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MAJOR ARTICLE

A Fully Integrated Infectious Diseases and Antimicrobial Stewardship Telehealth Service Improves *Staphylococcus aureus* Bacteremia Bundle Adherence and Outcomes in 16 Small Community Hospitals

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Background. Infectious diseases (ID) and antimicrobial stewardship (AS) improve *Staphylococcus aureus* bacteremia (SAB) outcomes. However, many small community hospitals (SCHs) lack on-site access to these services, and it is not known if ID telehealth (IDt) offers the same benefit for SAB. We evaluated the impact of an integrated IDt service on SAB outcomes in 16 SCHs.

Methods. An IDt service offering IDt physician consultation plus IDt pharmacist surveillance was implemented in October 2016. Patients treated for SAB in 16 SCHs between January 2009 and August 2019 were identified for review. We compared SAB bundle adherence and outcomes between patients with and without an IDt consult (IDt group and control group, respectively).

Results. A total of 423 patients met inclusion criteria: 157 in the IDt group and 266 in the control group. Baseline characteristics were similar between groups. Among patients completing their admission at an SCH, IDt consultation increased SAB bundle adherence (79% vs 23%; odds ratio [OR], 16.9; 95% CI, 9.2–31.0). Thirty-day mortality and 90-day SAB recurrence favored the IDt group, but the differences were not statistically significant (5% vs 9%; $P = .2$; and 2% vs 6%; $P = .09$; respectively). IDt consultation significantly decreased 30-day SAB-related readmissions (9% vs 17%; $P = .045$) and increased length of stay (median [IQR], 5 [5–8] days vs 5 [3–7] days; $P = .04$). In a subgroup of SAB patients with a controllable source, IDt appeared to have a mortality benefit (2% vs 9%; OR, 0.12; 95% CI, 0.01–0.98).

Conclusions. An integrated ID/AS telehealth service improved SAB management and outcomes at 16 SCHs. These findings provide important insights for other IDt programs.

Keywords. *Staphylococcus aureus* bacteremia; antimicrobial stewardship; rural medicine; small community hospital; telehealth.

Infectious diseases (ID) consultation improves outcomes for patients with *Staphylococcus aureus* bacteremia (SAB), including mortality, readmissions, and adherence to best-practice care bundles [1–9]. These benefits have primarily been demonstrated with in-person ID consultation, yet many small community hospitals (SCHs) <200 beds lack access to on-site ID physicians [10]. These facilities may also lack access to ID-trained pharmacists for antimicrobial stewardship (AS) surveillance of positive blood cultures, which is key for early identification, intervention, and referral of SAB patients for ID consultation. Indeed, studies have increasingly described the complementary role of AS surveillance and ID consultation in optimizing SAB management and outcomes [11–18].

Telehealth can improve access to both ID consultation and AS services, but best practices for remote SAB management have not been defined. Two retrospective SAB studies found that telephone-only consultation led to higher mortality than in-person consultation [19, 20], whereas 1 study found that live audio-visual telemedicine consultation (when paired with an AS care bundle) resulted in similar outcomes [11]. One randomized trial found that ID telephone consultation improved quality of care but had no impact on mortality [21]. Further studies are needed to define the impact of different telehealth modalities (eg, asynchronous electronic consults [eConsults] vs synchronous 2-way audiovisual [telemedicine] visits) on

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SAB outcomes and to describe ID telehealth (IDt) and Tele-AS interventions for SAB in resource-limited settings. Herein, we describe the impact of an IDt consultation service with integrated Tele-AS surveillance on SAB management and outcomes at 16 SCHs in the Intermountain Healthcare system.

METHODS

Setting, Patients, and Study Design

This multicenter, retrospective, quasi-experimental study was approved by the Intermountain Healthcare Institutional Review Board. Intermountain Healthcare is an integrated regional health care system consisting of 24 hospitals, >200 clinics, and 75 telehealth services providing care to >1.5 million patients each year in the Intermountain West region (ie, Utah, Idaho, and Nevada; Western Colorado/Wyoming/Montana; Eastern Oregon/Washington; and Northern Arizona/New Mexico). Sixteen Intermountain SCHs (median [range] bed size, 25 [14–146] beds) in Utah and Idaho provide inpatient medical and surgical services to the surrounding communities and generally lack on-site access to subspecialty services. Ten (63%) of these SCHs are rural (6 with Critical Access Hospital designation), and 8 (50%) have intensive care units (ICUs), although critically ill patients are often transferred to a higher-level care facility.

The Intermountain Enterprise Data Warehouse (EDW) was used to identify the first positive *S. aureus* blood culture for patients ≥18 years of age admitted to one of these 16 SCHs between January 2009 and August 2019. Patients were excluded if, within 48 hours of the index blood culture or prior to blood culture identification as methicillin-susceptible vs methicillin-resistant *Staphylococcus aureus* (MSSA vs MRSA), they transferred, died, or were discharged to hospice care. Those with polymicrobial growth on blood cultures were also excluded unless the concomitant organism was judged to be a contaminant (eg, single positive blood culture for coagulase-negative *Staphylococcus* species).

