Antimicrobial Stewardship & Healthcare Epidemiology (2025), **5**, e121, 1–4
doi:10.1017/ash.2025.176

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Concise Communication

Staphylococcus aureus Bacteremia Electronic Reminder: an effective and accepted alert to consult infectious disease

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Abstract

Infectious disease consultation improves outcomes for *S. aureus* bacteremia. We developed an electronic health record alert (SABER) to automatically encourage consultation and replace manual intervention. In a pre-post evaluation, high rates of consultation and optimized patient management, shorter time to consult, and high provider-reported satisfaction were observed during SABER implementation.

(Received 16 January 2025; accepted 31 March 2025)

Introduction

Infectious disease (ID) consultation is associated with improved morbidity and mortality for patients with *S. aureus* bacteremia (SAB).[1,2] However, up to 50% of these patients may not receive a consultation even when ID clinicians are on site.[3,4] Hospitals have implemented different strategies to improve consultation, including mandates, antimicrobial stewardship chart audits followed by clinician-to-clinician communication, and electronic alerts.[5–7] At our hospital, we initially took the second approach, increasing our consultation rate from 75% to over 90% [unpublished data]. However, it commandeered resources away from other stewardship activities. We investigated whether an electronic health record (EHR) alert, *S. aureus* Bacteremia Electronic Reminder (SABER), could encourage ID consultation with similar effectiveness regarding speed and breadth of consultation while respecting clinician autonomy and avoiding alert fatigue.[8]

Methods

We conducted a mixed methods study. The study took place at a single academic hospital with on-site ID consultation. A multidisciplinary team of ID physicians, ID pharmacists, and information system specialists used a conceptual model of how clinicians interact with EHR to design SABER (Supplemental Figure S1).[9] The model influenced three features: 1) minimal firing, 2) clear, concise language, and 3) embedment of the consult order. In particular, a 36-hour delay between positive cultures and firing promoted clinician autonomy and patient-specific decision-making while avoiding alert fatigue. When it went live, clinicians were not specifically informed about the alert, and the antimicrobial stewardship team ceased manual monitoring and intervention for positive *S. aureus* blood cultures.

We conducted a pre-post quantitative study to determine whether time to ID consultation for SAB differed after implementing SABER. The pre- and post-intervention phases ran from November 2018 to October 2019 and February 2020 to February 2021, respectively. Hospitalized, adult patients were included in our analysis if they had a blood culture drawn at our facility positive for *S. aureus* during the pre- or post-intervention phase. Patients were excluded if they had an ID consult prior to blood culture positivity, died within 48 hours of a blood culture positivity, or transferred to palliative care within 48 hours of admission. All data was collected via chart abstraction.

Our independent variable was whether patients received care in the pre- or post-intervention phase. Our primary outcome was time to ID consultation, defined as the time from initial blood culture positivity to signed ID note, when recommendations were available to improve care. Table 1 lists secondary outcome variables—care metrics and clinical outcomes—and covariates, all of which were included in the multivariate modeling due to their clinical relevance.

For statistical analyses, we constructed Kaplan-Meier curves depicting time to ID consultation. Marginal differences were compared using the log-rank test. We built a multivariate Cox proportional hazard model comparing time to ID consultation in the pre- and post-intervention groups. Differences in secondary outcomes between the pre- and post-intervention groups were assessed with one-way ANOVA or *t*-tests. We used Fischer's exact test to estimate differences in in-hospital mortality.

