REVIEW ARTICLE

The Impact of Infectious Disease Specialist Consultation for *Staphylococcus aureus* Bloodstream Infections: A Systematic Review

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Staphylococcus aureus is a common cause of severe bloodstream infection. We performed a systematic review to assess whether consultation with infectious disease specialists decreased all-cause mortality or rate of complications of *S aureus* bloodstream infections. The review also assessed parameters associated with the quality of management of the infection. We searched for eligible studies in PubMed, Embase, Scopus, and clinical trials.gov as well as the references of included studies. We identified 22 observational studies and 1 study protocol for a randomized trial. A meta-analysis was not performed because of the high risk of bias in the included studies. The outcomes are reported in a narrative review. Most included studies reported survival benefit, in the adjusted analysis. Recommended management strategies were carried out significantly more often among patients seen by an infectious disease specialist. Trials, such as cluster-randomized controlled trials, can more validly assess the studies at low risk of bias.

Keywords. bloodstream infection; infectious disease specialist consultation; *Staphylococcus aureus*.

BACKGROUND

Staphylococcus aureus (*S aureus*) is a common cause of severe bloodstream infection [1]. The incidence was found to be 26/100 000 population per year, and the 30-day all-cause mortality is approximately 20% [3]. *S aureus* possesses a great affinity for foreign bodies and has a propensity to produce biofilm, making patients vulnerable to infections of catheters, prosthetic joints, heart valves, and pacemakers. They are also prone to metastatic infections and abscess formation. *S aureus* bloodstream infections may result in severe sepsis with organ failure and septic shock [4]. Risk factors for acquiring *S aureus* bloodstream infection include older age, dialysis treatment, diabetes mellitus, and immunosuppression [1, 5]. Factors associated with a poor prognosis of the infection include older age, comorbid conditions, severity of the infection, certain foci of infection including endocarditis, pneumonia, and undetermined focus, inadequate antibiotic treatment, and nonremoval of a removable infectious focus [3]. Echocardiography is recommended for all patients with *S aureus* bacteremia [6]. A recent review paper recommends that although the evidence in this field is weak, transthoracic echocardiography may be adequate for patients with a low risk of endocarditis [7]. Removal of the source of infection is important because nonremoval of an intravascular device has been associated with treatment failure [8], and a noneradicated focus has been found to be a predictor of mortality [9]. Timing and choice of antibiotic are important, because both delay in treatment and inappropriate choice of antibiotic are associated with decreased survival [3].

Expected Effect of the Intervention

The intervention consists of implementing infectious disease specialist consultations for patients with *S aureus* bacteremia. Current management recommendations may vary over time, but the intervention is an attempt to implement the best available practice. Four previous articles have summarized part of this evidence [7, 10–12]. When this article was submitted for publication, no full systematic review of the literature regarding this topic had been published; however, since then, an article has been published on this subject and will be discussed under Agreements and Disagreements With Other Studies or Reviews [13]. Our primary objective was to assess whether consultation with an infectious disease specialist among patients with *S aureus* bloodstream infection decreased mortality rates or rates of recurrence of the infection compared with those who did not receive the intervention. We also studied whether the intervention increased the quality of patient management.

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METHODS

Criteria for Considering Studies for This Review

All controlled trials and prospective or retrospective observational studies on this topic were eligible for inclusion in our study. The studies were grouped according to their design. The consultation could occur in person or by review of patient records. We included (1) studies comparing those receiving the intervention with those who did not and (2) studies comparing time periods with varying degrees of implementation of infectious disease specialist consultation.

Types of Outcome Measures

The primary outcome of interest was all-cause mortality within 7, 30, or 90 days of onset of infection as well as in-hospital mortality. Secondary outcomes included recurrence of bacteremia as well as parameters indicating quality of patient management. The latter included rates of examination by echocardiography, frequency of follow-up blood cultures, frequency of detection of focus of infection including endocarditis and metastatic infection, whether a removable focus was removed or drained, and adequacy of antibiotic treatment.

Search Methods for Identification of Studies

PubMed was searched from 1944 through August 26, 2015 with a combination of medical subject heading (MeSH) and free text terms. The search included terms to identify *S aureus*, the presence of bloodstream infection, and the presence of infectious disease specialist consultation. Embase and Scopus were searched through August 26, 2015. The detailed search strategy is provided in the Supplementary Material. Clinical trials.gov was searched for completed or ongoing randomized trials. Reference lists of all included studies were searched. Studies in all languages were eligible for inclusion in the review. A librarian experienced with literature search for systematic reviews was consulted. The identified articles were screened for relevance based on title or abstract. For studies that met the inclusion criteria, or cases in which the relevance was not clear, the full text was studied.

Assessment of Risk of Bias in Included Studies

Risk of bias was assessed using the Newcastle-Ottawa scale for assessing the quality of nonrandomized studies. This scale was subdivided into 3 categories, which were evaluated based on the selection of the exposed and nonexposed groups, the comparability of the groups, and the ascertainment of exposure or outcome. A star was awarded if the exposed cohort in the study was truly or somewhat representative of the cohort with this disease in the community, if the nonexposed cohort was drawn from the same community as the exposed cohort, if the outcome was assessed by record linkage or structured interview, and if there was demonstration that the outcome of interest was not present at the start of the study. For comparability, a star was given for adjustment for the most important confounding factor, and an additional star was given for adjustment of any other factor. For outcome, a star was awarded if the outcome measure was ascertained blindly or by independent record linkage, if the follow up was long enough for the outcome to occur, and if there was little loss to follow up. A study was awarded a maximum of 4 stars for selection, 2 stars for comparability, and 3 stars for outcome ascertainment [14]. All studies were assessed by 2 authors, the first author and one coauthor. Any disagreement regarding the assessment was resolved by discussion within the group. Particular attention was paid to selection bias and confounding and how these were identified and adjusted.