To capture any SAB-related care in the SCH setting, we evaluated patients admitted to an SCH for >48 hours (SCH admission population) (Figure 1). Patients discharged from the hospital or emergency department (ED) prior to 48 hours were still included in this population if the blood culture results were acknowledged in the chart, the treatment plan was stated, and the patient was not lost to follow-up. To best describe SCH outcomes for SAB, we then focused on a subgroup of SCH inpatients who completed their entire admission and received definitive SAB management at an SCH, omitting those who transferred, left against medical advice, or were discharged to hospice (SCH management population) (Figure 1).

ID Telehealth Intervention

The SCHs did not have access to ID consultation or AS services from January 2009 through June 2014. A dedicated ID advice line was implemented from July 2014 through September 2016 as part of a cluster randomized AS intervention trial (the SCORE study) [22]. SAB cases during this time period were excluded from the current study because no ID notes were written in the chart when telephone-only advice was given, and we were unable to determine which cases might have received telephonic ID physician input.

A formal integrated IDt program was established in October 2016 to provide IDt consultation and Tele-AS support to all 16 SCHs [23]. IDt services included a 24-hour advice line staffed by an attending ID physician who could choose to offer phone advice only, chart review with electronic medical record (EMR) documentation (eConsult), or synchronous 2-way audio-visual telemedicine consultation (TC) with EMR documentation. TCs and eConsults were offered weekdays from 7:30 AM to 4:30 PM, while telephone-only advice was offered after hours, on weekends, and on holidays (with follow-up eConsult or TC the next business day). EMR note templates were created to differentiate eConsults from TCs, whereas telephone-only advice was not captured for SAB patients. No access to in-person ID consultation was available during the study period. For outpatient follow-up, patients could either be seen by their local primary care provider (who could contact the IDt service for outpatient telephonic advice) or by an IDt physician in person (if the patient lived in close proximity to the central ID clinic).

The IDt pharmacist conducted daily blood culture surveillance on weekdays from 8:00 AM to 4:30 PM and participated in daily rounds with the IDt physician to provide recommendations for SAB patients. Upon discovery of SAB, the IDt pharmacist contacted the SCH care team with recommendations to optimize antibiotics, draw repeat blood cultures, and obtain an IDt consult to facilitate workup for SAB source and complications. IDt consultation was strongly encouraged (not mandatory) for all SAB patients, although the pharmacist did not recommend a consult if the IDt service was already following the patient or if the SCH team planned to withdraw care or transfer the patient to a higher level of care. All recommendations were logged prospectively in Research Electronic Data Capture (REDCap; Vanderbilt University). The IDt physicians and pharmacist also undertook extensive education efforts related to SAB including in-depth staffing of cases with frontline SCH clinicians, interactive tele-mentoring webinars, in-person SAB-focused Grand Rounds at selected SCH sites, and highlighting clinical pearls during local stewardship and medical staff meetings. No formal Intermountain guidelines for SAB management were available during the study period.

Data and Outcomes

Data pertaining to patient demographics, comorbidities, microbiology, imaging, hospital course, antibiotic treatment, and IDt consultation were captured electronically from the EDW, whereas severity of illness, source and complications