We assessed clinician acceptance of SABER using a conceptual model of how clinicians interact with the EHR.[9] We purposively recruited primary team members with different roles for whom the

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Cite this article: Keating JA, Perzynski J, Schnapp B, Safdar N, Brennan MB, Lepak AJ. *Staphylococcus aureus* Bacteremia Electronic Reminder: an effective and accepted alert to consult infectious disease. *Antimicrob Steward Healthc Epidemiol* 2025. doi: 10.1017/ash.2025.176

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https://doi.org/10.1017/ash.2025.176 Published online by Cambridge University Press

Table 1. Patient characteristics, quality of care indicators, and patient outcomes before and after implementing Staphylococcus aureus Bacteremia Electronic Reminder

Patient characteristics	Pre-SABER (n = 100)	Post-SABER (n = 113)	Univariate *p* value
Demographic variables			
Age, in years	55.6 ± 16.1	53.7 ± 18.1	0.4316
Male	70 (70.0)	71 (62.8)	0.27
Non-institutionalized	87 (87.0)	100 (88.5)	0.739
Comorbidity variables			
Cardiac disease	25 (25.0)	35 (31.0)	0.333
Chronic kidney disease	36 (36.0)	45 (39.8)	0.566
Diabetes	37 (37.0)	38 (33.6)	0.607
Implanted device	39 (39.0)	24 (21.2)	0.005
Liver disease	13 (13.0)	25 (22.1)	0.083
Malignancy	12 (12.0)	24 (21.2)	0.073
Transplant	7 (7.0)	15 (13.3)	0.133
ICU status	15 (15.0)	15 (13.3)	0.718
Primary service			
Medical	72 (72.0	85 (75.2)	0.594
Surgical	24 (24.0)	21 (18.6)	0.334
Transplant	4 (4.0)	7 (6.2)	0.47
Prior hospitalization (last 90 days)	35 (35.0)	47 (41.6)	0.324
Infection characteristic variables			
Prior SAB episode (ever)	21 (21.0)	29 (25.7)	0.423
Empiric treatment adequate	90 (90.0)	101 (89.4)	0.882
Metastatic infection	50 (50.0)	35 (31.0)	0.005
MRSA	20 (20.0)	31 (27.4)	0.205
PITT bacteremia score	1.9 ± 2.6	1.8 ± 2.1	0.6143
Portal of Entry			
Skin & soft tissue	31 (31.0)	34 (30.1)	0.885
Respiratory	4 (4.0)	3 (2.7)	0.583
Vascular (IVDU or catheter)	31 (31.0)	29 (25.7)	0.388
Osteoarticular	7 (7.0)	6 (5.3)	0.607
Gastrointestinal/Urinary	3 (3.0)	5 (4.4)	0.585
Undetermined	24 (24.0)	36 (31.9)	0.203
SAB clinical practice quality of care indicators			
ID Consultation	94 (94.0)	110 (97.3)	0.226
ECHO Performed	97 (97.0)	112 (99.1)	0.529
Repeat blood culture within 48h	98 (98.0)	111 (98.2)	0.902
SAB patient outcomes			
Documented blood culture clearance	98 (98.0)	112 (99.1)	0.491
Length of stay (days)	13.8 ± 14.1	15.8 ± 17.8	0.814
In-hospital death	9 (9.0)	8 (7.1)	0.606
30-d readmission	33 (33.0)	27 (23.9)	0.140

Data are presented as n (%) unless otherwise indicated.
Abbreviations: ICU, intensive care unit; IVDU, intravenous drug use; MRSA, methicillin resistant *S. aureus*; SAB, *S. aureus* bacteremia.

https://doi.org/10.1017/ash.2025.176 Published online by Cambridge University Press

