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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 healthcare costs. The Centers for Disease Control and Prevention emphasizes improved basic preventive measures to reduce bacterial transmission and infections for patients undergoing surgery.

Objective: To determine whether improved basic preventive measures can reduce perioperative *S. aureus* transmission and surgical site infections.

Design: A randomized clinical trial conducted over one year (9/20/2018–9/20/2019) with a 60-day follow-up period. Nineteen surgeons and their associated patients were randomized 1:1 via a random number generator to treatment or to usual care. Observers were blinded to patient groupings during assessment of outcome measures.

Setting: Major academic medical center.

Participants: A random sample of adult patients undergoing orthopedic total joint, orthopedic spine, oncologic gynecological, thoracic, general, colorectal, open vascular, plastic, or open urological surgery requiring general or regional anesthesia.

Intervention: Sustained improvements in perioperative provider hand hygiene, vascular care, environmental cleaning, and patient decolonization efforts.

Main outcome 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: A total of 106 and 130 adult patients in the treatment and control groups, respectively, received the intended treatment and were analyzed for the primary outcome. Treatment reduced the mean (\pm standard deviation) number of transmitted perioperative *S. aureus* isolates (1.25 ± 2.11 control vs. 0.47 ± 1.13 treatment, Wilcoxon-Mann-Whitney test $P=0.002$). Treatment reduced the incidence of *S. aureus* transmission (incidence risk ratio 0.56; 95% CI 0.37–0.86, $P=0.008$; clustering by surgeon, 95% CI 0.42–0.76, $P<0.001$). Approximately 4% of patients (11/236) suffered from surgical site infections, 7.69% in the control group (10/130) and 0.94% (1/106) in the treatment group. Transmission was associated with an increased risk of surgical site infection (11.0% [8/73] with transmission vs. 1.8% [3/163] without, risk ratio 5.95, 95% CI 1.62–21.86, $P=0.007$). Treatment reduced the risk of surgical site infection (Cox regression hazard ratio 0.12; 95% CI 0.015–0.918, $P=0.041$; with clustering by surgeon, 95% CI 0.027–0.506, $P=0.004$).

Conclusions: Improved basic preventive measures in the perioperative arena can reduce *S. aureus* transmission and surgical site infections.

Objective:

Surgical site infections (SSIs) increase patient morbidity and healthcare costs.^{1–8} The Centers for Disease Control and Prevention (CDC) emphasizes 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 Project (SCIP) focused on host defenses and inhibition of bacterial virulence with complete adherence predicting a decrease in postoperative infection rates.¹⁰ Elevated intraoperative inspired oxygen was found to be ineffective for SSI prevention in a meta-analysis involving 12 randomized 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 *S. aureus* SSIs.¹⁵ Single interventions however are prone to failure,¹⁶ and evidence indicates the need for a multi-faceted approach to maximally control high-risk intraoperative bacterial transmission events.¹⁷

We hypothesized that sustained improvements in perioperative provider 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.

Design and Methods:

Trial Design:

Randomized, prospective, clinical trial with parallel, 1:1 allocation of surgeons and their patients to treatment and usual care groups (Appendix A, trial protocol) following the CONSORT reporting guideline for randomized clinical trials (Appendix B).

Definitions:

Surveillance: 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), anesthesia provider hands (attending physician and assistant), patient skin sites (nasopharynx, axilla, and groin), and intravascular catheter samples for the enrolled patient and patient to follow when able, and patient nasopharynx and axilla, provider hands, bedrail, patient skin site proximal to the wound dressing, and injection port samples during recovery.¹⁸

Transmission: *S. aureus* transmission was defined as ≥ 2 *S. aureus* isolates obtained from ≥ 2 distinct, temporally-associated reservoirs and/or the isolation of ≥ 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/regional anesthesia and who provided written consent were eligible for enrollment. Patients <18 years of age, scheduled to undergo procedures outside of the surgical specialties listed above or 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 (130 control, 106 treatment) and was performed over one year (9/20/2018 to 9/20/2019) at the University of Iowa. The study was IRB approved (201802843) and registered at [clinicaltrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT03638947) (NCT03638947) prior to first patient enrollment. Each of nineteen surgeons prospectively identified and enrolled eligible patients after obtaining consent. Consents were placed by the surgeon and/or assistant into bins within the clinic and collected at the end of each day.