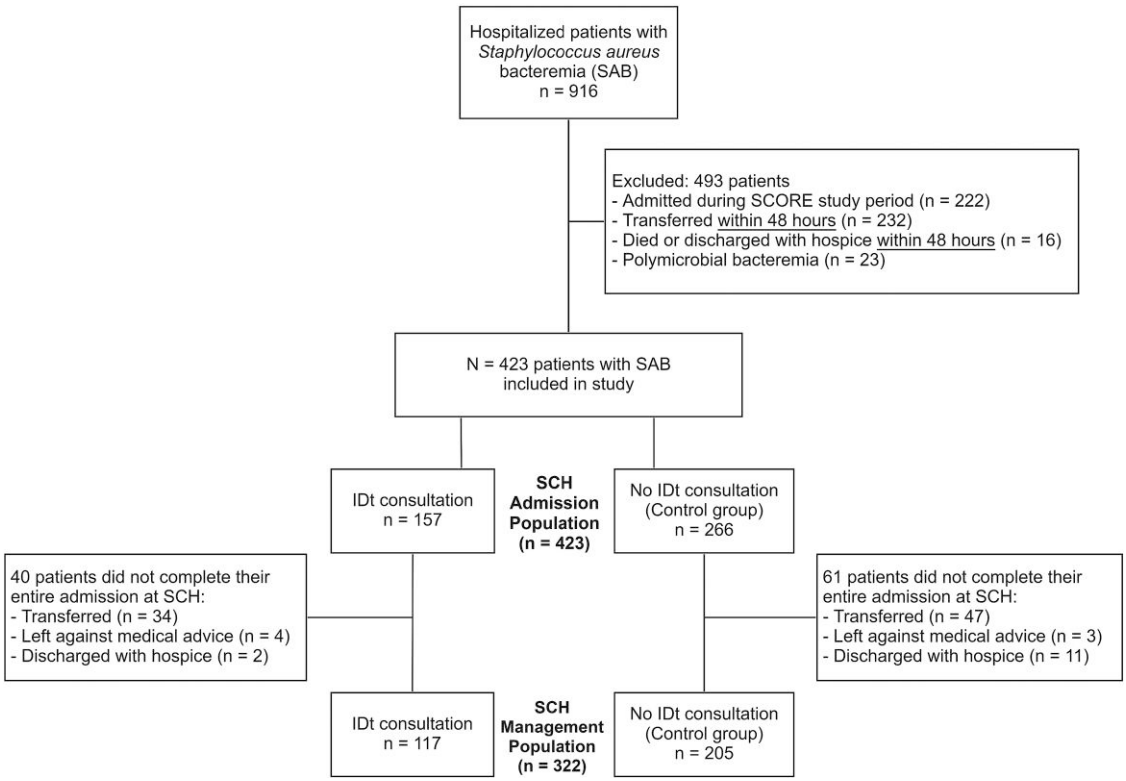

Figure 1. Flowchart of included patients. SCH Admission Population—patients with SAB admitted to 1 of 16 SCHs. SCH Management Population—patients with SAB who completed their entire hospital course and received definitive management at the SCH. Abbreviations: SAB, *Staphylococcus aureus* bacteremia; SCH, small community hospital.

of SAB, source control procedures, readmissions, and follow-up ID clinic visits were captured via manual chart review. Thirty-day mortality was assessed using Utah and Idaho Department of Health Vital Records.

The primary outcome of interest was adherence to best-practice recommendations in an SAB bundle (Table 1) [5].

Table 1. *Staphylococcus aureus* Bacteremia Bundle Components

1. Echocardiogram obtained (either TTE, TEE, or both)
2. Negative repeat blood cultures obtained before SCH discharge to demonstrate SAB clearance
3. Optimal IV antibiotic administered within 72 h of index blood culture[a]
4. Source control procedure (if applicable) performed within 72 h of index blood culture
5. Optimal IV antibiotic prescribed at discharge[b,c]
6. Optimal IV antibiotic duration prescribed at discharge[c,d]

Abbreviation: IV, intravenous; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*; SAB, *Staphylococcus aureus* bacteremia; SCH, small community hospital; TEE, transesophageal; TTE, transthoracic.

[a]Cefazolin or nafcillin for MSSA; or vancomycin, daptomycin, linezolid, or ceftaroline for MRSA.

[b]Ideally cefazolin or nafcillin for MSSA, but credit was given for any IV β-lactam with MSSA activity (eg, ceftriaxone) to allow for dosing convenience and coverage of concomitant organisms if needed; vancomycin, daptomycin, linezolid, or ceftaroline for MRSA.

[c]The final 2 bundle components were only assessed in patients receiving definitive SCH management who survived to discharge.

[d]Two or more weeks for uncomplicated SAB, ≥4 weeks for complicated SAB.

Adherence to bundle components 1–3 (both individually and combined) was evaluated for the full SCH admission and SCH management populations. Source control within 72 hours (bundle element 4) was evaluated only for a subgroup of patients with a controllable source of SAB (ie, source could be drained, removed, or debrided), and appropriateness of discharge antibiotics (bundle elements 5 and 6) was evaluated only for SCH management patients who survived to discharge. Criteria for complicated vs uncomplicated SAB were determined from national guidelines [24, 25], and sources of bacteremia were classified as high, intermediate, or low risk for mortality based on established definitions (mortality rate >20%, 10%–20%, and <10%, respectively) [26].

Secondary outcomes included in-hospital and 30-day mortality, 30-day all-cause and SAB-related readmissions, 90-day SAB recurrence, length of stay (LOS), and transfers. SAB-related readmission was defined as repeat hospitalization due to the same source as the initial infection, metastatic or disseminated complications of SAB, recurrent SAB, or adverse reaction from the antibiotic regimen. LOS was evaluated only among SCH management patients who survived to discharge, and transfers were only evaluated for SCH admission patients. Primary and secondary outcomes were compared in patients with a formal IDt consultation (eConsult or TC with EMR note) and those without an IDt

consultation (control group). Outcomes were also compared in control group patients admitted before vs after IDt program implementation in 2016 to identify potential trends.