Measures of Treatment Effect

The Revman data analysis tool, developed by the Cochrane Collaboration, was used for summarizing the outcomes. Data were entered in outcome tables, and odds ratios (ORs) with 95% confidence intervals (CIs) were calculated by the Mantel-Haenzsel method. For adjusted analysis, the log OR and standard error were entered, and ORs were calculated by inverse variance methods. All results were reported for those receiving the intervention compared with those who did not. If the included study reported results for the control group compared with the intervention group, the results were inversed for the purpose of this review so that the magnitude of the results from all studies and subgroup analyses could be compared. A pooled analysis was not performed because of the high risk of bias in the included studies, irrespective of the statistical measures of heterogeneity. The estimates of treatment effect and CIs for each study were displayed by forest plots, and a funnel plot was used to assess the existence of publication bias.

RESULTS

Results of the Search

The final database search was conducted on August 26, 2015 and revealed 1785 records identified after removal of duplicates. In addition, 18 studies were identified from the references of included studies. In total, 1803 record abstracts or titles were screened and 1741 were excluded during the screening. Sixty-one full-text articles and 1 study protocol were assessed, and 22 studies and 1 study protocol met the inclusion criteria for this systematic review. Thirty-nine studies were excluded because the intervention did not specify information for *S aureus* or primary outcomes of interest for this review (Figure 1).

Among the 22 studies included, 16 assessed the effect of infectious disease consultation by comparing those receiving the consultation with those who did not [10, 15–28] and whether the advice given was heeded or not [8]. Five studies compared time periods in which an intervention with infectious disease consultation was offered or implemented on a mandatory basis to a time period in which this intervention was not systematically offered [29–33], and 1 study compared early and late time periods after implementation of mandatory infectious

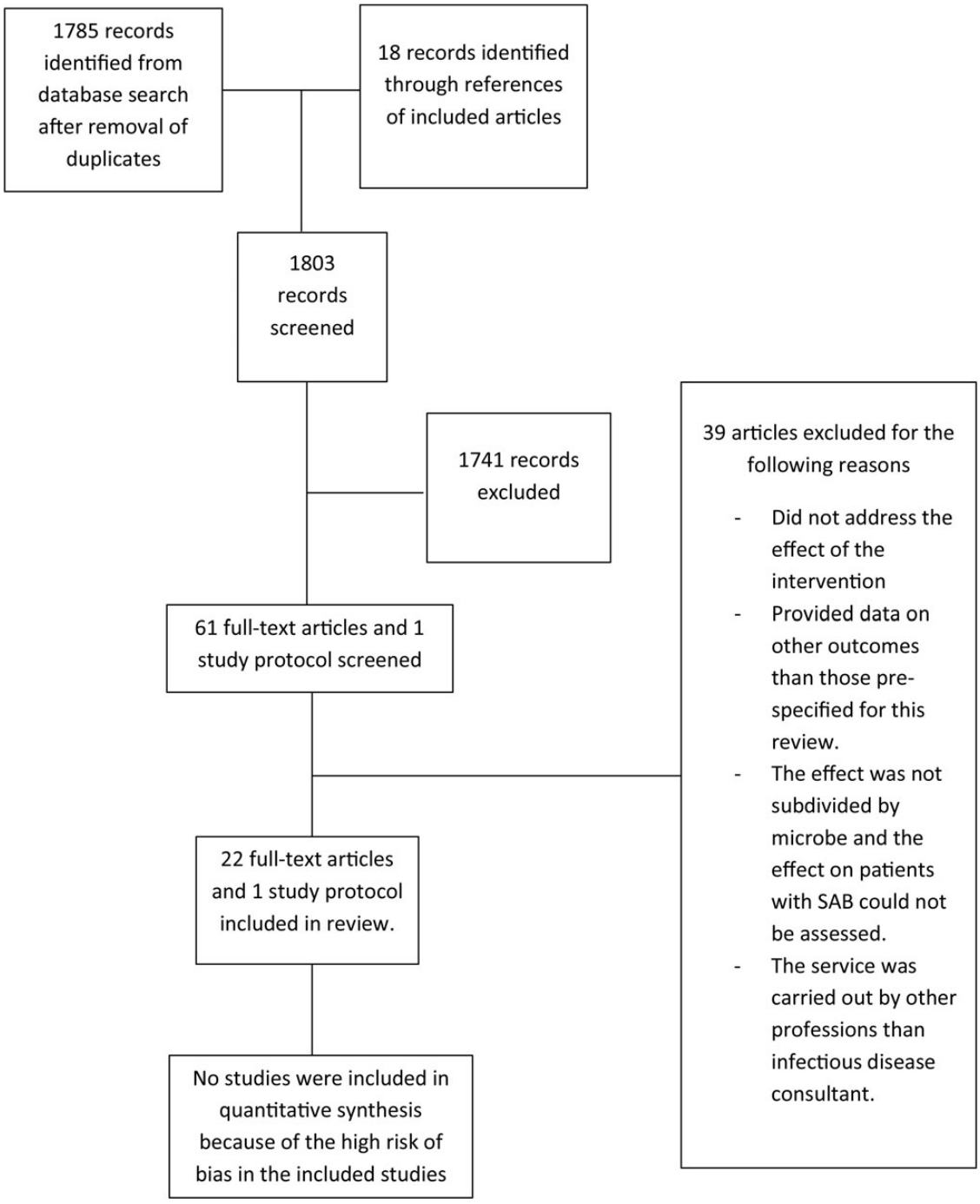


Figure 1. Literature search flowchart. Abbreviation: SAB, *Staphylococcus aureus* bloodstream infection.

