to consult an ID physician; these patients were the pre-policy implementation group. Providers of SAB patients admitted from 1 June 2018 through 29 February 2020 were required to consult ID physicians and were prompted by the AMS team if contact was not initiated upon EMR review; these patients were the post-policy implementation group. Patients were excluded from the

study if they left against medical advice before completing the course of antibiotics, expired before treatment could be initiated by a physician, or refused to begin treatment for the infection. Patients who were admitted and treated again within 30 days of successful discharge were not counted again as separate patients to prevent duplication. A detailed explanation of the arrival at the final study population is found in Figure 1.

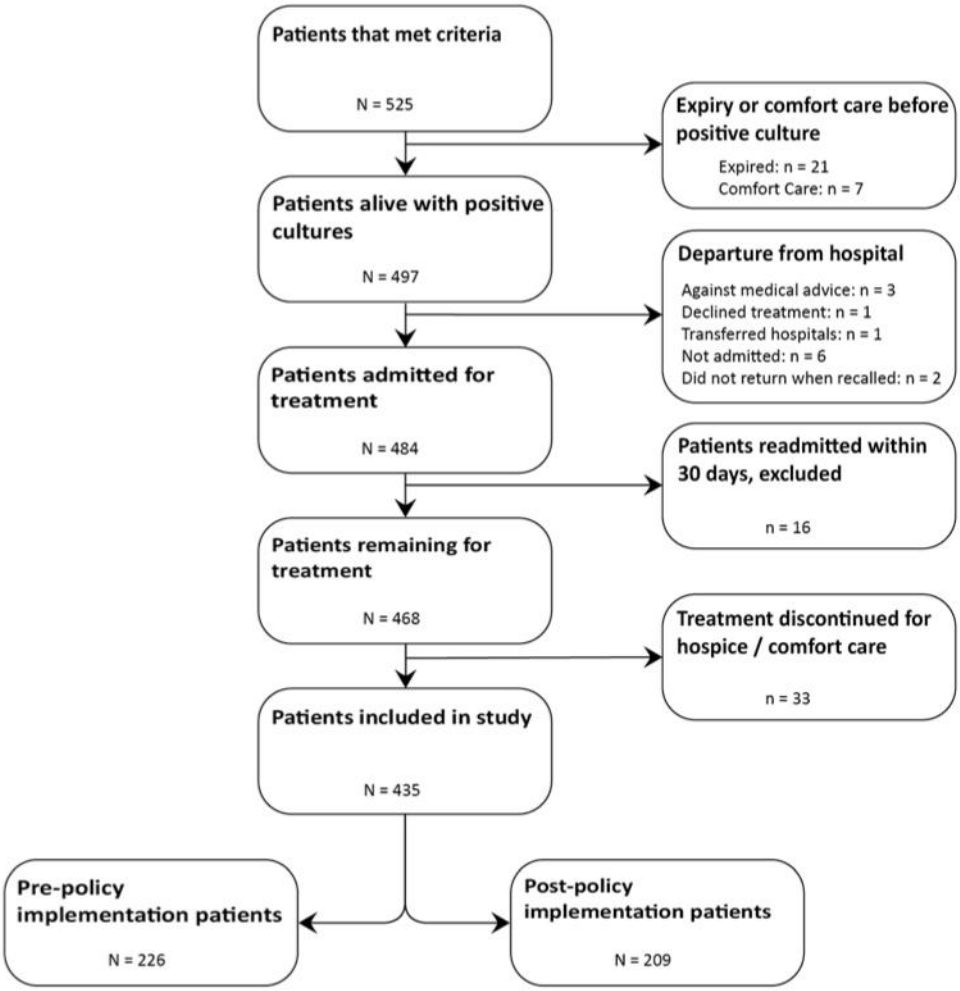

Figure 1: Study Flow Diagram.

Patients medical records were reviewed and accessed by the research team via Cerner EMR, and data were abstracted into Research Electronic Data Capture (REDCap) for data management [13].