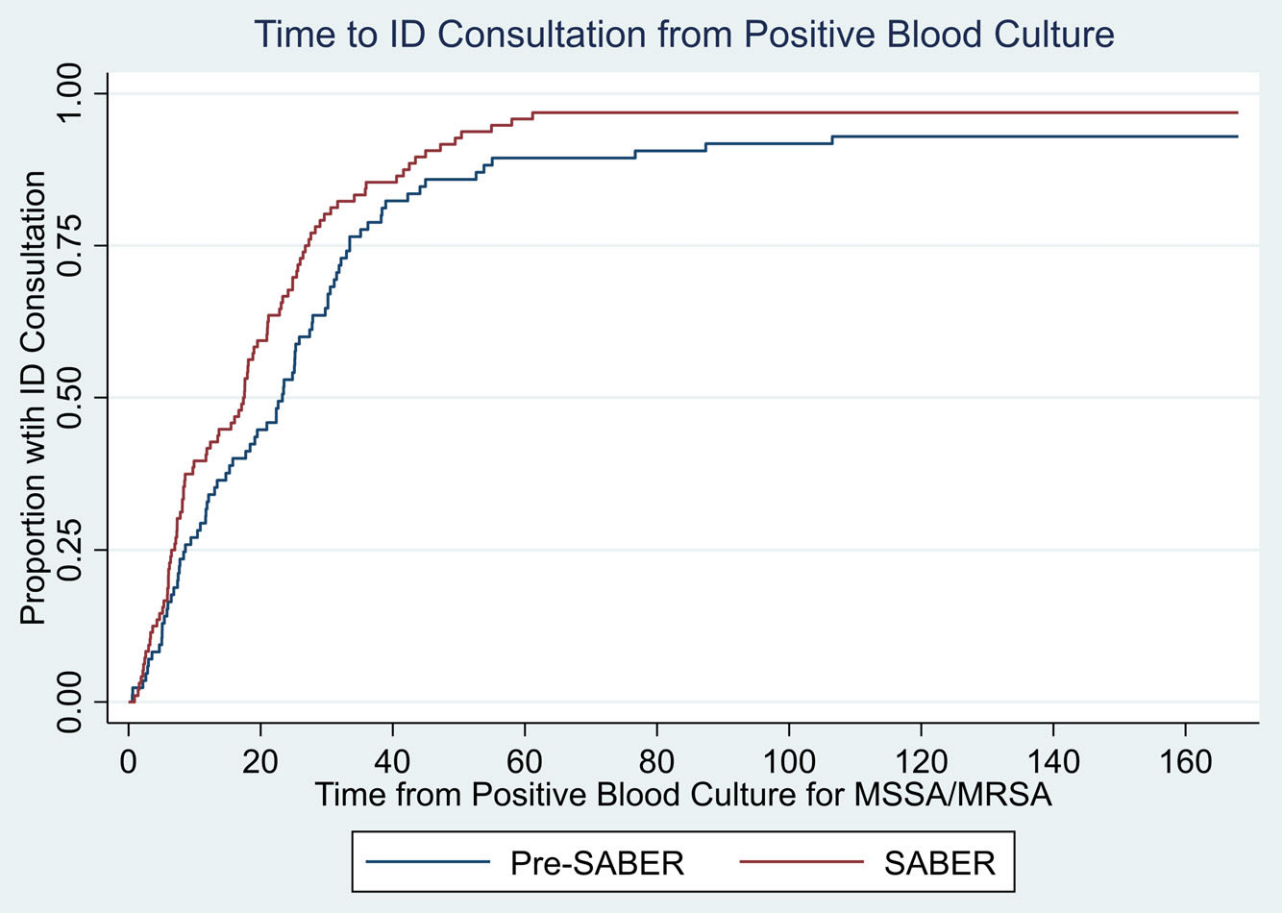

Figure 1. Time (in hours) to infectious disease consultation before and after implementing Staphylococcus aureus Bacteremia Electronic Reminder.

alert fired. We attempted to recruit clinicians who opted not to consult but were unsuccessful. Each participant verbally consented and completed a 45-minute, one-on-one, audio-recorded interview. The interviewer (J.P.) was not a clinician, minimizing concerns about the interview's influence on subsequent clinical collaborations. Interviews were conducted using a semi-structured guide rooted in the conceptual model. Participants received $100 for participation. Audio recordings were transcribed verbatim and de-identified before rapid qualitative inquiry.[10] The seasoned analyst (J.K.) debriefed with the interviewer to discuss emergent themes and quotes, enhancing credibility. The University of Wisconsin Health Sciences Institutional Review Board exempted this study (#2019–0888 and #2019–1467).