disease consultation for patients with *S aureus* bloodstream infection [34] (Table 1).

The studies were published between 1998 and 2015 and included between 18 and 847 subjects. In total, there were data on 6927 patients. Eight studies were carried out in Europe [17, 18, 25, 27, 30–33], 3 studies were carried out in Asia [21, 23, 34], 1 study was carried out in Australia [22], and 10 studies were carried out in North America [8, 10, 15, 16, 19, 20, 24, 26, 28, 29].

Risk of Bias in Included Studies

All of the included studies are observational and as such are at an increased risk of bias, mainly selection bias. Some studies reported incomplete follow-up data [18, 27, 34], which make their outcome assessment somewhat less robust. However, most studies included all patients meeting defined criteria consecutively over a given period, so that the overall outcome assessments were deemed to be reliable. Most studies excluded those who died

Table 1. Description of Included Studies

Study	Setting	Study Design	Intervention/Control	Number of Patients (Intervention/Control)
Lundberg et al [15]	900-bed teaching hospital	Matched retrospective cohort study	IDC/No IDC	18 (9/9)
Fowler et al [8]	University medical center	Prospective cohort study	Advice from IDC heeded/not heeded	244 (112/132)
Mylotte and Tayara [16]	300-bed public university affiliated hospital	Retrospective cohort study	IDC/No IDC	281 (100/181)
Kaech et al [17]	800-bed university hospital	Retrospective cohort study	IDC/No IDC	308
Jenkins et al [29]	400-bed teaching hospital	Retrospective cohort study	Preintervention period/Intervention period	234 (100/134)
Rieg et al [18]	1600-bed tertiary care center	Cohort study. First period retrospective, second period prospective.	IDC/No IDC	521 (350/171)
Lahey et al [19]	Tertiary care hospital	Prospective cohort study	IDC/No IDC	240 (122/118)
Nagao et al [34]	1240-bed tertiary hospital	Retrospective cohort study	Early and late period after mandatory IDC was implemented	346 (194/152)
Honda et al [20]	Large tertiary care hospital	Prospective cohort study	IDC/No IDC	341 (111/230)
Choi et al [21]	Hospital with <400 beds	Retrospective cohort study	IDC/No IDC	100 (42/58)
Robinson et al [22]	955-bed tertiary referral center	Retrospective cohort study	IDC/No IDC	599 (162/437)
Isobe et al [23]	University hospital	Retrospective cohort study	IDC/No IDC	115 (28/87)
Pragman et al [10]	279-bed medical center	Retrospective cohort study	IDC/No IDC	233 (179/54)
Pastagia et al [24]	1171-bed tertiary care center	Retrospective cohort study	IDC/No IDC	699 (461/238)
Forsblom et al [25]	University hospital	Retrospective cohort study	IDC/telephone consultation only/No IDC	342 (245/62/35)
Lopez-Cortes et al [30]	12 tertiary hospitals	Quazi-experimental study	Preintervention period/Intervention period.	508 (221/287)
Fries et al [26]	Tertiary care hospital	Retrospective cohort study	IDC/No IDC	177 (142/35)
Tissot et al [27]	1000-bed tertiary care center	Retrospective cohort study	IDC/No IDC	148 (118/30)
Borde et al [31]	200-bed community hospital	Cohort study. First period retrospective, second period prospective.	Preintervention period/Intervention period	59 (20/39)
Saunderson et al [32]	Large acute university hospital	Cohort study. First period retrospective, second period prospective.	Preintervention period/Intervention period	63 (35/28)
Bai et al [28]	6 academic and community hospitals	Retrospective cohort study	IDC/No IDC	847 (506/341)
Saunderson et al [33]	Teaching hospital	Cohort study. First period retrospective, second period prospective.	Preintervention period/Intervention period.	477 (183/294)

Abbreviation: IDC, infectious disease consultation.

before the blood culture results were available, or where care was withdrawn, because they would not have been able to benefit from the intervention. In all the studies where baseline variables were displayed, there were differences in factors that could be associated with the risk of mortality between the intervention groups (Supplementary Table 1). Sixteen studies provided effect estimates adjusted for potential confounding factors [10, 15–21, 24, 25, 27–30, 33, 34], and 6 studies provided unadjusted effect estimates only [8, 22, 23, 26, 31, 32]. The degree of adjustment of all important confounders differed between the studies (Supplementary Table 1). The details of the Newcastle-Ottawa score are presented in Table 2. A funnel plot of studies assessing unadjusted outcomes did not show any sign of publication bias (Figure 2).