The primary outcome variable was in-hospital mortality, and the secondary outcomes were the proportion of SAB patients readmitted within 30 days of discharge, acute kidney injury (AKI) at discharge, length of hospital stay, and adherence to evidence-based guidelines on antibiotic treatment. Abstracted data included demographics (e.g., age); comorbidities (e.g., cardiovascular history); microbiological data (e.g., antibiotic sensitivities); antibiotic prescribed; providers involved (e.g., ID physician, other); testing and consultation ordered (e.g., echocardiogram, consultation date); if the consultation occurred spontaneously, was AMS-prompted, or did not occur; and clinical outcomes. Being immunocompromised can promote metastatic seeding and complicate treatment of disease. For this study, patients were considered immunocompromised if they met any of the following

criteria: diabetes of any kind, cancer, autoimmune disease, on immunosuppressive medications, or a history of splenectomy. As identification of the source of infection is important to treatment, if the admitting physician noted inflammation or suspected infection around a port-a-catheter or other indwelling device, this was considered identification of a skin wound, lesion, or infected surgical site. Uncomplicated SAB was assigned as a diagnosis to patients with positive blood cultures who did not have endocarditis or implanted devices, demonstrated negative cultures in 48–96 h, and showed no evidence of metastatic of sites of infection. Complicated SAB was assigned as a diagnosis to patients with positive blood cultures who did not meet criteria for uncomplicated SAB, including those who simply did not promptly clear the infection.

This project was approved by the Institutional Review Board at the University of Kansas Medical Center and the associated hospitals. Inclusion criteria were provided to the microbiology lab which returned a list of eligible patients for data abstraction using the Cerner EMR. Daily reports of patients with positive *S. aureus* blood cultures are collected by Sentri 7 clinical surveillance software which are reported to the ID pharmacist for follow-up by the AMS team as of June 2018. The post implementation group was selected using the same inclusion criteria by the ID pharmacist for the hospital.

Data were obtained from patient electronic medical records in the Cerner EMR on hospital servers and stored in REDCap [13]. After the deidentified data were abstracted, the database was provided to the biostatistician for analysis.

Data were analyzed using SAS version 9.4 (SAS Int. Inc., Carry, NC, USA). Likelihood Chi-square and Fishers exact tests were used for 2*2 and r*c contingency tables to test the association and agreement for the categorical and nominal variables. Further, the Cochran–Mantel–Haenszel test was used to reveal association between categorical/nominal variables after controlling for the strata variables in a multiway table. Mantel–Fleiss criterion were used to assess the validity of the chi-square approximation for the distribution of the Mantel–Haenszel statistic for 2*2 tables. The Hodges–Lehmann method, a robust and nonparametric estimator of a populations location parameter, was used to compare groups. Using this approach for non-symmetric populations, parameters are estimated based on the pseudo-median, which is closely related to the population median was used to compare length of stay.

Generalized linear multivariable logistic regression model was used to test the association between binomial distributed outcomes such as in hospital mortality and day readmitted; all statistical tests at $p \leqslant 0.05$ were considered significant and predictor variables, after adjusting for confounding variables.

To analyze data for adherence to IDSA guidelines, an algorithm (Supplementary Materials Appendix 1) was created that incorporated current standards published by IDSA in consultation with the ID pharmacist due to previously identified practice variation nationwide [5,6]

3. Results

A total of 525 patients initially met inclusion criteria; 33 patients were excluded from the pre-policy implementation group, and 24 were excluded from the post-policy implementation group. The final sample included 435 patients 51% (n = 227) from the pre-policy group and 49% (n = 208) from the post-policy implementation group.

3.1. Patient Characteristics of Pre and Post-Policy Implementation Groups

The ages of patients in the study ranged from 18 to 95 years, with a mean age of 59 years (SD 16.3). Further demographic data are summarized in Table 1.

Table 1: Patient Demographics and Characteristics.