Results

One hundred patients were in the pre-intervention group and 113 in the post-intervention group (Table 1). Compared to the pre-intervention group, the post-intervention group had higher proportions of many comorbidities, MRSA, and unclear portals of entry, all of which would bias towards worse clinical outcomes. A lower proportion had metastatic infection. Ninety-four (94%) and 110 (97.5%) patients with SAB received an ID consult in the pre- and post-intervention group, respectively. Of those in the post-intervention phase, 100 patients received an ID consult without SABER firing. It fired 13 times, triggering 10 consults. Two patients did not receive a consult due to their goals of care; the primary team declined to explain why they did not consult on the final patient.

Time to consultation was shorter in the post-intervention, compared to the pre-intervention, group after covariate adjustment (Figure 1, aHR 1.63, 95% CI, 1.14–2.35, $P = 0.008$). Univariate analysis found no difference in secondary outcomes (Table 1).

Four clinicians provided feedback on SABER's acceptability: 2 attendings, 1 advanced practice practitioner, and 1 resident. While clinicians were generally concerned with alerts, they thought SABER overcame common pitfalls and especially liked the delayed firing (Supplemental Table S1). They identified potential improvements, notably embedding a link to the on-call pager to prevent having to go into paging system to find the on-call fellow.

Discussion

SABER successfully replaced human antimicrobial stewardship efforts to promote ID consultation for patients with SAB. Similar proportions of patients received consultation at a slightly quicker pace. Quality metrics and patient outcomes did not substantially change, but importantly remained very high. Furthermore, clinicians found the alert acceptable, and it allowed our stewardship team to re-invest their limited resources in activities that could not be automated. Interestingly, we observed earlier consultation in the SABER implementation period. We hypothesize a combination of increased visibility of the importance of ID consultation (via the EHR alert which all clinicians see) and clear, decisive language in the alert to consult ID, may have precipitated behavior change to consult ID earlier (Supplemental Table 1).

https://doi.org/10.1017/ash.2025.176 Published online by Cambridge University Press

While other EHR alerts have been effective, many involved mandatory consultations.[7] Ours is noteworthy because it prioritizes clinical autonomy and minimizing alert fatigue. Our data substantiated that this trust is well placed; most clinicians consulted ID before the alert fired.

One potential criticism is that the alert only fired 13 times. However, this perceived shortcoming underscores its strength. As a fail-safe mechanism, alerts should be infrequent. The firing logic functioned in the background for all 113 patients with SAB, freeing time for other stewardship activities.

Limitations to internal validity include: potential residual confounding given the lack of randomization, lack of statistical power for our secondary outcomes, and concerns about qualitative data saturation. The alert may have changed consultation practices, with immediate orders placed but delayed calls to the ID team, and slower completed consults on clinically stable patients. This would have biased towards the null hypothesis and created a conservative estimate of the faster consult speed. Limitations to external validity include: single center with on-site ID consultants and baseline high consultation rates. A clear next step is to design support for community-academic partnerships that facilitate remote consultation in resource-limited settings.

In conclusion, SABER is a promising tool to promote ID consultation for patients with SAB. It serves as a case study that alerts can balance effectiveness with clinician autonomy and acceptance. Gains in personnel time can be devoted to other tasks less amenable to EHR intervention.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ash.2025.176

Acknowledgments. None.

Author contributions. AJL and MBB conceived of and designed the study. AJL and BS designed the intervention. AJL and JP collected data. JP and JAK conducted qualitative analysis. JAK, MBB, and AJL conducted the quantitative analyses, drafted and critically revised the manuscript with assistance from JP, NS, and BS.

Financial support. This work was supported by a pilot award from the Department of Medicine at the University of Wisconsin-Madison. JK was funded by the UW-Madison Institute for Clinical & Translational Research with support from NIH-NCATS Clinical and Translational Science Award 1UL1TR002373 and funds through a grant from the Wisconsin Partnership Program at the University of Wisconsin School of Medicine and Public Health Program, Wisconsin Partnership Program (WPP 5129).

Competing interests. All authors report no conflicts of interest relevant to this article.

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