Effects of Interventions

All-Cause Mortality and Recurrence Rates

Most studies comparing those who received the intervention with those who did not reported a clear benefit of infectious disease consultation in unadjusted analysis for all-cause mortality after 1 week, 4 weeks, and in-hospital. The effect was less clear for 12-week mortality, with 2 studies showing a benefit [18, 25] and 2 studies showing no significant benefit [8, 10] (Figure 3). Eleven studies provided adjusted estimates of 1 or multiple of these outcomes: 1 study showed benefit after 1 week (OR = 0.03; 95% CI, .00–.26) [27]; 2 studies showed benefit after 4 weeks (OR = 0.44 [95% CI, .22–.88] [20] and OR = 0.27 [95% CI, .10–.75]) [27]; and 2 studies suggested a benefit, although the statistical evidence for this effect was insufficient (OR = 0.23 [95% CI, 0.02–2.56] [21] and OR = 0.71 [95% CI, .35–1.48]) [16]. Three studies showed benefit in adjusted analysis after 12 weeks [18, 24, 25], with OR from 0.28 (95% CI, .13–.62) [25] to 0.50 (95% CI, .29–.87) [18], and 1 study suggested a benefit, although this was not statistically significant (OR = 0.67; 95% CI, .14–3.22) [10]. Most studies that assessed in-hospital mortality showed benefit in adjusted analysis with OR estimates ranging from 0.45 (95% CI,

Table 2. Summary of the Newcastle-Ottawa Score of Included Studies[a]

Article	Selection	Comparability	Outcome
Lundberg et al [15]	****	**	***
Fowler et al [8][b]	****		***
Mylotte and Tayara [16]	****	**	***
Kaech et al [17]	****	**	***
Jenkins et al [29][c]	***	**	***
Rieg et al [18][d]	****	**	**
Lahey et al [19]	****	**	***
Honda et al [20]	****	**	***
Choi et al [21]	****	**	***
Robinson et al [22]	****		***
Isobe et al [23]	****		***
Pragman et al [10]	****	**	**
Pastagia et al [24]	****	**	**
Forsblom et al [25]	****	**	***
Lopez-Cortes et al [30][c]	***	**	***
Fries et al [26]	****		**
Tissot et al [27]	****	**	***
Borde et al [31]	***		***
Saunderson et al [32][c]	***		***
Bai et al [28]	****	**	***
Saunderson et al [33][c]	***	**	***

[a] Content of the Newcastle-Ottawa scale: selection is graded based on representativeness of the exposed cohort, selection of the nonexposed cohort, ascertainment of exposure, and demonstration that the outcome of interest was not present at the start of the study. Comparability refers to control of cofactors with 1 star for adjustment of the most important cofactor and an additional star for adjustment for additional cofactors. Outcome refers to how the outcome was assessed, if the follow-up time was long enough, and whether it was complete. A study can be awarded a maximum of 4 stars for selection, 2 stars for comparability, and 3 stars for outcome ascertainment.

[b] Adjusted analysis was reported to have been performed, but results are not included in the article.

[c] Compares different time periods: the exposed cohort is from the same community but not the same time, and as such the study has not been awarded a star in question 2 under selection (not fully comparable communities).

[d] Ninety patients lost to follow up for 90-day mortality.

.22–.93) [19] to 0.72 (95% CI, .52–.99) [28], except for Kaech [17]. Bai [28] assessed in-hospital mortality after 12 weeks both by a propensity score-matched analysis and by a thoroughly adjusted logistic regression model and showed a benefit of the intervention (hazard ratio = 0.72; 95% CI, .52–.99) (Figure 4).

Among studies comparing 2 time periods, 6 provided unadjusted measures and 3 provided adjusted measures of all-cause mortality. In unadjusted analysis, most studies showed reduced or borderline reduced all-cause 4-week mortality [30, 33, 34], except for the study on pediatric patients by Saunderson [32]. In adjusted analysis, Lopez-Cortes [30] showed benefit for 4-week mortality (OR = 0.59; 95% CI, .36–.97), and 2 studies showed borderline statistical evidence for benefit with OR = 0.60 (95% CI, .35–1.03) [34] and OR = 0.62 (95% CI, .37–1.04) [33], respectively. For 12-week mortality, 3 studies did not show a clear benefit in the unadjusted analysis [29, 30, 32] (Figure 3), whereas 1 study showed a benefit in the intervention period in unadjusted analysis with OR = 0.62 (95% CI, .40–.96) but not in adjusted analysis (OR = 0.85; 95% CI, .57–1.27) [33] (Figure 4).

Eight studies examined the recurrence of bloodstream infection within 12 weeks. In the study by Fowler et al [8], there was less recurrence among those who heeded the advice of the infectious disease consultant compared with those who did not (OR = 0.28; 95% CI, .10–.77); other studies were inconclusive (OR = 0.22 [95% CI, .04–1.23] [25] and OR = 1.29 [95% CI, .42–4.02]) [18] (Figure 3). One study examined the adjusted risk of 12-week relapse and suggested a protective effect of the intervention (OR = 0.33; 95% CI, .10–1.08) [10] (Figure 4).

Patient Management Strategies

The intervention led to increased rates of examination with echocardiography and an increased rate of acquisition of repeat blood cultures in most studies. There was also an increase in detection of metastatic complications and focus of infection. Studies that assessed adequacy of choice and timing of antibiotic treatment reported a positive effect of the intervention. The effect was less clear when it came to removal of a removable infectious focus, with some studies reporting increased rates and some not showing a clear effect (Figure 5).