Statistical Analysis

Categorical data were compared using Fisher's exact test, and continuous data were compared using the Mann-Whitney *U* test. Multivariate regression analyses were used to determine independent predictors of primary and secondary outcomes using odds ratios with 95% confidence intervals. Covariate adjustors were selected based on previous SAB studies or if the *P* value was ≤.1 on univariate analysis. To avoid overfitting, we limited the number of covariates to those with the strongest associations, and we assessed goodness of fit using likelihood ratio tests. Logistic regression models were used for all outcomes except LOS, which used a linear regression model. *P* values <.05 were considered significant, and all statistical analyses were performed using Stata (version 15.1).

RESULTS

Patients

A total of 916 patients with SAB were identified between January 2009 and August 2019, and 423 met inclusion criteria: 157 in the IDt group and 266 in the control group (Figure 1). Baseline characteristics were similar between the 2 groups, with a few key exceptions. Fewer IDt patients were admitted to the smallest rural hospitals (≤25 beds) compared with control group patients (6% vs 16%; $P = .005$). The incidence of high-, intermediate-, and low-risk source of SAB was similar between groups, but the IDt group had more patients with an endovascular source (17% vs 10%; $P = .049$) and fewer patients with an unknown source (10% vs 18%; $P = .026$) compared with the control group. IDt patients also had a higher prevalence of indwelling hardware (39% vs 29%; $P = .032$) (Table 2).

Table 2. Baseline Characteristics

Characteristics[a]	IDt Group (n = 157)	Control Group (n = 266)	*P* Value
Year of hospital admission	…	…	…
January 2009–December 2014 (pre-IDt)	0 (0)	212 (80)	**<.001**
October 2016–August 2019 (post-IDt)	157 (100)	54 (20)	**<.001**
Age, median (IQR), y	66 (49–75)	64 (51–75)	.667
Male	95 (61)	155 (58)	.683
Charlson Comorbidity Index, median (IQR)	6 (3–10)	6 (3–10)	.810
End-stage renal disease	7 (4)	18 (7)	.398
Substance use disorder	23 (15)	24 (9)	.080
Admitting hospital size and location	…	…	…
≤25 beds (n = 8 hospitals; all rural)	10 (6)	42 (16)	**.005**
26–75 beds (n = 5 hospitals; 1 rural, 4 urban)	44 (28)	113 (42)	**.004**
76–150 beds (n = 3 hospitals; all urban)	103 (66)	111 (42)	**<.001**
Source of bacteremia	…	…	…
High-risk source	48 (31)	77 (29)	.742
Endovascular	27 (17)	27 (10)	**.049**
Central nervous system	11 (7)	15 (6)	.676
Respiratory	10 (6)	33 (12)	.066
Intra-abdominal	0 (0)	2 (1)	.532
Intermediate risk source	97 (62)	167 (63)	.836
Bone and joint	45 (29)	62 (23)	.247
Skin and soft tissue	36 (23)	56 (21)	.715
Unknown	16 (10)	49 (18)	**.026**
Low-risk source	12 (8)	22 (8)	.856
Genitourinary	5 (3)	5 (2)	.510
Intravenous catheter	7 (4)	17 (6)	.395
MRSA bacteremia	37 (24)	55 (21)	.542
Staphylococcus aureus in urine	18 (11)	22 (8)	.304
Presence of hardware	62 (39)	77 (29)	**.032**
Complicated SAB	143 (91)	246 (92)	.712
ICU admission	59 (38)	109 (41)	.538
Vasopressors	13 (8)	10 (4)	.073
Mechanical ventilation	2 (1)	10 (4)	.224

Statistically significant *P*-values are listed with bolded text.

Abbreviations: ICU, intensive care unit; IDt, infectious diseases telehealth; IQR, interquartile range; MRSA, methicillin-resistant *Staphylococcus aureus*; SAB, *Staphylococcus aureus* bacteremia.

[a]Values are presented as No. (%) unless otherwise noted.

ID Telehealth Intervention

IDt physicians completed 309 consult notes for the 157 IDt patients (198 TCs and 111 eConsults). The median number of IDt consult notes per patient (range) was 2 (1–5). Eighty-one patients (52%) received TCs only, 30 (19%) received eConsults only, and 46 (29%) received a combination of TCs and eConsults. The percentage of eConsults increased over time (15% in 2016/2017 to 59% in 2019; $P < .001$), while TCs decreased (85% in 2016/2017 to 41% in 2019; $P < .001$). Notably, there were no significant differences in baseline characteristics, SAB bundle adherence, or clinical outcomes among TC-only vs eConsult-only patients, although the small number in each group prevented robust comparisons (eg, 30-day mortality was 6% [5/81] for TC-only vs 7% [2/30] for eConsult-only; $P = 1.000$). Significantly more IDt patients received ID outpatient follow-up visits within 30 and 60 days (28% vs 10%; $P < .001$; and 35% vs 11%; $P < .001$; respectively).