Interventions:

Usual Care: Wall-mounted and anesthesia cart-based 62% ethanol dispensers (B4 Brands Avant foaming hand sanitizer, Lisbon, IA 52243), 70% isopropyl alcohol pads (Covidien, Mansfield, MA 02048) for injection port disinfection, top down cleaning of the anesthesia machine and equipment with cotton cloths soaked in a quaternary ammonium compound (Virex, Diversey Inc, Sturtevant, Wisconsin 53177), and patient decolonization including nasal mupirocin ointment and chlorhexidine wipes for 5 days including the morning of surgery, no decolonization protocol, or chlorhexidine wipes the day before and morning of surgery.

Treatment:

Hand hygiene: A bag of 70% isopropyl alcohol connected to a one-handed pump (Frantz Medical, Mentor, Ohio 44060) was attached to the IV pole prior to arrival to the OR and to the bedrail IV pole prior to transport to the recovery unit.¹²

Organization of the anesthesia work area: A wire basket (Clinton Industries, York PA 17403) 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/used equipment.¹⁹

Frequency and quality of environmental cleaning: A microfiber cloth (16 in. x 16 in., The Rag Company, Boise, ID 83703) was soaked in a quaternary ammonium compound (Virex, Diversey Inc, Sturtevant, Wisconsin 53177) 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 utilized. Use of surface disinfection wipes containing a quaternary ammonium compound and isopropyl alcohol (PDI healthcare, Woodcliff Lake, New Jersey 07677) 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, Mentor, Ohio, 44060) were attached to the IV pole prior to arrival to the operating room and to the bedrail IV pole prior to departure to the recovery unit. These devices can disinfect in 10 seconds and with one turn.¹³

Patient decolonization with nasal povidone iodine (3M ST Paul, Minnesota 55144):¹⁴: This product was used as directed on the morning of surgery in same day holding prior to OR entry and after induction of anesthesia and patient stabilization in the operating room.

Targeted UV-C light therapy (Helios, Surfacide, Waukesha, WI 53188): UV-C therapy was directed to operating room environments that had been exposed to *S. aureus* transmission within the prior 2 weeks.²¹ Surveillance was utilized for the detection process (RDB Bioinformatics, Omaha, NE 68154).

Quarterly feedback via surveillance failure mode analysis (RDB Bioinformatics, Omaha, NE 68154):^{15, 18}: Surveillance unit reservoirs contributing to temporally-associated *S. aureus* transmission events were identified and processed 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 surveillance unit *S. aureus* transmission exposure from the patient at home prior to surgery until 10:00 A.M. on the first postoperative day. We utilized previously described microbiological analyses.^{15,18}

Secondary: Patients were followed for 60 postoperative days. Research assistants screened all patient charts for evidence of elevated white blood cell count, fever, anti-microbial order, office note documentation of infection, and culture acquisition. Patients were called up to 3 times following study completion. Patients with 1 of the 5 criteria and/or positive on the phone call were flagged for review by the principal investigator to determine if possible infections met National Healthcare Safety Network (NHSN) definitions of SSI.²²

Patient Demographics and Procedural Information: Information pertaining to patient discharge location, age greater than 50 years,¹⁸ sex, American Society of Anesthesiologists (ASA) physical status classification > 2, dirty or infected surgery, duration > 2 hours, orthopedic, plastic, and general abdominal surgery, and decolonization strategy (nasal mupirocin and chlorhexidine, chlorhexidine only, or no protocol) was collected.

Sample Size:

We originally planned to screen 1000 patients from the 10 surgical specialties over a two-year study period with the surgeons randomized 1:1, yielding 500 patients in each treatment arm on which 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 (40% down to 28%) (Appendix A trial protocol).²³ Our planned analysis of the study data exactly midway through the trial revealed significant effect for the primary outcome (P 0.0078) and resulted in study termination.

Randomization:

Hospital and orthopedic, general abdominal and plastic surgical specialties have been previously associated with intraoperative bacterial transmission.^{17,18} The association of bacterial transmission with surgical specialty is likely related to variation in preoperative decolonization protocols.¹⁸ Thus, this study involved randomization by surgeon via a random number generator (by statistician) to ensure that previous decolonization practices that might impact infections were balanced among the treatment and control groups. All patients enrolled by a given surgeon after obtaining informed, written consent were randomized to receive the treatment assigned to the surgeon. Approximately 44% (19/43) of the surgeons involved in the specialties meeting inclusion criteria participated.