DISCUSSION

Summary of Main Results

Most studies comparing those who received infectious disease consultation with those who did not showed benefit on all-cause mortality in unadjusted analysis and many also in adjusted analysis, with varying degree of adjustment for confounding variables. At least 1 study with very thorough adjustment for covariates showed benefit of the intervention [28].

Among studies comparing time periods with and without mandatory infectious disease consultation, most studies showed benefit after 4 weeks, but a less clear effect after 12 weeks. Due to the design of these studies, other events having an effect on mortality may have occurred at the same time as the implementation of mandatory infectious disease consultation so that the effect of the program itself is less discernable. On the other hand, these studies analyze the entire population with *S aureus* bloodstream infection, and they may be more likely to reflect the overall effect of the intervention. The reason why there is a difference in effect on 4-week and 12-week mortality in studies comparing time periods could be because the outcome at 4 weeks is more likely to reflect mortality secondary to the infection, whereas 12-week mortality may also reflect the severity of underlying conditions. None of the included studies reported data which indicated that the intervention was harmful for patients.

The included studies detected an increase in quality of the management of patients with *S aureus* bloodstream infections. Data from observational studies show that these management strategies have been shown to increase the success rates of

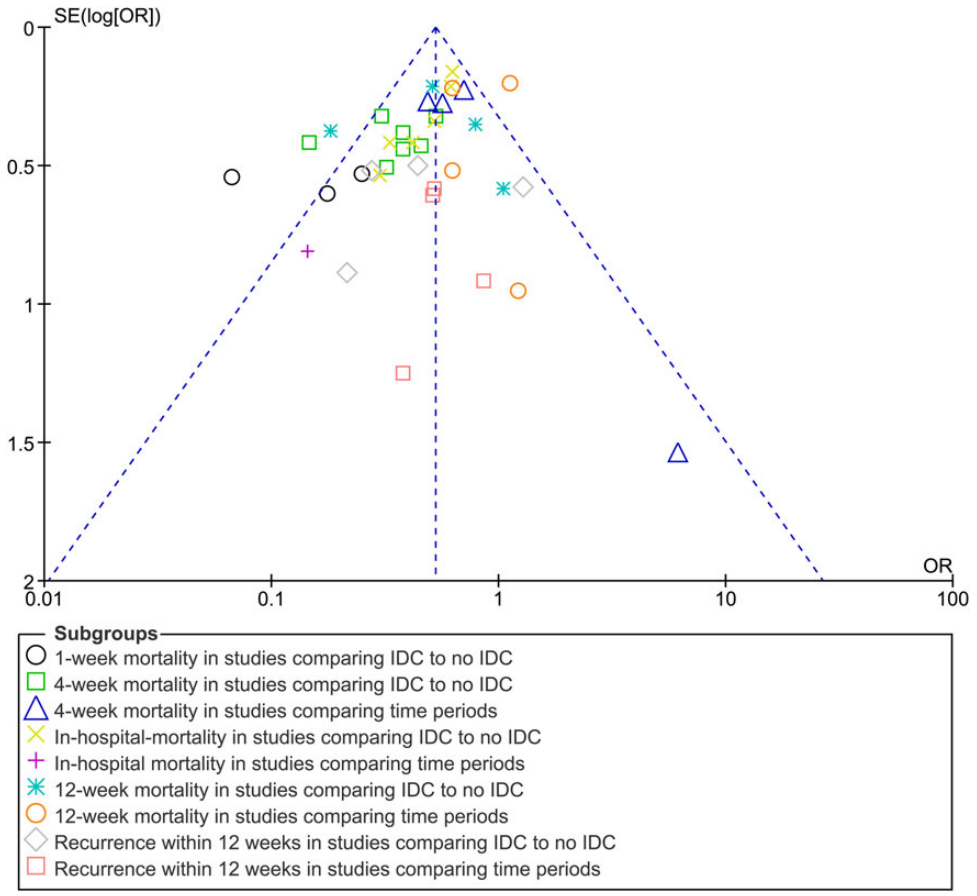


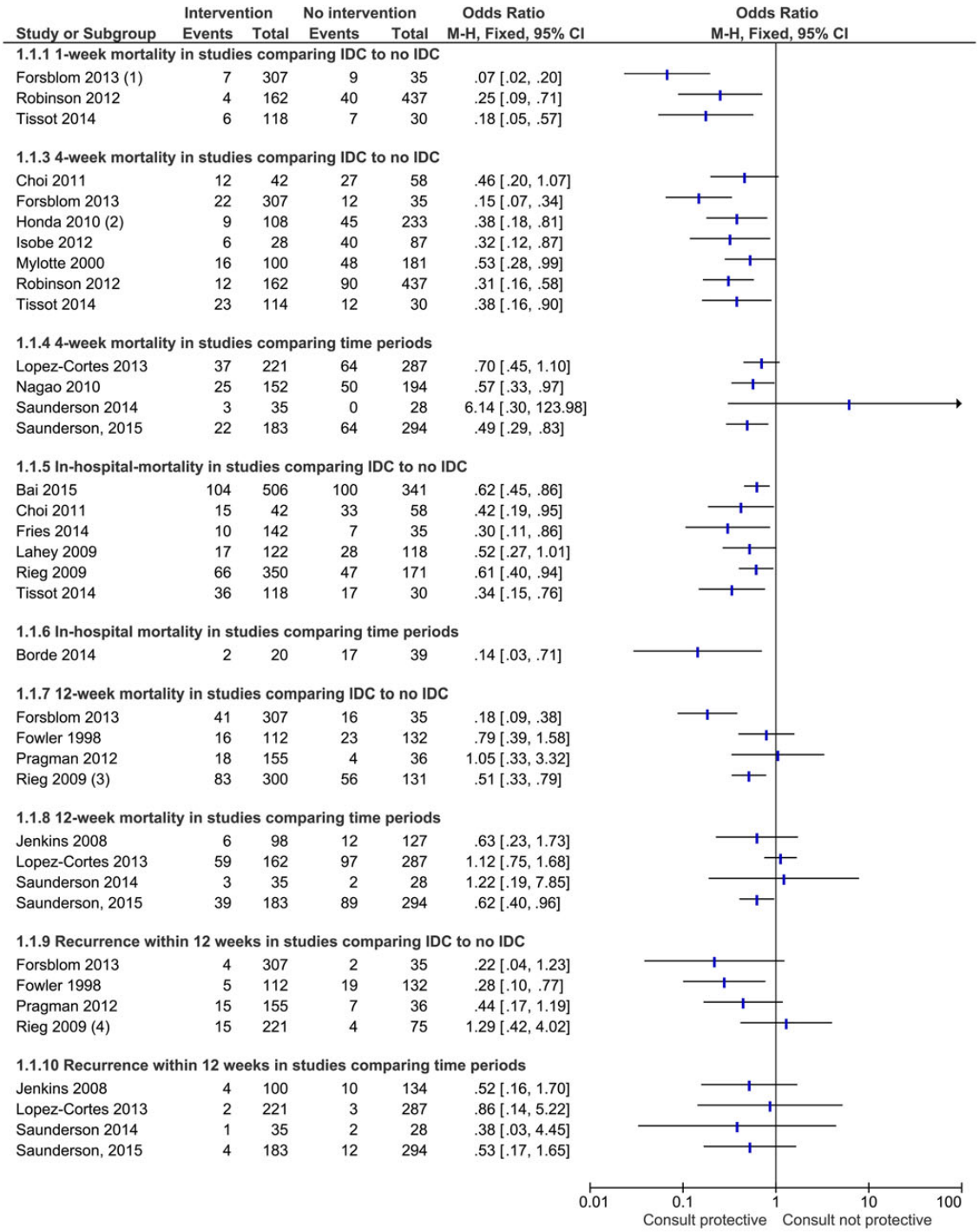
Figure 2. Funnel plot of unadjusted all-cause mortality and recurrence of studies comparing infectious disease consultation (IDC) to no IDC. Abbreviations: OR, odds ratio; SE, standard error.

