The Effect of Improving Basic Preventive Measures in the Perioperative Arena on *Staphylococcus aureus* Transmission and Surgical Site Infections
A Randomized Clinical Trial

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**Abstract**

**IMPORTANCE** Surgical site infections increase patient morbidity and health care costs. The Centers for Disease Control and Prevention emphasize improved basic preventive measures to reduce bacterial transmission and infections among patients undergoing surgery.

**OBJECTIVE** To assess whether improved basic preventive measures can reduce perioperative *Staphylococcus aureus* transmission and surgical site infections.

**DESIGN, SETTING, AND PARTICIPANTS** This randomized clinical trial was conducted from September 20, 2018, to September 20, 2019, among 19 surgeons and their 236 associated patients at a major academic medical center with a 60-day follow-up period. Participants were a random sample of adult patients undergoing orthopedic total joint, orthopedic spine, oncologic gynecologic, thoracic, general, colorectal, open vascular, plastic, or open urological surgery requiring general or regional anesthesia. Surgeons and their associated patients were randomized 1:1 via a random number generator to treatment group or to usual care. Observers were masked to patient groupings during assessment of outcome measures.

**INTERVENTIONS** Sustained improvements in perioperative hand hygiene, vascular care, environmental cleaning, and patient decolonization efforts.

**MAIN OUTCOMES AND MEASURES** Perioperative *S aureus* transmission assessed by the number of isolates transmitted and the incidence of transmission among patient care units (primary) and the incidence of surgical site infections (secondary).

**RESULTS** Of 236 patients (156 [66.1%] women; mean [SD] age, 57 [15] years), 106 (44.9%) and 130 (55.1%) were allocated to the treatment and control groups, respectively, received the intended treatment, and were analyzed for the primary outcome. Compared with the control group, the treatment group had a reduced mean (SD) number of transmitted perioperative *S aureus* isolates (1.25 [2.11] vs 0.47 [1.13]; *P* = .002). Treatment reduced the incidence of *S aureus* transmission (incidence risk ratio; 0.56; 95% CI, 0.37-0.86; *P* = .008; with robust variance clustering by surgeon: 95% CI, 0.37-0.86; *P* < .001). Overall, 11 patients (4.7%) experienced surgical site infections, 10 (77%) in the control group and 1 (0.9%) in the treatment group. Transmission was associated with an increased risk of surgical site infection (8 of 73 patients [11.0%] with transmission vs 3 of 163 [1.8%] without; risk ratio, 5.95; 95% CI, 1.62-21.86; *P* = .007). Treatment reduced the risk of surgical site infection (hazard ratio, 0.12; 95% CI, 0.02-0.92; *P* = .04; with clustering by surgeon: 95% CI, 0.03-0.51; *P* = .004).

**Key Points**

**Question** What is the effect of implementing Centers for Disease Control and Prevention recommendations emphasizing improved basic preventive measures for prevention of bacterial transmission and infection development on perioperative *Staphylococcus aureus* transmission and surgical site infection?

**Findings** In this randomized clinical trial involving 236 adult patients, sustained improvements in basic perioperative preventive measures resulted in a substantial reduction in *S aureus* transmission that was associated with a significant reduction in surgical site infections.

**Meaning** In this study, perioperative adherence to Centers for Disease Control and Prevention recommendations for improved basic preventive measures to prevent bacterial spread and infection development improved perioperative patient safety.

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CONCLUSIONS AND RELEVANCE  Improved basic preventive measures in the perioperative arena can reduce *S aureus* transmission and surgical site infections.