Blinding:

Patients were not informed of their treatment assignment. All outcomes were measured by research personnel that were not aware of patient grouping assignments.

Statistical Methods:

Statistical analysis: Multiple statistical methods were used. For simplification, we list the statistical methods in the precise sequence as reported in the results, and vice-versa.

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

Fisher's exact test was used to examine the potential association of each of the covariates mentioned above with *S. aureus* transmission; none was associated (all $P \geq 0.120$).

A two-sided Wilcoxon-Mann-Whitney test was used to examine the association between treatment assignment and 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 incidence risk ratio (IRR) because the incidence of transmission (30.9% of $N = 73$ of 236 cases) was so large that the odds ratio estimated using logistic regression would be a biased estimator of the relative risk.²⁴ We repeated the analysis using multi-level Poisson regression clustering to the surgeon or specialty levels.

Fisher's exact test was used to compare (i) the proportion treatment cases with transmission events before vs. after surveillance feedback and (ii) 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 clustering to the surgeon.

The proportion of patients with surgical site infections (SSIs) was compared by the Fisher's exact test. Time to infection was evaluated by Cox proportional hazard modeling. We repeated the analysis using multi-level Poisson regression clustering to the surgeon or specialty levels.

There was no missing data for the primary and secondary outcomes. Calculations were performed using Stata version 16.1. All P-values and confidence intervals (CI) were 2-sided. $P < 0.05$ was taken to indicate statistical significance.

Results:

A total of 106 and 130 adult patients in the treatment and control groups, respectively, received the intended treatment and were analyzed for the primary outcome.

Participant flow:

The overall patient enrollment schematic is shown in Fig. 1. Approximately 2,372 patients among the 19 participating surgeons were eligible for enrollment. A total of 236 patients were enrolled (130 control, 106 treatment) with no systematic differences between enrolled

and eligible patients among randomized surgeons according to ASA status > 2 and sex (Mantel-Haenszel test $P = 0.66$ and $P = 0.18$, respectively).

Recruitment:

Patients were recruited from 9/20/2018 to 9/20/2019.

Baseline data:

Baseline patient and procedural demographics stratified by treatment and transmission are shown (Table 1). Floor or intensive care unit (ICU) discharge, age greater than 50 years,¹⁸ male sex, ASA > 2, and plastic surgery were associated with the treatment group. None of those covariates associated with the treatment assignment were associated with *S. aureus* transmission.

Outcomes and estimation:

Treatment reduced the number of transmitted perioperative *S. aureus* isolates (1.25 ± 2.11 control vs. 0.47 ± 1.13 treatment, Wilcoxon-Mann-Whitney test $P=0.002$; Fig. 2). *S. aureus* transmission and SSI development by surgeon is shown in Table 2.

Treatment reduced the number of surveillance units exposed to *S. aureus* transmission (incidence risk ratio [IRR] 0.56; 95% CI 0.37–0.86, $P = 0.008$; with robust variance clustering by surgeon, 95% CI 0.42–0.76, $P < 0.001$; and with robust variance clustering by specialty, 95% CI 0.39–0.81, $P=0.002$).

Transmission was associated with an increased risk of SSI (11.0% [8/73] with *S. aureus* transmission detection had infection vs. 1.8% [3/163] without *S. aureus* transmission detection had infection, risk ratio 5.95, 95% CI 1.62–21.86, $P=0.007$; with clustering by surgeon, 95% CI 2.47–14.38, $P < 0.001$; and with clustering by specialty, 95% CI 3.04–11.67, $P < 0.001$).

Approximately 4% of patients (11/236) suffered from SSIs, 7.69% in the control group (10/130) and 0.94% (1/106) in the treatment group. One patient in the treatment group suffered from a deep organ space infection involving MSSA that was complicated by bacteremia. Ten patients in the control group suffered from wound infections with 2 complicated by bacteremia and one complicated by septic shock and death.

Treatment reduced risk of SSI (Cox regression hazard ratio [HR] 0.12; 95% CI 0.015–0.918, $P=0.041$; with clustering by surgeon, 95% CI 0.027–0.506, $P=0.004$; and with clustering by specialty, 95% CI 0.025–0.546, $P=0.006$; Fig.3).