treatment [3, 9, 35]. The increase in detection of complications such as endocarditis and metastatic infection could be due to a higher proportion of high-risk patients being referred to a specialist. However, increased rates of examination with echocardiography have also led to increased rates of detection of endocarditis in patients who exhibited no specific clinical signs or symptoms [36]. Moreover, this increase was also noted in studies comparing time periods before and after implementation of routine consultation, which supports that the increase reported is associated with an increase in detection [29].

Overall Completeness and Applicability of Evidence

Most included studies were carried out at larger tertiary referral centers or university hospitals, but some were from smaller hospitals. The studies were conducted in North America, Europe, Asia, and Australia, and as such they provided a fairly good representation of the situation in many industrialized countries. The studies themselves were heterogeneous in their recruitment, size of the intervention groups, types and timing of outcomes assessed, and how potential confounders were adjusted in the analysis. This is a cause for concern regarding the overall robustness of the results and the true effect of the intervention. It is unclear how much of a pooled estimate of such studies is due to the actual effect of the intervention and how much is due to the baseline difference in mortality risk between those who received the intervention and those who did not. On one hand, in some studies, patients with an ultimately or rapidly fatal disease or those residing in a nursing home were underrepresented among those being seen by the infectious disease specialist. These factors may affect the outcome estimate in favor of the intervention, even if the intervention is not truly beneficial. On the other hand, in some studies, those receiving the intervention had indicators of more severe disease, as indicated by admissions to the intensive care unit. This could affect the outcome estimate in favor of the nonexposed group, although the intervention was actually beneficial. For this reason, we chose not to meta-analyze the data and opted instead to summarize the findings of these studies and describe their strengths and weaknesses.