The IDt pharmacist made 168 recommendations for the 157 IDt patients, of which 164 (98%) were accepted. The most common recommendations were for IDt physician consult (42%), stopping unnecessary antibiotics (23%), and renal dose adjustment (15%). Referral by the IDt pharmacist was the primary reason for IDt physician consult in 70 of the 157 IDt patients (45%). Of the 54 control group patients admitted after IDt program implementation in 2016, the pharmacist recommended IDt consult for 32 (59%), none of which were accepted. However, acceptance of pharmacist recommendations for IDt

Table 3. *Staphylococcus aureus* Bacteremia Bundle Adherence and Clinical Outcomes

	SCH Admission Population			SCH Management Population		
	IDt Group (n = 157)	Control Group (n = 266)	*P* Value	IDt Group (n = 117)	Control Group (n = 205)	*P* Value
SAB bundle adherence (primary outcome)[a]	…	…	…	…	…	…
Adherence to bundle elements 1–3	115 (73)	65 (24)	**<.001**	93 (79)	47 (23)	**<.001**
1. Echocardiogram (TTE, TEE, or both)	140 (89)	131 (49)	**<.001**	105 (90)	87 (42)	**<.001**
2. Negative repeat blood cultures obtained	142 (90)	116 (44)	**<.001**	115 (98)	88 (43)	**<.001**
3. Optimal IV antibiotics within 72 h	137 (87)	131 (49)	**<.001**	101 (86)	91 (44)	**<.001**
4. Source control within 72 h[b]	67/96 (70)	83/155 (54)	**.012**	53/65 (82)	67/117 (57)	**.001**
5. Optimal IV antibiotic prescribed at discharge[c]	…	…	…	113/114 (99)	112/198 (57)	**<.001**
6. Optimal duration prescribed at discharge[c]	…	…	…	100/114 (88)	63/198 (32)	**<.001**
Secondary outcomes	…	…	…	…	…	…
In-hospital mortality	5 (3)	9 (3)	1.000	3 (3)	7 (3)	.752
30-d mortality	12 (8)	30 (11)	.244	6 (5)	19 (9)	.202
30-d all-cause readmission	23 (15)	56 (21)	.121	15 (13)	41 (20)	.126
30-d SAB-related readmission	15 (10)	44 (17)	.058	10 (9)	34 (17)	**.045**
90-d SAB recurrence	4 (3)	15 (6)	.154	2 (2)	12 (6)	.094
Length of stay, median (IQR),[d] d	…	…	…	5 (5–8)	5 (3–7)	**.043**
Transfers	34 (22)	47 (18)	.371	…	…	…

Statistically significant P-values are listed with bolded text.

Abbreviation: IV, intravenous; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*; SAB, *Staphylococcus aureus* bacteremia; SCH, small community hospital; TEE, transesophageal; TTE, transthoracic.

[a]Values are presented as No. (%) unless otherwise noted.

[b]Denominators represent only those patients who were eligible for source control in each group.

[c]Denominators represent only SCH management patients who survived to discharge.

[d]Length of stay was calculated only for SCH management patients who survived to discharge.

consult did increase over time (3/8 [38%] in 2016 vs 25/28 [89%] in 2019; $P = .006$).

SAB Bundle Adherence and Outcomes

Adherence to every SAB bundle component and adherence to bundle components 1–3 combined were significantly higher in the IDt group than the control group for both the SCH admission and SCH management populations (Table 3). In the SCH admission population, the most common reason for bundle nonadherence was lack of negative repeat blood cultures, although 37 patients (12 IDt, 25 control group) received clearance blood cultures after transfer to another facility. The most common reason for nonadherence among SCH management patients was the antibiotic duration prescribed at discharge. In the SCH management population, patients admitted to SCHs with ≤25 beds had significantly lower adherence to bundle components 1–3 combined than patients admitted to larger hospitals (4/35 [11%] vs 136/287 [47%], respectively; $P < .001$). However, of the 35 patients admitted to SCHs with ≤25 beds, IDt intervention significantly improved adherence compared with the control group (3/5 [60%] vs 1/30 [3%]; $P = .006$).

Unadjusted in-hospital mortality was similar between groups for both the SCH admission and SCH management populations. Thirty-day mortality, all-cause readmission, and SAB recurrence all favored the IDt group; however, none of these differences were statistically significant. SAB-related readmissions were significantly lower, and length of stay was significantly longer in the IDt group for the SCH management population (Table 3). Outcomes were not significantly different for control group patients admitted before (2009–2014) vs after (2016–2019) IDt program implementation (SAB bundle adherence, 25% vs 22%; $P = .726$); 30-day mortality, 12% vs 7%; $P = .469$; SAB-related readmission, 17% vs 15%; $P = .838$; and SAB recurrence, 6% vs 4%; $P = .743$; respectively). Transfer rates were similar between groups. Of the 34 IDt patients who transferred, 27 transfers (79%) were recommended by the IDt physician for procedures that were unavailable at the SCH, such as TEE or surgical intervention by a subspecialty service (eg, orthopedics or neurosurgery).