Ancillary analyses:

There were fewer treatment surveillance units with any *S. aureus* transmission detection with feedback as compared to surveillance units before feedback, (3/38 cases study months 5–8 (after feedback) vs. 11/38 cases study months 1–4 (before feedback), risk ratio 0.27, 95% CI 0.08–0.90, $P = 0.04$). The impact of failure mode analysis in achieving a sustained reduction in *S. aureus* transmission during the study period and a description of specific feedback utilized and lessons learned can be found in appendix C.

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 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 provider 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 represented typical surgical populations. While treatment patients were older and sicker 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, an outcome associated with increased risk of SSI development. In turn, a reduction in *S. aureus* transmission correlated with a reduction in SSIs. Two prior trials have shown a correlation between attenuation of perioperative bacterial transmission and infection reduction.^{12,13} A controlled before and after study involving 111 ORs randomized to a hand hygiene improvement strategy leveraging provider proximity was conducted at Dartmouth. The authors found that a several-fold improvement in provider hand hygiene above baseline significantly reduced stopcock and environmental transmission along with postoperative healthcare-associated infections (HAIs).¹² In another study at Dartmouth, a randomized clinical trial involving 572 patients demonstrated the efficacy of a catheter care station incorporating improved disinfection of injection ports and syringe tips in reducing high-risk stopcock transmission events and postoperative HAIs. HAI 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. Intervention^{12,13} efficacy was confirmed at the University of Iowa, thereby providing evidence of intervention efficacy beyond Dartmouth. We utilized a multimodal approach to address all perioperative reservoirs with proven contributions to transmission and infection including patient skin sites, environmental sites, provider hands, intravascular catheter injection ports, and syringe

tips.^{13,17} The interventions were applied perioperatively, and surveillance was employed 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 utilizing a single intervention approach^{12,13} and those addressing a single contributing reservoir (i.e. patient decolonization).^{14, 30} Thus, we have confirmed greater efficacy of a set of evidence-based interventions in preventing *S. aureus* transmission and infection development as compared to usual perioperative infection control practice. The measures that we utilized are simple to implement, widely available, and serve to facilitate better patient care.^{12,13,14,15,18,19–21}

A solid body of published evidence utilized whole cell genome and single nucleotide variant analysis to confirm the contributions of perioperative patient, provider 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 prior 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 to improve basic preventive measures to prevent bacterial spread and associated infection development.^{6,7}

Study 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*.^{18,27} Most epidemiologically-related transmission links identified via our model for 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.

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.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key Points:**Questions:**

What is the impact of Centers for Disease Control and Prevention recommendations emphasizing improved basic preventive measures for prevention of bacterial transmission and infection development on perioperative *S. aureus* transmission and surgical site infections?

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 correlated with a significant reduction in surgical site infections.

Meaning:

Perioperative adherence to CDC recommendations for improved basic preventive measures to prevent bacterial spread and infection development is indicated to improve perioperative patient safety.