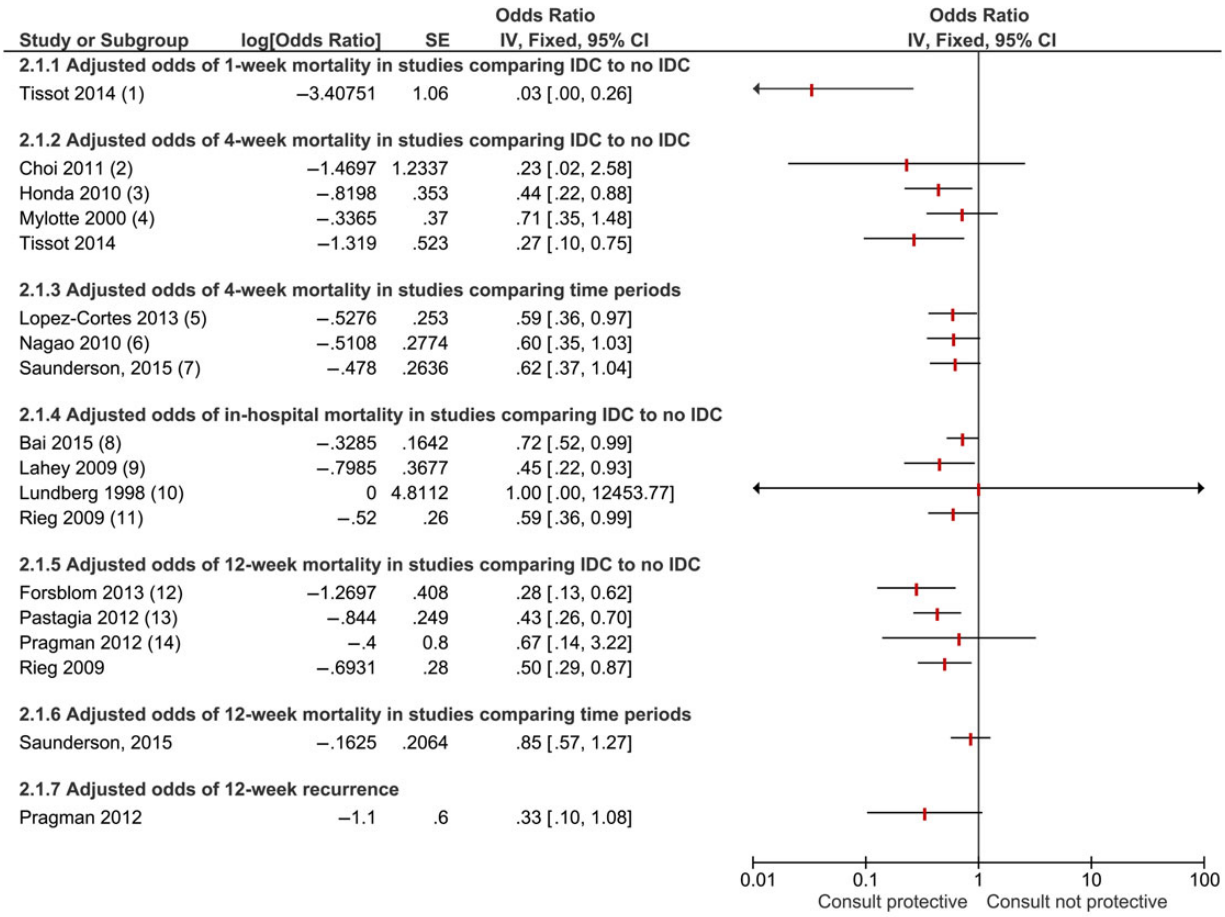
One randomized controlled trial for this intervention is registered (clinical trials.gov identifier NCT00622882), and if the study is completed it may give a more robust estimate of its overall effect. In general, it can be problematic to perform



Footnotes
(1) Any consultation compared to no consultation.
(2) 108 consultations took place within 28 days.
(3) 90 patients lost to follow-up.
(4) Excluding 90 patients lost to follow-up and 83 patients who died within 90 days.

Figure 3. Unadjusted outcome analysis for mortality and recurrence. Abbreviations: CI, confidence interval; IDC, infectious disease consultation.

randomized trials with no specialist consultation because the risk of this suboptimal management can cause harm to patients. The study in question was registered in 2008, before many of the studies referenced in this review were conducted, so the uncertainty about the benefit of the intervention was more pronounced. However, one approach for currently studying



Footnotes

(1) Variables reported from the final model were IDC, age, sex, pneumonia, severity and no removal of focus of infection.
(2) Estimated for 30 day mortality (n=39) and recurrence (n=5) together. Adjusted for underlying diseases.
(3) Measured as hazard ratio. In addition to IDC, variables retained in the final model were ICU admission, cirrhosis and age.
(4) In addition to IDC, APS >60, respiratory source, unknown source, diabetes and age ≥ 65 were included in the analysis.
(5) The intervention, age >60, Pitt score >2 and high risk source of infection were reported as significantly associated with mortality.
(6) Immunosuppressants, MRSA, repeat blood culture, therapy length and timing, echocardiography, pediatrics, time period and year entered.
(7) Assessed by multivariable Cox regression adjusted for age, sex, hospital acquired infection, MRSA and CCI.
(8) Propensity score matched for age, sex, site, service, setting, comorbidity, MRSA, severity, early focus and embolic stroke within 2 days.
(9) Adjusted for age, health care associated acquisition, major complication, CCI, antibiotic susceptibility and ICU admission.
(10) Matched on age, prior length of stay,comorbidity, prosthesis, heart valve dysfunction, chronic intravenous cannulation, initial endocarditis.
(11) Age ≥ 60, McCabe non-fatal, MRSA, endocarditis, ICU and IDC were presented in final model. Cardiac and renal disease were entered.
(12) IDC, comorbidity, leucocyte indium-111 scan, CT, pneumonia, ICU, corticosteroids and phone consult reported as significant.
(13) IDC, age, race, concurrent condition, MRSA history and strain, ICU, nursing home, vasopressor, antibiotic therapy and source entered.
(14) In addition to IDC, covariates in the model were age, CCI, service, origin, infection type and propensity score for ID involvement.