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Introduction

Surgical site infections (SSIs) increase patient morbidity and health care costs.1–8 The Centers for Disease Control and Prevention (CDC) emphasize strategic improvements in basic preventive measures to prevent bacterial spread and associated infection development.6,7 Host defenses, pathogen virulence, the microenvironment of the wound, and the size of the inoculum contribute to the pathophysiology of SSI development.9 The Surgical Care Improvement Project10 focused on host defenses and inhibition of bacterial virulence, with complete adherence predicting a decrease in postoperative infection rates. Elevated intraoperative inspired oxygen was found to be ineffective for SSI prevention in a meta-analysis involving 12 randomized clinical trials.11 Single interventions targeting improvements in intraoperative hand hygiene,12 vascular care,13 and patient decolonization14 have reduced the incidence of SSIs. The bacterial inoculum has been linked by whole-cell genome analysis to 50% of *Staphylococcus aureus* SSIs.15 However, single interventions are prone to failure,16 and evidence indicates the need for a multifaceted approach to maximally control high-risk intraoperative bacterial transmission events.17 We hypothesized that sustained improvements in perioperative hand hygiene, intravascular catheter hub disinfection, environmental cleaning, and patient decolonization efforts would generate substantial reductions in perioperative reservoir *S aureus* transmission that would result in SSI reduction.

Methods

Trial Design

This randomized, prospective, clinical trial had a parallel, 1:1 allocation of surgeons and their patients to treatment and usual care groups. The trial protocol is available in Supplement 1. Reporting followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guideline for randomized clinical trials. The study was approved by the institutional review board of the University of Iowa.

Definitions

Bacterial cultures obtained for each patient allowed for identification of potential *S aureus* transmission events occurring within and between patients. Serially collected samples included the enrolled patient at home (patient nose, axilla, and groin), baseline and case-end anesthesia environment (adjustable pressure-limiting valve and agent dial of the anesthesia machine), hands of anesthesia attending physician and assistant, patient skin sites (nasopharynx, axilla, and groin), and intravascular catheter samples for the enrolled patient and, when possible, the patient to follow. During recovery, serially collected samples included patient nasopharynx and axilla, hands of health care professionals, bedrail, patient skin site proximal to the wound dressing, and injection port samples.18 We defined *S aureus* transmission as at least 2 *S aureus* isolates obtained from at least 2 distinct, temporally associated reservoirs and/or the isolation of at least 1 pathogen from a reservoir at case end that was not present at case start.12,18
Participants

Eligibility
Adult patients scheduled to undergo orthopedic total joint, orthopedic spine, oncologic gynecological, thoracic, general, colorectal, open vascular, plastic, and open urological surgery requiring general and/or regional anesthesia and who provided written informed consent were eligible for enrollment. Patients younger than 18 years, scheduled to undergo procedures outside the listed surgical specialties, not requiring general or regional anesthesia, or who had a documented allergy to iodine, shellfish, or chlorhexidine were excluded.

Setting
This prospective, randomized clinical trial involved 236 patients and was performed from September 20, 2018, to September 20, 2019, at the University of Iowa. Each of 19 surgeons prospectively identified and enrolled eligible patients after obtaining written informed consent. Consent forms were placed by the surgeon and/or assistant into bins within the clinic and collected at the end of each day.

Interventions

Usual Care
Usual care included wall-mounted and anesthesia cart-based 62% ethanol dispensers (Avant foaming hand sanitizer; B4 Brands), 70% isopropyl alcohol pads (Covidien) for injection port disinfection, and top-down cleaning of the anesthesia machine and equipment with cotton cloths soaked in a quaternary ammonium compound (Virex; Diversey Inc). Patient decolonization included 1 of 3 procedures, as follows: (1) nasal mupirocin ointment and chlorhexidine wipes for 5 days, including the morning of surgery, (2) no decolonization protocol, or (3) chlorhexidine wipes the day before and morning of surgery.

Infection Prevention Bundle
Hand Hygiene
Hand hygiene consisted of a bag of 70% isopropyl alcohol attached to a 1-handed pump (Frantz Medical) attached to the intravenous (IV) pole before arrival to the operating room (OR). Another bag was attached to the bedrail IV pole before transport to the recovery unit.12

Organization of the Anesthesia Work Area
The anesthesia work area was reorganized so that a wire basket (Clinton Industries) lined with a plastic bag was placed on the IV pole prior to patient OR entry. This served as a receptacle and storage location for contaminated and used equipment.19