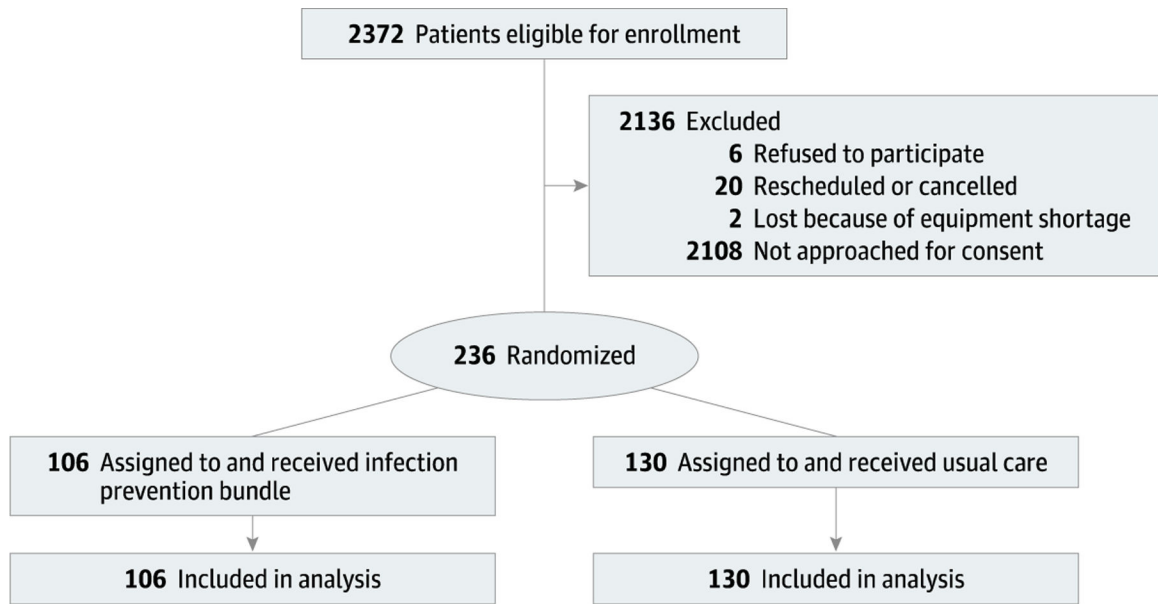


Figure 1.
Patient Enrollment Schematic

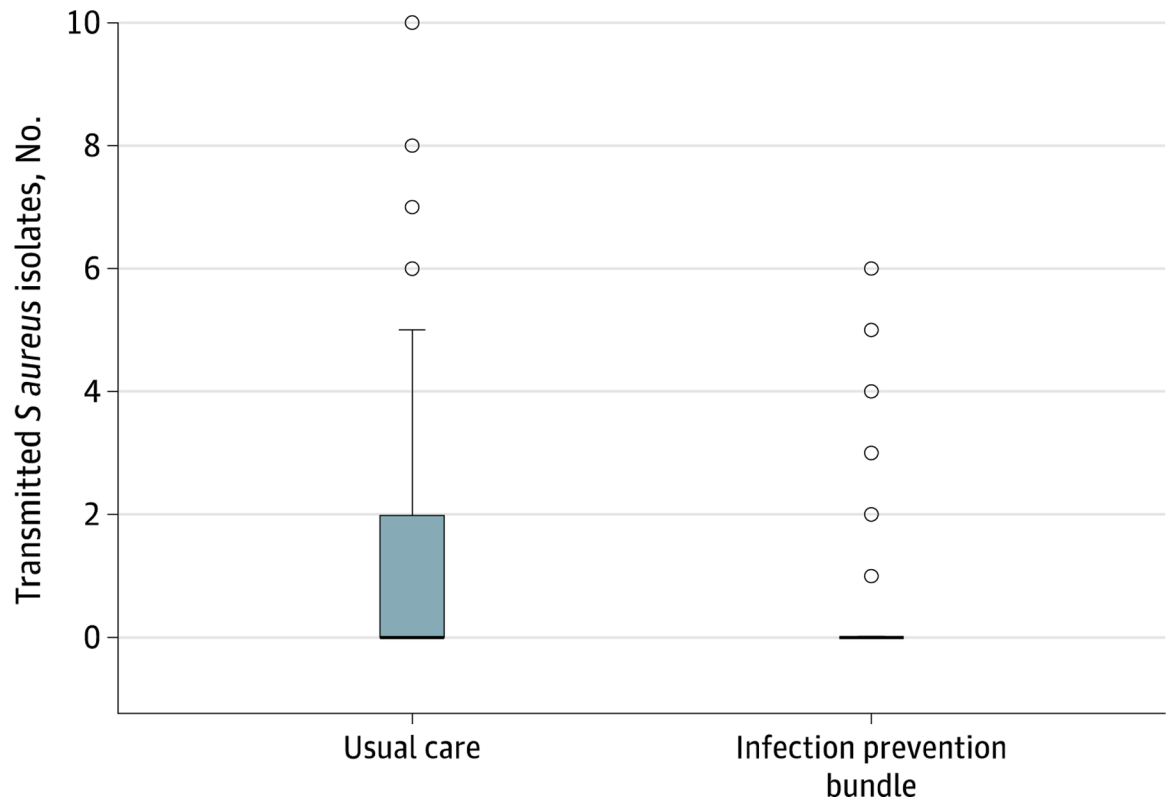
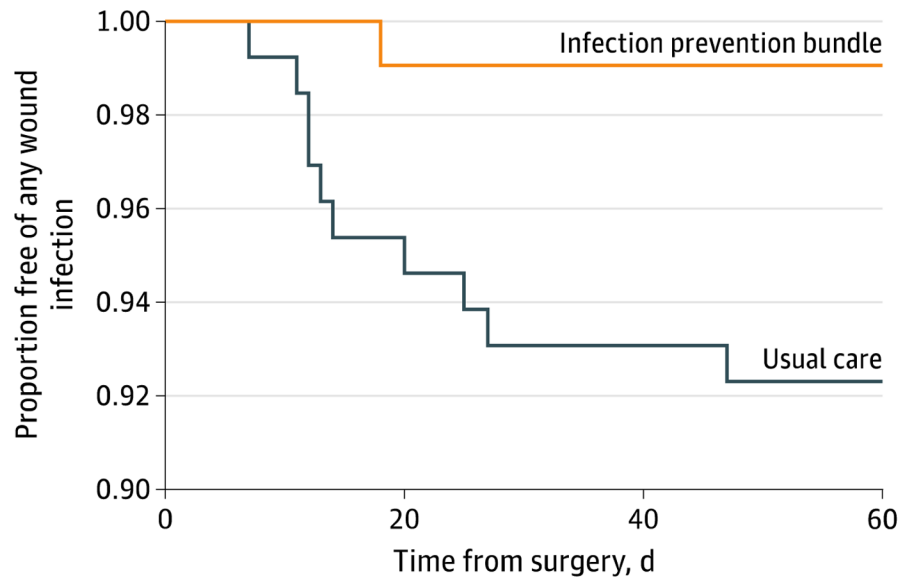