In multivariable regression analyses adjusting for age, comorbidities, SCH size, SAB source, and complicated SAB, IDt consultation was an independent predictor of SAB bundle adherence. Odds ratios for mortality and SAB-related readmission favored the IDt group but were not statistically significant (Table 4). These results were robust to sensitivity analyses in which substance use disorder, MRSA, receipt of vasopressors, chronic kidney disease, *Staphylococcus aureus* bacteriuria, and year of admission for the control group were included in the model. IDt consultation was associated with lower 30-day mortality in a subgroup of SCH management patients who had SAB from a controllable source (1/65 [2%] vs 10/117 [9%]; OR, 0.12; 95% CI, 0.01–0.98), although 2 variables

Table 4. Multivariate Analysis Models for Predictors of *Staphylococcus aureus* Bacteremia Bundle Adherence, SAB-Related Readmission, and 30-Day Mortality in the SCH Management Population

	SAB Bundle Adherence[a,b]		SAB-Related Readmission[b]		30-Day Mortality[b]	
Variable	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
IDt group (vs control)	16.9 (9.2–31.0)	**<.001**	0.5 (0.2–1.0)	.057	0.5 (0.2–1.4)	.170
Admission to SCH ≤25 beds	0.2 (0.08–0.7)	**.007**	0.9 (0.3–2.4)	.828	0.7 (0.1–3.8)	.699
Age	1.0 (0.9–1.1)	.431	0.9 (0.9–1.1)	.309	1.2 (0.9–1.5)	.193
Age^2	1.0 (0.9–1.0)	.426	1.0 (0.9–1.0)	.806	1.0 (0.9–1.0)	.482
Charlson comorbidity index >4	1.2 (0.5–2.9)	.653	2.0 (0.8–4.9)	.147	1.2 (0.3–5.4)	.846
Endocarditis	7.3 (2.6–20.6)	**<.001**	1.1 (0.3–4.2)	.939	2.3 (0.4–12.3)	.314
Complicated SAB	0.08 (0.03–0.2)	**<.001**	–[c]	…	1.9 (0.3–13.3)	.537

Statistically significant P-values are listed with bolded text.

Abbreviations: IDt, ID telehealth; OR, odds ratio; MRSA, methicillin-resistant *Staphylococcus aureus*; SAB, *Staphylococcus aureus* bacteremia; SCH, small community hospital.

[a]Adherence to SAB bundle elements 1–3 combined.

[b]Multivariate analysis results were not meaningfully different when adding substance use disorder, MRSA, receipt of vasopressors, chronic kidney disease, and *Staphylococcus aureus* in urine to any of the 3 models. Furthermore, results were not meaningfully different when adding control group year of admission (2009–2014 vs 2016–2019) to any of the 3 models.

[c]Complicated SAB was excluded from this multivariate analysis (SAB-related readmission in the SCH management population) due to perfect prediction but was found to be a predictor of SAB-related readmission in the SCH admission population (OR, 7.7; 95% CI, 1.1–55.3; $P = .044$).

(Charlson Comorbidity Index and complicated SAB) had to be excluded from the model due to perfect prediction. Endocarditis and receipt of vasopressors were predictors of transfer on multivariate analysis, but IDt consultation was not significantly associated with transfers.

DISCUSSION

Patients receiving IDt consultation at 16 SCHs had significantly better SAB bundle adherence and reduced SAB-related readmissions compared with the control group. Mortality and SAB recurrence rates also favored the IDt group, although these differences were not statistically significant. No differences in outcomes were found based on IDt consult type (ie, eConsults vs TCs), and tele-AS surveillance played a key role in antibiotic optimization and referral of SAB patients for IDt consult. These findings provide important insight into the management of SAB in resource-limited settings.

Adherence to best practice recommendations for SAB has been known to improve outcomes for over 2 decades [5], yet bundle adherence to elements 1–3 was <25% in the control group. Even lower adherence (3%–11%) was noted at the smallest rural hospitals, which might have been impacted by difficult access to services such as echocardiography. However, the strikingly low adherence rates suggest that control group patients were often discharged without appropriate workup for SAB source and complications, which likely explains the higher incidence of SAB from "unknown" source, shorter length of stay, and higher SAB-related readmissions. Lack of ID clinic follow-up likely also contributed to higher readmissions in the control group, which has prompted expansion of outpatient video visit capabilities for our service so patients can access ID follow-up regardless of where they reside. The overall rates of 30-day mortality (10%) and 90-day SAB recurrence (4%) were lower in our study than in previous studies [3, 26]. While this prevented a robust comparison to find significant differences, the mortality and recurrence rates in the IDt group were still favorable compared with the control group.