	Total Frequency	Pre-Policy	Post Policy	*p* Value
Patients	435	52% (n = 226)	48% (n = 208)	
Gender				0.267
Male	270	59.7% (n = 135)	64.9% (n = 135)	
Female	164	40.3% (n = 91)	35.1% (n = 73)	
Transgender	1	100% (n = 1)	0% (n = 0)	
History				
Valvular Disease	39	10.2% (n = 23)	7.7% (n = 16)	0.358
Illicit Drug Use	39	10.2% (n = 23)	7.7% (n = 16)	0.358
History of Sepsis, MRSA or MSSA infection	79	21.2% (n = 48)	14.8% (n = 31)	0.083
Endocarditis	9	2.7% (n = 6)	1.4% (n = 3)	0.372
Hospitalization within 30 days	134	34% (n = 77)	27.3% (n = 57)	0.125
Comorbidity				
Cardiovascular Disease	158	34.1% (n = 77)	38.8% (n = 81)	0.310
Immunocompromised State	249	55.3% (n = 125)	59.3% (n = 124)	0.397
On Dialysis	57	13.7% (n = 31)	12.4% (n = 26)	0.693
Discitis or Osteomyelitis	33	7.1% (n = 16)	8.1% (n = 17)	0.678
Triage Information				
Fever	182	43.8% (n = 99)	39.7% (n = 83)	0.387
Altered Mental Status	113	26.1% (n = 59)	25.8% (n = 54)	0.949
Diagnostics				
MRSA Cultured	190	43.8% (n = 99)	43.5% (n = 91)	0.956
MSSA Cultured	247	57.1% (n = 129)	56.5% (n = 118)	0.896
TEE Ordered	313	71.2% (n = 149)	83.7% (n = 164)	0.002
TTE Ordered	44	28.3% (n = 27)	16.3% (n = 17)	0.003
Consultation				
Total ID Consultation	389	79.7% (n = 180)	100% (n = 209)	0.0001
AMS Prompted Consult	69	0% (n = 0)	33.1% (n = 69)	
Cases Without Consult	46	20.4% (n = 46)	0% (n = 0)	<0.0001

The length of stay for the patients ranged from 1 to 88 days, with a mean of 13 days (SD 11.2). Endocarditis was diagnosed in 17% of patients (n = 73). Pre-policy, 11% (n = 46) of cases failed to receive a consult compared to 0% (n = 0) cases post-policy p = <0.0001. ID physicians were consulted for 74% (n = 320) of cases unprompted and 16% (n = 69) of cases with prompt, with an average of one day to consult after a positive blood culture (SD 4.88). Patients were prescribed antibiotics for an average of four weeks (SD 2). Nine percent of patients (n = 38) expired during their hospital admission, 22% (n = 95) were readmitted within 30 days, and 30% (n = 129) were discharged with unresolved acute kidney injury.

3.2. In-Patient Mortality

Mortality was 11% (n = 25) pre-policy to 6% (n = 13) after policy implementation, p = 0.07. More patients who did not receive an ID consult died (33%, n = 15) compared to patients who received an ID consult (5%, n = 17) and compared to those whose initial provider was prompted (9%, n = 6), p < 0.0001 (Table 2). Patients managed by ID specialists were 87% less likely to die than those managed

by hospitalists (0.13, 95% CI 0.061–0.283), $p < 0.0001$. Antibiotic management by hospitalists had higher mortality (32%, n = 14) than those managed by ID specialists (6%, n = 22), $p < 0.0001$. Fever was associated with a 60% decreased chance of mortality (0.40, 95% CI 0.185–0.871); patients without fever on presentation died more often (76%, n = 29) than those who presented fever (24%, n = 9), $p = 0.02$.

Table 2: Potential Factors Influencing Mortality.

	Deaths	Survivals	*p* Value
ID consulted with or without prompt	6% (n = 23)	94% (n = 369)	<0.0001
30 Day Readmission	6% (n = 22)	94% (n = 359)	<0.0001
Guideline Adherence	10% (n = 31)	90% (n = 268)	0.074
Presenting with Fever	5% (n = 9)	95% (n = 173)	0.017
IV Drug Use	8% (n = 3)	92% (n = 36)	0.809
History of MRSA, MSSA, or Sepsis	6% (n = 5)	94% (n = 74)	0.402
History of Cardiovascular Disease	12% (n = 19)	88% (n = 139)	0.067
History of Immunocompromised Condition	8% (n = 20)	92% (n = 229)	0.548
History of Recent Hospitalization (30 days)	10% (n = 14)	90% (n = 120)	0.399

The mean age of those who died was 65 years (SD 12.2), with a range from 36 to 88 years, whereas the mean age for survivors was 59 years (SD 16.6), with a range from 18 to 95 years. The mean length of stay was 12 days for those who died (n = 38) and 13 days for those who survived (n = 397), $p = 0.04$ Mortality was lower among patients with uncomplicated SAB infections (5%, n = 7) compared to those with complicated SAB (11%, n = 31), $p = 0.03$. A diagnosis of uncomplicated SAB was associated with patients being 60% less likely to die (0.40, 95% CI 0.172–0.934).

3.3. 30-Day Readmission Rate

The mean age of patients who were readmitted within 30 days (n = 95) was 59 years (SD 15.3), not readmitted (n = 340) was 60 years (SD 16.6). The average initial stay for those who were readmitted was longer (16 days; n = 95) than those who were not readmitted (12 days; n = 340), z = 2.25, $p = 0.01$. Patients with a history of endocarditis were 4.7 times more likely (4.67, 95% CI, 1.228–17.737) to be readmitted (5%, n = 5) compared to patients without a history of endocarditis (95%, n = 90), ($p = 0.03$).