Frequency and Quality of Environmental Cleaning
A microfiber cloth (16 in × 16 in; The Rag Company) was soaked in a quaternary ammonium compound (Virex; Diversey Inc) and used to clean the anesthesia machine and monitors before patient OR entry and before patient admission to the recovery unit. A top-down cleaning approach was used. Surface disinfection wipes, containing a quaternary ammonium compound and isopropyl alcohol (PDI Health Care), were used to clean the anesthesia machine following induction of anesthesia and patient stabilization.19,20

Intravascular Catheter and Syringe Tip Disinfection
Disinfection caps containing 70% isopropyl alcohol (Frantz Medical) were attached to the IV pole before arrival to the OR and to the bedrail IV pole before departure to the recovery unit. These devices can disinfect in 10 seconds and with 1 turn.13

Patient Decolonization With Nasal Povidone Iodine
Nasal povidone iodine (3M)14 was used as directed on the morning of surgery in same-day holding before OR entry. It was also used after induction of anesthesia and patient stabilization in the OR.
Targeted UV-C Light Therapy  | Targeted UV-C therapy (Helios) was directed to OR environments that had been exposed to *S. aureus* transmission within the prior 2 weeks. Surveillance was used for the detection process (RDB Bioinformatics).

Quarterly Feedback via Surveillance Failure Mode Analysis  | Surveillance unit reservoirs contributing to temporally associated *S. aureus* transmission events were identified and processed with failure mode analysis (RDB Bioinformatics) to generate typical transmission maps. Contributing reservoirs falling in the 90th percentile were highlighted and became improvement targets.

Outcomes
Primary
We observed the number of transmitted *S. aureus* isolates and the surveillance unit *S. aureus* transmission exposure from the patient at home before surgery until 10:00 AM on the first postoperative day. We used previously described microbiological analyses.

Secondary
Patients were followed for 60 postoperative days. Research assistants (L.E. and R.B.) screened all patient medical records for evidence of elevated white blood cell count, fever, antimicrobial order, office note documentation of infection, and culture acquisition. Patients were called up to 3 times following study completion. Patients with at least 1 of the 5 criteria and/or reporting an SSI on the telephone were flagged for review by the principal investigator (R.W.L.) to determine whether possible infections met National Healthcare Safety Network definitions of SSI.

Patient Demographic and Procedural Information
We collected information pertaining to patient discharge location, age (<50 years or ≥50 years), sex, and American Society of Anesthesiologists (ASA) physical status classification. We also collected information related to dirty or infected surgery; surgery duration longer than 2 hours; orthopedic, plastic, and general abdominal surgery; and decolonization strategy (ie, nasal mupirocin and chlorhexidine, chlorhexidine only, or no protocol).

Sample Size
We originally planned to include 1000 patients from the 10 surgical specialties over a 2-year study period with the surgeons randomized 1:1, yielding 500 patients in each treatment group to evaluate the primary outcome. We calculated conservatively that this would provide 85% power to detect a 30% relative reduction in any *S. aureus* transmission event (ie, from 40% to 28%) (Supplement 1). Our planned analysis of the study data exactly midway through the trial revealed a significant effect for the primary outcome (P ≤ .008) and resulted in study termination.

Randomization
Hospital orthopedic, general abdominal, and plastic surgical specialties have been previously associated with intraoperative bacterial transmission. The association of bacterial transmission with surgical specialty is likely related to variation in preoperative decolonization protocols. Thus, this study involved randomization by surgeon via a random number generator (by statistician) to ensure that previous decolonization practices that might affect infections were balanced among the treatment and control groups. All patients enrolled by a given surgeon after obtaining written informed consent were randomized to receive the treatment assigned to the surgeon. A total of 19 of 43 surgeons (44.2%) involved in the specialties meeting inclusion criteria participated.

Masking
Patients were not informed of their treatment assignment. All outcomes were measured by research personnel who were not aware of patient grouping assignments.
Statistical Analysis
Multiple statistical methods were used. For simplification, we list the statistical methods in the precise sequence they are reported in the results.

The Fisher exact test was used to compare patient and procedural demographic information for treatment vs control groups and for cases involving *S aureus* transmission. Similarly, the distribution of patients by ASA scores greater than 2 and by sex for enrolled vs eligible patients were compared by surgeon using the Mantel-Haenszel test.