Figure 4. Adjusted outcome analysis for mortality and recurrence. Abbreviations: APS, acute physiology score; CCI, Charlson comorbidity index; CI, confidence interval; ICU, intensive care unit; IDC, infectious disease consultation; MRSA, methicillin-resistant *Staphylococcus aureus*; SE, standard error.

this clinical intervention could be to randomize patients to mandatory specialist consultation rather than referral for consultation with a specialist, at the physician's discretion. Cluster-randomized trials at the institution level would be one way of performing such a trial, avoiding cross-contamination of the intervention within an institution.

There are limitations to our study. The literature search was carried out with help from a qualified searcher, but the primary screening of abstracts and papers was carried out by 1 author, and, as such, there is a risk of overlooking papers and introducing selection bias. However, we searched 3 databases in addition to the references of all included studies, and when there was doubt about the inclusion criteria, it was discussed among the coauthors. In addition, the included papers were reviewed by experts in epidemiology and infectious diseases. We chose to use the Newcastle-Ottawa scale to assess the quality of the studies, because this reveals more details than the Grade system, where all of the included studies

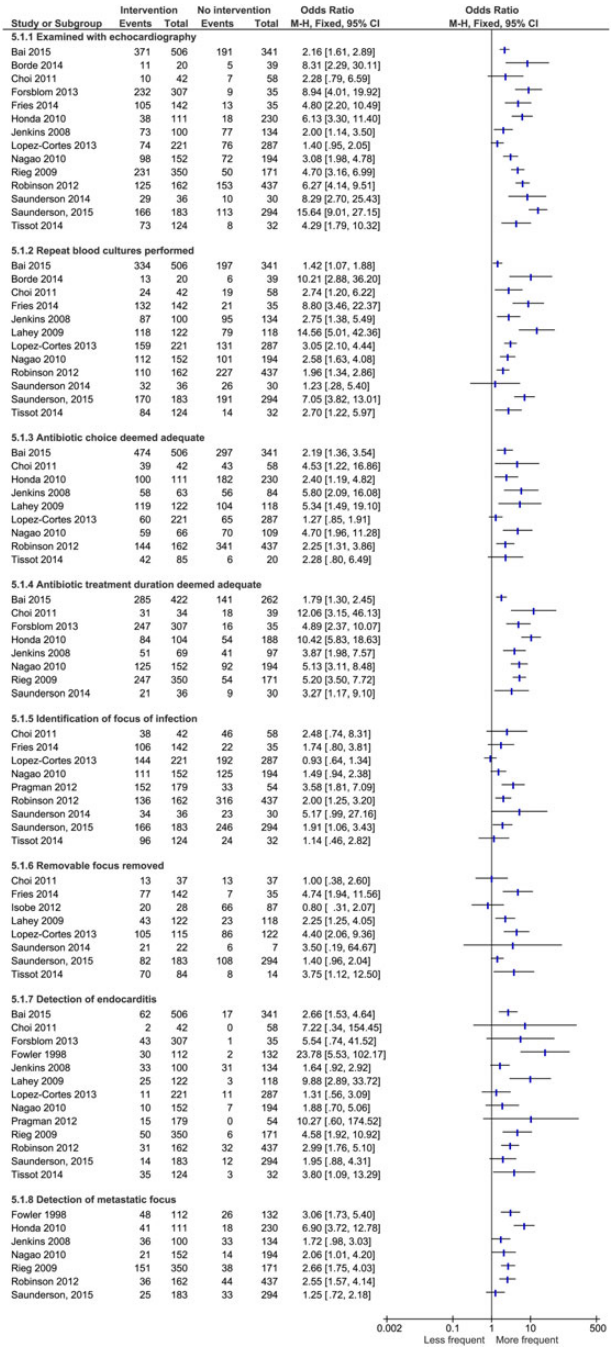


Figure 5. Effect of the intervention on patient management. Abbreviation: CI, confidence interval.

would be classified as low or very low quality because of the study design. However, the Newcastle-Ottawa scale may not be optimal for assessing clinical observational studies, and it may not be sufficiently sensitive to detect subtle but important differences in quality between the included studies [37, 38]. In general, there is a need for improved instruments for assessing the quality of observational studies included in systematic reviews [39].

Agreements and Disagreements With Other Studies or Reviews

Another systematic review on the same topic was published by Vogel et al [13] while this article was under review. The selection of papers is quite similar, and the conclusion regarding the beneficial effect of the intervention is also similar. Our approaches differ in that we have chosen not to conduct a meta-analysis of these studies because of the methodological differences and uncertainty about the true causal effect, to avoid producing a biased pooled estimate. Some studies have discussed a subset of these papers as part of the discussion of their own research or as part of narrative reviews [7, 10–12]. All of these reviews emphasized the improved management of these patients by the intervention, and some recommended that the intervention should be offered to all patients with *S aureus* bloodstream infection [7, 10].

CONCLUSIONS

Infectious disease specialist consultation for patients with *S aureus* bloodstream infection is associated with improved patient management and, plausibly, improved survival. Because of the inherent difficulties of assessing the true effect of interventions in observational studies, more robust methods, such as cluster-randomized controlled trials at the institution level, should be developed.

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Potential conflicts of interest. All authors: No reported conflicts. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest.

Supplementary Data

Supplementary material is available online at Open Forum Infectious Diseases online (http://OpenForumInfectiousDiseases.oxfordjournals.org/).

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