Determining the optimal type of IDt consult is an important clinical and logistical consideration for telehealth programs. While telephone-only consultation is inferior for SAB due to lack of valid information for the consultant and poor adherence to advice [19, 20], it is possible that eConsults and TCs (which both involve detailed chart review and EMR documentation) could be feasible alternatives to bedside consultation in facilities with limited resources, particularly SCHs. We found no difference in outcomes between eConsults and TCs, although the evaluation was limited by small sample size. Our ratio of eConsults-to-TCs increased over time for 2 key reasons: IDt physicians chose eConsults for efficiency as the service got busier [23], and they built strong relationships with many local providers through extensive SAB-related education. This empowered local clinicians to implement best practices for SAB, which allowed IDt physicians to opt for eConsults when feeling comfortable with management after conducting in-depth EMR review and communicating with the local provider. While our findings related to eConsults and TCs for SAB are encouraging, further study is needed to define optimal IDt consultation types for various ID conditions.

The integration of Tele-AS with the IDt service optimized clinical outcomes. Nearly half of IDt consults were referred by the IDt pharmacist, which highlights the importance of blood culture surveillance and early AS intervention when ID consults for SAB are not mandatory. Education efforts were also key to improving local SAB management and emphasizing the value of IDt consultation to frontline clinicians, which was reflected in increased acceptance of IDt pharmacist recommendations for IDt consult over time.

While the optimal telehealth model remains to be defined, we continue to observe the importance and complementary nature of the Tele-AS and IDt components of our program.

There are several noteworthy limitations to our study. First, we did not capture telephone-only advice in either group. This may have especially influenced the management of control group patients and biased the study toward finding no difference in several outcomes between groups. Second, we did not capture concomitant infections, which may have influenced antibiotic prescribing and adherence rates. Third, the EMR-documented discharge plan may have been subject to change (eg, change in antibiotic or duration, or follow-up visits outside our system). Fourth, we did not conduct a cost-savings or cost-effectiveness analysis, which is an important area of future study for IDt programs. Lastly, our IDt interventions occurred within 1 health care system, and the findings may not be applicable to other health care systems or IDt services supporting outreach facilities. While this study also has limitations inherent to a retrospective evaluation, our findings are consistent with Meredith et al. [11] that IDt plus Tele-AS interventions can improve SAB outcomes at SCHs.

CONCLUSIONS

An integrated IDt service with Tele-AS surveillance improved management and outcomes of SAB patients at 16 SCHs within the Intermountain Healthcare system. Our findings support the feasibility and impact of IDt intervention for SAB in resource-limited settings and provide important insights for other IDt programs. Additional study is needed regarding the impact of Tele-AS intervention, IDt consultation, and consult modality on outcomes for SAB and other ID conditions.