3.4. Acute Kidney Injury

Patients who were discharged with AKI (n = 129) had a mean age of 65 years (SD 14.67), whereas those without (n = 309) had a mean age of 58 (SD 16.61). The average length of stay for both groups was 13 days. Patients whose antibiotic management was handled by a non-ID provider (28%, n = 106) had a 57% lower chance of discharge with AKI than if management was handled by an ID physician (72%, n = 275) $p = 0.006$ (Table 3). Of patients who were discharged with AKI, provider adherence to guidelines (23%, n = 98) conferred a 1.7 times greater chance (1.65, 95% CI 1.034, 2.636) of a patient discharging with AKI than non-adherence (7%, n = 31), $p = 0.03$. Those who had cardiovascular disease (56%, n = 72) had a 1.6 times increased risk of AKI compared to those who did not report a history of cardiovascular disease (44%, n = 57) (1.607, 95% CI 1.054, 2.45), $p = 0.03$. Immunocompromised patients were more likely (64%, n = 83) to be discharged with AKI compared to non-immunocompromised patients with AKI (36%, n = 46), $p = 0.05$.

Table 3: Potential Factors Influencing AKI.

	Deaths	Survivals	*p* Value
ID consulted with or without prompt	28% (n = 109)	72% (n = 280)	0.084
Antibiotics managed by ID Physician	28% (n = 106)	72% (n = 275)	0.006
Guideline Adherence	33% (n = 98)	66% (n = 201)	0.035
Heart Valve Disease	36% (n = 14)	64% (n = 25)	0.371
IV Drug Use	23% (n = 9)	77% (n = 30)	0.346
History of Cardiovascular Disease	36% (n = 57)	64% (n = 101)	0.027
History of Immunocompromised Condition	33% (n = 83)	67% (n = 166)	0.050
Currently on Dialysis at presentation	12% (n = 7)	88% (n = 50)	0.002

3.5. Hospital Length of Stay

The average hospital stay was longer for patients whose contact with ID had to be prompted by the AMS team (15 days, n = 69) compared to patients whose providers began contact autonomously (13 days, n = 320) and patients without any ID contact (9 days, n = 46), $p = 0.004$. Patients who had ID consultation initiated autonomously (n = 320) were more likely to have a shorter hospital stay than those whose consult had to be prompted (n = 69) but a longer stay than those who received no consult at all (n = 46), $p = 0.003$. Those who had fever at intake had a shorter hospital stay (11 days, n = 182) than those who did not show a fever initially (14 days, n = 253), $z = -3.3411$, $p = 0.001$. The average length of stay for patients whose antibiotics were managed by non-hospitalist, non-ID physicians were the longest (17 days, n = 9); ID physician-managed patients had intermediate stay length (14 days, n = 381) and hospitalist-managed patients had the shortest stay length (9 days, n = 44), $z = -2.92$, $p = 0.003$.

3.6. Adherence to Guidelines

Patients were 1.6 times more likely (CI 95%, 1.09–2.49) to receive care adherent to IDSA guidelines after the policy was implemented (51%, n = 156) compared patients who received care prior to policy implementation (48%, n = 145), $p = 0.02$. During pre-policy implementation, 11% of cases (n = 46) did not have a consult with ID physician on SAB, whereas 0% of cases (n = 0) did not have an ID consult post-policy implementation, $p < 0.0001$.

3.7. Multivariate Analysis

The greatest impact on patient mortality was management by non-ID physicians; these patients had an 8.1 increased chance of mortality during the hospital stay compared to those managed by ID consultants (CI 95%, 3.701–17.569) (Table 4). Patients who did not have a history of cardiovascular disease had a 0.56 decreased chance of mortality compared to those with existing cardiovascular disease (CI 95%, 0.214–0.900). No other variables were associated with predicting mortality in this study, including history of an immunocompromised condition, recent hospitalization, infected wound, adherence to guidelines, or time to consult from positive blood culture.

Table 4: Logistic regression predicting patient mortality.