The Fisher exact test was also used to examine the potential association of each of the covariates mentioned earlier with *S aureus* transmission. None were associated.

A 2-sided Wilcoxon-Mann-Whitney test was used to examine the association of treatment assignment with the number of transmitted *S aureus* isolates. Poisson regression was used to estimate the incidence risk ratio (IRR) of *S aureus* transmission for the independent variable of treatment. Poisson regression was used to estimate the IRR because the incidence of transmission was so large (ie, much greater than 10%) that the odds ratio estimated using logistic regression would be a biased estimator of the relative risk.24 We repeated the analysis using multilevel Poisson regression clustering by surgeon or specialty.

The Fisher exact test was used to compare the proportion of patients in the treatment group with transmission events before vs after surveillance feedback and the proportion of patients with SSI with and without documented *S aureus* transmission. Poisson regression was used to compare the proportion of patients with SSI with and without documented *S aureus* transmission, clustered by surgeon.

The proportion of patients with SSIs was compared with the Fisher exact test. Time to infection was evaluated by Cox proportional hazard modeling. We repeated the analysis using multilevel Poisson regression clustering by surgeon and specialty.

There were no missing data for the primary and secondary outcomes. Calculations were performed using Stata version 16.1 (StataCorp). All *P* values were 2-sided, and *P* < .05 was taken to indicate statistical significance.

Results

Participant Flow
The overall patient enrollment schematic is shown in Figure 1. Approximately 2372 patients among the 19 participating surgeons were eligible for enrollment. Patients were recruited from September 20, 2018, to September 20, 2019. A total of 236 patients were enrolled (130 [55.1%] control; 106 [44.9%] treatment), with 156 women (66.1%) and a mean (SD) age of 57 (15) years. There were no systematic differences between enrolled and eligible patients among randomized surgeons.
according to ASA score or sex. Every patient received the intended treatment and was analyzed for the primary outcome.

**Baseline Data**

Baseline patient and procedural demographic characteristics, stratified by treatment and transmission, are shown in the eTable in Supplement 2 and Table 1. None of the covariates were associated with *S* *aureus* transmission. There was no difference between patients with and without *S* *aureus* transmission by surgical specialty (plastic surgery: 11 [15.1%] vs 17 [10.4%]; *P* = .38; orthopedic surgery: 12 [16.4%] vs 35 [21.5%]; *P* = .39; general abdominal surgery: 4 [5.5%] vs 7 [4.3%]; *P* = .74).

**Outcomes and Estimation**

Treatment reduced the mean (SD) number of transmitted perioperative *S* *aureus* isolates (control: 1.25 [2.11]; treatment: 0.47 [1.13]; *P* = .002) (Figure 2). Table 2 shows *S* *aureus* transmission and SSI development by surgeon.

### Table 1. Procedural Demographic Characteristics by *Staphylococcus aureus* Transmission

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Transmission (n = 73)</th>
<th>No transmission (n = 163)</th>
<th><em>P</em> value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &gt;50 y</td>
<td>48 (65.75)</td>
<td>121 (74.23)</td>
<td>.21</td>
</tr>
<tr>
<td>Women</td>
<td>53 (72.60)</td>
<td>103 (63.19)</td>
<td>.18</td>
</tr>
<tr>
<td>ASA score &gt;2</td>
<td>27 (36.99)</td>
<td>79 (48.47)</td>
<td>.12</td>
</tr>
<tr>
<td>Dirty or infected site</td>
<td>5 (6.85)</td>
<td>4 (2.45)</td>
<td>.14</td>
</tr>
<tr>
<td>Surgery duration &gt;2 h</td>
<td>68 (93.15)</td>
<td>148 (90.80)</td>
<td>.62</td>
</tr>
<tr>
<td>Specialty</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic</td>
<td>11 (15.07)</td>
<td>17 (10.43)</td>
<td>.38</td>
</tr>
<tr>
<td>Orthopedic</td>
<td>12 (16.44)</td>
<td>35 (21.47)</td>
<td>.39</td>
</tr>
<tr>
<td>General abdominal</td>
<td>4 (5.48)</td>
<td>7 (4.29)</td>
<td>.74</td>
</tr>
<tr>
<td>Preoperative decolonization strategy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal mupirocin and chlorhexidine for 5 d</td>
<td>12 (16.44)</td>
<td>35 (21.47)</td>
<td>.39</td>
</tr>
<tr>
<td>Chlorhexidine for day before and morning of surgery</td>
<td>45 (61.64)</td>
<td>90 (55.21)</td>
<td>.39</td>
</tr>
<tr>
<td>No protocol</td>
<td>16 (21.92)</td>
<td>38 (23.31)</td>
<td>.87</td>
</tr>
<tr>
<td>Discharge location</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Same day</td>
<td>25 (34.25)</td>
<td>56 (34.36)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Floor</td>
<td>43 (58.90)</td>
<td>99 (60.74)</td>
<td>.89</td>
</tr>
<tr>
<td>Intensive care unit</td>
<td>5 (6.85)</td>
<td>8 (4.91)</td>
<td>.76</td>
</tr>
</tbody>
</table>