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References

1. Vogel M, Schmitz RP, Hagel S, et al. Infectious disease consultation for *Staphylococcus aureus* bacteremia—a systematic review and meta-analysis. J Infect **2016;** 72:19–28.
2. Bai AD, Showler A, Burry L, et al. Impact of infectious disease consultation on quality of care, mortality, and length of stay in *Staphylococcus aureus* bacteremia: results from a large multicenter cohort study. Clin Infect Dis **2015;** 60: 1451–61.
3. Goto M, Jones MP, Schweizer ML, et al. Association of infectious diseases consultation with long-term post-discharge outcomes among patients with *Staphylococcus aureus* bacteremia. JAMA Netw Open **2020;** 3:e1921048.
4. López-Cortés LE, Del Toro MD, Gálvez-Acebal J, et al. Impact of an evidence-based bundle intervention in the quality-of-care management and outcome of *Staphylococcus aureus* bacteremia. Clin Infect Dis **2013;** 57:1225–33.
5. Fowler VG jr, Sanders LL, Sexton DJ, et al. Outcome of *Staphylococcus aureus* bacteremia according to compliance with recommendations of infectious diseases specialists: experience with 244 patients. Clin Infect Dis **1998;** 27: 478–86.
6. Jenkins TC, Price CS, Sabel AL, Mehler PS, Burman WJ. Impact of routine infectious diseases service consultation on the evaluation, management, and outcomes of *Staphylococcus aureus* bacteremia. Clin Infect Dis **2008;** 46:1000–8.
7. Robinson JO, Pozzi-Langhi S, Phillips M, et al. Formal infectious diseases consultation is associated with decreased mortality in *Staphylococcus aureus* bacteraemia. Eur J Clin Microbiol Infect Dis **2012;** 31:2421–8.
8. Lahey T, Shah R, Gittzus J, Schwartzman J, Kirkland K. Infectious diseases consultation lowers mortality from *Staphylococcus aureus* bacteremia. Medicine (Baltimore) **2009;** 88:263–7.
9. Pérez-Rodríguez MT, Sousa A, López-Cortés LE, et al. Moving beyond unsolicited consultation: additional impact of a structured intervention on mortality in *Staphylococcus aureus* bacteraemia. J Antimicrob Chemother **2019;** 74: 1101–7.
10. Stenehjem E, Hyun DY, Septimus E, et al. Antibiotic stewardship in small hospitals: barriers and potential solutions. Clin Infect Dis **2017;** 65:691–6.
11. Meredith J, Onsrud J, Davidson L, et al. Successful use of telemedicine infectious diseases consultation with an antimicrobial stewardship-led *Staphylococcus aureus* bacteremia care bundle. Open Forum Infect Dis **2021;** 8:XXX–XX.
12. Arensman K, Dela-Pena J, Miller JL, et al. Impact of mandatory infectious diseases consultation and real-time antimicrobial stewardship pharmacist intervention on *Staphylococcus aureus* bacteremia bundle adherence. Open Forum Infect Dis **2020;** 7:XXX–XX.
13. Sherbuk JE, McManus D, Topal JE, Malinis M. Improved mortality in *Staphylococcus aureus* bacteremia with the involvement of antimicrobial stewardship team and infectious disease consultation. Infect Control Hosp Epidemiol **2019;** 40:932–5.
14. Borde JP, Batin N, Rieg S, et al. Adherence to an antibiotic stewardship bundle targeting *Staphylococcus aureus* blood stream infections at a 200-bed community hospital. Infection **2014;** 42:713–9.
15. Smith JR, Frens JJ, Snider CB, Claeys KC. Impact of a pharmacist-driven care package on *Staphylococcus aureus* bacteremia management in a large community healthcare network: a propensity score-matched, quasi-experimental study. Diagn Microbiol Infect Dis **2018;** 90:50–4.
16. Buehrle K, Pisano J, Han Z, Pettit NN. Guideline compliance and clinical outcomes among patients with *Staphylococcus aureus* bacteremia with infectious diseases consultation in addition to antimicrobial stewardship-directed review. Am J Infect Control **2017;** 45:713–6.
17. Nguyen CT, Gandhi T, Chenoweth C, et al. Impact of an antimicrobial stewardship-led intervention for *Staphylococcus aureus* bacteraemia: a quasi-experimental study. J Antimicrob Chemother **2015;** 70:3390–6.
18. Remtulla S, Zurek K, Cervera C, Hernandez C, Lee M-C, Hoang HL. Impact of an unsolicited, standardized form-based antimicrobial stewardship intervention to improve guideline adherence in the management of *Staphylococcus aureus* bacteremia. Open Forum Infect Dis **2019;** 6:XXX–XX.
19. Forsblom E, Ruotsalainen E, Ollgren J, Järvinen A. Telephone consultation cannot replace bedside infectious disease consultation in the management of *Staphylococcus aureus* bacteremia. Clin Infect Dis **2013;** 56:527–35.
20. Saunderson RB, Gouliouris T, Nickerson EK, et al. Impact of routine bedside infectious disease consultation on clinical management and outcome of *Staphylococcus aureus* bacteraemia in adults. Clin Microbiol Infect **2015;** 21:779–85.
21. Weis S, Hagel S, Palm J, et al. Effect of automated telephone infectious disease consultations to nonacademic hospitals on 30-day mortality among patients with *Staphylococcus aureus* bacteremia: the SUPPORT cluster randomized clinical trial. JAMA Netw Open **2022;** 5:e2218515.
22. Stenehjem E, Hersh AL, Buckel WR, et al. Impact of implementing antibiotic stewardship programs in 15 small hospitals: a cluster randomized intervention. Clin Infect Dis **2018;** 67:525–32.

23. Vento TJ, Veillette JJ, Gelman SS, et al. Implementation of an infectious diseases telehealth consultation and antibiotic stewardship program for 16 small community hospitals. Open Forum Infect Dis **2021;** 8:XXX–XX.
24. Liu C, Bayer A, Cosgrove SE, et al. Clinical practice guidelines by the Infectious Diseases Society of America for the treatment of methicillin-resistant *Staphylococcus aureus* infections in adults and children. Clin Infect Dis **2011;** 52:e18–55.
25. Mermel LA, Allon M, Bouza E, et al. Clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection: 2009 update by the Infectious Diseases Society of America. Clin Infect Dis **2009;** 49: 1–45.
26. Soriano A, Marco F, Martínez JA, et al. Influence of vancomycin minimum inhibitory concentration on the treatment of methicillin-resistant *Staphylococcus aureus* bacteremia. Clin Infect Dis **2008;** 46:193–200.