Predictor		Wald X^2	*p*	Odds Ratio
Antibiotics managed by ID Physician	2.087	25.597	0.084	8.064
History of Cardiovascular Disease	−0.822	5.058	0.025	0.439
ID Consultation	−0.569	1.062	0.006	0.566
History of Immunocompromised Condition	0.335	0.635	0.035	1.398
Recent Hospitalization (30 Days)	−0.242	0.270	0.371	0.785
IDSA Guideline Adherence	−0.512	0.954	0.346	0.599
Age	0.030	4.541	0.027	1.030
Time to Consultation	0.032	1.255	0.050	1.032

A history of cardiovascular disease was associated with a 52% chance that a patient would be readmitted within 30 days (CI 95%, 0.331–0.813). Antibiotic management by a non-ID physician was associated with 3.12 increased chance for readmission within 30 days compared to ID physician antibiotic management (CI 95%, 1.577–6.154). Non-adherence to guidelines increased the chance a patient would return within 30 days by 2.13 times (CI 95%, 1.276–3.555). A patient who was not on dialysis had a 23% chance of readmission within 30 days (CI 95%, 0.097–0.520). No other variables were associated with 30-day readmission rates.

Regarding AKI, patients who were not on dialysis were 3.520 times more likely than patients on dialysis to discharge with AKI (95% CI, 1.515–8.176) (Table 5). Patients who reported not having a history of immunocompromised conditions were 50% less likely to have AKI than those who reported a history of an immunocompromised condition (95% CI, 0.307–0.828). Finally, patients who were not managed by infectious disease physicians were 55% less likely to be discharged with AKI than those managed by infectious disease physicians (95% CI, 0.218–0.927).

Table 5: Logistic regression predicting AKI at discharge.

Predictor		Wald X^2	*p*	Odds Ratio
No History of Immunocompromised Condition	−0.685	7.321	0.007	0.504
History of Cardiovascular Disease	0.357	2.019	0.155	1.428
Antibiotics Managed by ID Physician	−0.799	4.690	0.030	0.450
Not Currently on Dialysis at Admission	1.258	8.564	0.003	3.520
Vancomycin Troughs Not Monitored	−0.177	0.332	0.564	0.838
No Use of Vancomycin	0.314	1.337	0.248	1.369
No Use of Nafcillin	0.239	0.421	0.571	1.270

4. Discussion

This study evaluated the effect of implementing a hospital-wide policy that mandated ID consultation for all SAB infections and the use of an AMS team of pharmacists to ensure compliance. Involving AMS pharmacists ensured patients received care in adherence to guidelines for SAB. The impact that mandatory consultation had on clinical outcomes highlights the importance of multi-department teamwork amongst a hospitals microbiology laboratory, hospitalists, pharmacists, and ID clinicians. Benefits demonstrated in this study underscore the need for continued investment by leadership committees in AMS programs that have a physical presence in the hospital through the employ of ID specialist physicians and pharmacists, necessary data collection software, and staff dedicated to patient safety.

Patients who received an ID consult were less likely to die than patients who did not receive a consult. The study intervention appeared to identify patients who would likely have benefited from an ID consult. Other research has suggested that improved clinical outcomes for SAB infection are associated with ID consultation; this has led to hospitals mandating consultation or developing automatic systems that notify the ID team [10]. The results of this study suggest there is additional mortality benefit to the involvement of the AMS pharmacy review teams for SAB at an institution with mandatory ID consultation. Our results are consistent with a study that evaluated the effect adding ID consultation to a comprehensive AMS program already in place which found a significant mortality benefit for the infectious disease consultation group (IDC group) vs. the non-IDC group (5% vs. 23%) [14].

We observed a significant mortality benefit of 87% associated with ID physician management compared to non-ID physicians. These results are similar to the 57% decrease in mortality attributed to evidence-based practices from the large Veterans Health Administration study performed across 124 hospitals [11]. ID physicians are likely to optimize antibiotics, facilitate diagnostic studies for pathogen detection, and identify infection source for better control [15–17].

The current study indicated that incorrect antibiotic prescription was associated with an increased likelihood of 30-day readmission for patients. This is consistent with previous studies that suggest that AMS review decreases the time to appropriate antibiotic selection, as a decrease in median time to initiation of appropriate antibiotic therapy using an AMS program was associated with a reduction in 30-day readmission [18,19]. Our results are also consistent with a study that evaluated the effects of ID consultation on SAB management at seven hospitals at three time points, adding consult and AMS separately, which also found that adherence to guidelines improved when ID consultation was implemented at their institution (54% to 65% bundle adherence), and further increased with the addition of AMS review (to 76% adherence) [20]. Accordingly, it is possible that multi-disciplinary teams of AMS pharmacists, ID physicians, and physicians managing the patient achieve additional benefit for patients with SAB.