Abbreviation: ASA, American Society of Anesthesiologists.

**Figure 2. Effect of the Multifaceted Approach on Perioperative *Staphylococcus aureus* Reservoir Transmission**

Treatment reduced the mean (SD) number of transmitted perioperative *S* *aureus* isolates (control: 1.25 [2.11]; treatment: 0.47 [1.13]; *P* = .002). The center of the box represents the median, and the size of the box indicates the interquartile range. The small horizontal lines show the so-called adjacent values, and circles are outliers.
Treatment reduced the number of surveillance units exposed to *S aureus* transmission (IRR, 0.56; 95% CI, 0.37-0.86; *P* = .008; with robust variance clustering by surgeon: 95% CI, 0.42-0.76; *P* < .001; with robust variance clustering by specialty: 95% CI, 0.39-0.81; *P* = .002).

Transmission was associated with an increased risk of SSI. A total of 8 of 73 patients (11.0%) with *S aureus* transmission detection had infection vs 3 of 163 (1.8%) without transmission detection (risk ratio, 5.95; 95% CI, 1.62-21.86; *P* = .007; with clustering by surgeon: 95% CI, 2.47-14.38; *P* < .001; with clustering by specialty: 95% CI, 3.04-11.67; *P* < .001).

A total of 11 of 236 patients (4.7%) experienced SSIs, 10 (7.7%) in the control group and 1 (0.9%) in the treatment group. The 1 patient in the treatment group experienced a deep organ space infection involving methicillin-sensitive *S aureus* that was complicated by bacteremia. The 10 patients in the control group experienced wound infections; of those, 2 (20.0%) were complicated by bacteremia, and 1 (10.0%) was complicated by septic shock and resulted in the patient’s death. Treatment reduced the risk of SSI (hazard ratio, 0.12; 95% CI, 0.02-0.92; *P* = .04; with clustering by surgeon: 95% CI, 0.03-0.51; *P* = .004; with clustering by specialty: 95% CI, 0.03-0.55; *P* = .006) (Figure 3).

**Ancillary Analyses**

There were fewer treatment surveillance units with any *S aureus* transmission detection after feedback than before feedback (3 of 38 cases [7.9%] during study months 5-8 [after feedback] vs 11 of 38 cases [13.4%] during study months 1-4 [before feedback]; risk ratio, 0.27; 95% CI, 0.08-0.90; *P* = .04). The effect of failure mode analysis in achieving a sustained reduction in *S aureus* transmission during the study period and a description of specific feedback used and lessons learned can be found in the eAppendix in Supplement 2.

**Table 2. Staphylococcus aureus Reservoir Exposure, Transmission, and SSI Development by Surgeon and Treatment**

<table>
<thead>
<tr>
<th>Surgeon, No.</th>
<th>Cases, No.</th>
<th>No./group total (%)</th>
<th>Transmission*</th>
<th>Any</th>
<th>Between</th>
<th>SSI</th>
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<td></td>
<td></td>
<td></td>
<td>Isolates</td>
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<tr>
<td>Treatment group</td>
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<td></td>
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<tr>
<td>7</td>
<td>41</td>
<td>23/50 (46.0)</td>
<td>10/23 (43.5)</td>
<td>2/3</td>
<td>66.7</td>
<td>1/1</td>
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<td>8</td>
<td>27</td>
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<td>9</td>
<td>4</td>
<td>7/50 (14.0)</td>
<td>2/23 (8.7)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>4/50 (8.0)</td>
<td>3/23 (13.0)</td>
<td>1/3</td>
<td>33.3</td>
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<tr>
<td>11</td>
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<tr>
<td>18</td>
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<td>41/162 (25.3)</td>
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<td>5/10</td>
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<td>5.3</td>
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<td>8/162 (4.95)</td>
<td>2/50 (4.0)</td>
<td>1/19</td>
<td>5.3</td>
<td>0</td>
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</table>

Abbreviation: SSI, surgical site infection.

* Isolate transmission is the number of transmitted isolates recovered among all cases by surgeon; any transmission is the number of cases by surgeon where at least 1 transmission event was detected with or between cases, and between transmission is transmission that occurred between patient care environments.
Discussion

The CDC has emphasized the importance of basic preventive measures for infection prevention.6,7 We have shown that improvements in basic, perioperative preventive measures can reduce *S aureus* transmission and SSIs.

While most SSI prevention efforts have focused on host optimization and the inhibition of bacterial virulence,9-11 a substantial body of evidence indicates the need for improved basic preventive measures.12-15 A multimodal program targeting parallel improvements in hand hygiene, intravascular catheter disinfection, environmental cleaning, and patient decolonization is needed to address the complex interplay of intraoperative bacterial reservoirs.17 Surveillance is needed to mitigate component failure and/or fatigue.15,18 The individual efficacy of several interventions in addressing these reservoirs has been demonstrated,12,14 and a surveillance system for monitoring perioperative bacterial transmission has been developed as a feedback mechanism.15,18 We combined these individual components to create an evidence-based, multifaceted approach for perioperative infection prevention that we hypothesized would generate substantial reductions in perioperative *S aureus* transmission and SSIs.

Our randomized study design accounted for patient decolonization strategies that would otherwise potentially confound the primary endpoint, and enrolled patients were representative of typical surgical populations. While treatment patients were older and had more severe illnesses overall, these variables were not associated with the primary or secondary study outcomes, which is consistent with prior work.17,18

Treatment reduced perioperative *S aureus* transmission, which is associated with increased risk of SSI development. In turn, a reduction in *S aureus* transmission was associated with a reduction in SSIs. Two prior trials12,13 have shown an association of attenuation of perioperative bacterial transmission with infection reduction. A controlled before-and-after study involving 111 ORs randomized to a hand hygiene improvement strategy leveraging proximity was conducted at Dartmouth.12 The authors found that a several-fold improvement in hand hygiene above baseline significantly reduced stopcock and environmental transmission along with postoperative health care–associated infections.12 Another study at Dartmouth, a randomized clinical trial involving 572 patients,13 demonstrated the efficacy of a catheter care station that incorporated improved disinfection of injection ports and syringe tips in reducing high-risk stopcock transmission events and postoperative health care–associated infections. Health care–associated infection reductions included SSIs for both trials. Trial limitations included single-site implementation, a single intervention approach, an intraoperative focus, and failure to demonstrate sustainability during the intervention period or to account for seasonal variation.12,13,25

The current study addressed these prior limitations. Intervention12,13 efficacy was confirmed at the University of Iowa, thereby providing evidence of intervention efficacy beyond Dartmouth. We

Figure 3. Effect of the Multifaceted Program on Surgical Site Infections

![Graph showing the effect of the multifaceted program on surgical site infections.](image-url)