Further corroborating previous studies, the current study also identified that patients with a history of being immunocompromised had a higher likelihood of discharging with AKI. It has previously been suggested that AKI is associated with serum complement C3 and C4, as well as anti-neutrophil cytoplasmic antibodies or T-cell mediated injury, similar to pauci-immune glomerulonephritis [21–23]. Previous studies have identified that ID consultation appeared protective against a patient developing AKI at day seven of infective endocarditis [24]. The current study indicated that ID consultation increased the risk of discharge with AKI, which may be related to increased guideline adherence. IDSA guideline antibiotic recommendations for SAB have nephrotoxic properties and the pharmacy, which doses vancomycin at the hospital, maintained higher trough levels after policy implementation.

Previous studies of mandated ID consultation with AMS pharmacist intervention achieved varied success with their post-intervention group regarding institution of a care package lead by clinical pharmacists and ID physicians. Another study had similar results regarding post-implementation of intervention by an ID pharmacist who made recommendations for antibiotics and ID physician involvement with 100% consultation after policy implementation, but other studies reported the occurrence of consultation after policy implementation to be between 60% and 93.4%; these results are more comparable to our pre-implementation statistics, where ID consultation was 70% [25].

A longer average hospital stay was associated with ID consultation compared to non-ID physicians. However, ID physicians managed more complicated bacteremia, metastatic sites of infection, polymicrobial infections, or were consulted before bacteremia developed, which required longer hospitalization to obtain source control. Notably, other studies observed conflicting results for length of stay for patients managed by ID physicians for the same reasons, with some studies indicating increases in complicated patients and others having one to two day decreases in duration [20,26].

The limitations of this study include the retrospective design and reliance on manual chart review by multiple researchers. Documentation in the EMR relies on interpretation of notes

written by physicians, advanced practice providers, scribes, or technicians with varying style. This study is geographically limited to one city in the midwestern US and one hospital system, which could artificially select a patient population by preferences, habits, or insurer-preferred hospitals. Additionally, the city serves as a regional location for transfer of care for patients who need specialist care, and it has multiple hospital systems, so some readmitted patients may not have been captured by the study if they presented to a different hospital system.

Prior to policy implementation, many providers were accustomed to consulting with ID physicians for SAB which may be due to the ID pharmacists presence in the hospital or familiarity between providers with the consult service. The ID pharmacist routinely provided recommendations prior to policy implementation as well, so many providers were accustomed to beginning the process, which may have confounded results of our study.

This study could be replicated in a large community hospital setting with teaching services and largely hospitalist-led groups, as policy implementation continued to improve outcomes despite the pre-implementation groups relatively high likelihood to consult ID. A mandatory policy for ID consultation with several teaching services could benefit clinical outcomes even as students begin to learn standard of care for SAB patients.

5. Conclusions

In conclusion, this study suggests that a policy of mandatory ID consultation with pharmacist-driven AMS review to ensure compliance is effective in improving patient mortality, 30-day readmission rates, and receiving evidence-based care. This study was unique in that it demonstrated the added benefit of an AMS pharmacist team to ensure compliance, in addition to the mandated ID consultation for optimizing SAB treatment and source control in the United States.

Supplementary Materials: The following supporting information can be downloaded at: https://journals.jams.pub/conversion/supplementary/c32673a1f35fd95ba975547cc55c1b26, Appendix 1: Algorithm operationalizing IDSA standards.

Author Contributions: Conceptualization, M.A. and L.B.; methodology, T.K.; software, H.O.; validation, M.A. and L.B.; formal analysis, H.O.; investigation, T.K.; resources, L.B.; data curation, T.K.; writing—original draft preparation, T.K.; writing—review and editing, E.A. and M.A.; visualization, T.K.; supervision, M.A.; and project administration, M.A. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Boards of the study hospital and University of Kansas School of Medicine-Wichita (protocol code KU-VC 1787 and 16 April 2020).

Informed Consent Statement: Patient consent was waived due to the use of PHI involving no more than minimal risk to the privacy of individuals with adequate plans to protect and destroy identifiers at the earliest opportunity. In a retrospective chart review, obtaining consent from discharged patients or next of kin would significantly impact the study size and lead to unmeaningful results.

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Conflicts of Interest: The authors declare no conflict of interest.

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