Treatment reduced the risk of surgical site infection (hazard ratio, 0.12; 95% CI, 0.02-0.92; *P* = .04; with clustering by surgeon: 95% CI, 0.03-0.51; *P* = .004; with clustering by specialty: 95% CI, 0.03-0.55; *P* = .006).
used a multimodal approach to address all perioperative reservoirs with proven contributions to transmission and infection, including patient skin sites, environmental sites, hands, intravascular catheter injection ports, and syringe tips.13,17 The interventions were applied perioperatorically, and surveillance was used to monitor the interventions to achieve sustainability during the study period.15,18,25 The study duration accounted for seasonal variation.26 As expected, this comprehensive, evidence-based approach generated an effect that exceeded prior studies using a single intervention approach12,13 and those addressing a single contributing reservoir (ie, patient decolonization).14,27 Thus, we have confirmed greater efficacy of a set of evidence-based interventions in preventing S. aureus transmission and infection development as compared with usual perioperative infection control practice. The measures that we used are simple to implement, are widely available, and facilitate better patient care.12-15,18-21

A solid body of published evidence has used whole-cell genome and single nucleotide variant analysis to confirm the contributions of perioperative patient, hand, environmental, and stopcock reservoirs to postoperative infections and increased patient mortality across multiple academic medical centers.13,15,17,28,29 The current study supports these findings by showing an association of S. aureus transmission with increased risk of SSI development. Based on past and current evidence of causality and demonstrative ability to attenuate known risk factors for SSI development by addressing proven reservoirs, it is ill-advised to ignore CDC recommendations for improving basic preventive measures to prevent bacterial spread and associated infection development.6,7

Limitations
This study has limitations. Bacterial strain characteristics at the University of Iowa may not represent those at other hospitals. However, the studied interventions have proven efficacy at multiple hospital sites,12-14 and surveillance feedback will allow hospital sites to optimize bundle implementation and address pathogens beyond S. aureus.18,30 Most epidemiologically related transmission links identified via our model for the study of bacterial cross-contamination are confirmed with single nucleotide variant analysis.17,18,28,29 We have demonstrated the utility of this approach in group-level feedback, an important contribution to the substantial and sustained reductions in S. aureus transmission and SSIs achieved in this study.

Conclusions
In conclusion, improved perioperative basic preventive measures can reduce perioperative S. aureus transmission and SSIs. Widespread adherence to CDC recommendations for improved basic preventive measures to reduce the spread of bacteria and associated infections is indicated to improve perioperative patient safety.
Basic Perioperative Preventive Measures vs Usual Care for Reducing S aureus Transmission

Author Contributions: Drs Loftus and Brown had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Acquisition, analysis, or interpretation of data: Loftus, Dexter, Goodheart, McDonald, Keech, Noiseux, Pugely, Sharp, Sharafuddin, Lawrence, Shanklin, Tracy, Erickson, Granchi, Evans, Schmidt, Godding, Brenneke, Persons, Herber, Hadder, Brown.

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Administrative, technical, or material support: Goodheart, McDonald, Keech, Noiseux, Pugely, Sharp, Tracy, Erickson, Granchi, Evans, Schmidt, Godding, Brenneke, Persons, Hadder.

Supervision: Loftus, Godding, Yeager, Hadder.

Conflict of Interest Disclosures: Dr Loftus reported receiving fee-for-service laboratory analysis and software reporting from RDB Bioinformatics during the conduct of the study and having a patent for a multilevel laboratory-based surveillance system for ESKAPE pathogens pending; receiving research funding from Sage Medical, B. Braun Melsungen, Draeger, and Kenall Lighting; being a partner of RDB Bioinformatics, the company that owns OR PathTrac; and speaking at educational meetings sponsored by Kenall Lighting and B. Braun Melsungen outside the submitted work. Dr Dexter reported serving as a consultant to corporations via the University of Iowa Department of Anesthesia Division of Management Consulting, the payments for which are used to fund division research, outside the submitted work. Dr Pugely reported serving as a consultant for Globus Medical and Medtronic and serving on the advisory board of United Health Group outside the submitted work. Dr Hadder reported receiving grants from Drager outside the submitted work. No other disclosures were reported.

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Data Sharing Statement: See Supplement 3.

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REFERENCES:


**SUPPLEMENT 1.**
Trial Protocol

**SUPPLEMENT 2.**
eAppendix. Specific Feedback Related to Failure Mode Analysis and Lessons Learned
eTable. Baseline Patient Characteristics

**SUPPLEMENT 3.**
Data Sharing Statement