Figure 2. Effect of the multifaceted approach on perioperative staphylococcus aureus reservoir transmission.



No. at risk				
Usual care	130	124	121	120
Infection prevention bundle	106	105	105	105

Figure 3.
Effect of the multifaceted program on surgical site infections

Table 1:**Baseline Patient and Procedural Demographics Stratified by Treatment and Transmission**

Baseline Patient and Procedural Demographics (N=236 patients enrolled)	Treatment	Control
Treatment assignment N (%)	106 (44.92)	130 (55.08)
Age > 50 N (%)	88 (83.02)	81 (62.31)
Female N (%)	43 (40.57)	113 (86.92)
ASA > 2 N (%)	62 (58.49)	44 (33.85)
Dirty or Infected Site N (%)	3 (2.83)	6 (4.62)
Duration > 2 Hours N (%)	97 (91.51)	119 (91.54)
Plastic surgery N (%)	1 (0.94)	27 (20.77)
Orthopedic surgery N (%)	27 (25.47)	20 (15.38)
General abdominal surgery N (%)	5 (4.72)	6 (4.62)
Preoperative decolonization strategy		
Nasal mupirocin and chlorhexidine for 5 days N (%)	27 (25.47)	20 (15.38)
Chlorhexidine for day before and morning of surgery N (%)	55 (51.89)	80 (61.54)
No protocol N (%)	24 (22.64)	30 (23.08)
Discharge location		
Same day	27 (25.47)	54 (41.54)
Floor	69 (65.09)	73 (56.15)
Intensive care unit	10 (9.43)	3 (2.31)

Baseline Patient and Procedural Demographics by <i>S. aureus</i> Transmission N (%), Total N=236 (106 treatment, 130 control)	Yes	No	P-Value
<i>S. aureus</i> Transmission N (%)	73 (30.93)	163 (69.07)	
Age > 50 N (%)	48 (65.75)	121 (74.23)	0.21
Female N (%)	53 (72.60)	103 (63.19)	0.18
ASA > 2 N (%)	27 (36.99)	79 (48.47)	0.12
Dirty or Infected Site N (%)	5 (6.85)	4 (2.45)	0.14
Duration > 2 Hours N (%)	68 (93.15)	148 (90.80)	0.62
Plastic surgery N (%)	11 (15.07)	17 (10.43)	0.38
Orthopedic surgery N (%)	12 (16.44)	35 (21.47)	0.39
General abdominal surgery N (%)	4 (5.48)	7 (4.29)	0.74
Preoperative decolonization strategy			
Nasal mupirocin and chlorhexidine for 5 days N (%)	12 (16.44)	35 (21.47)	0.39
Chlorhexidine for day before and morning of surgery N (%)	45 (61.64)	90 (55.21)	0.39
No protocol N (%)	16 (21.92)	38 (23.31)	0.87
Discharge location			
Same day	25 (34.25)	56 (34.36)	1.0
Floor	43 (58.90)	99 (60.74)	0.89
Intensive care unit	5 (6.85)	8 (4.91)	0.76

ASA=American Society of Anesthesiologists (ASA) health classification status.

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

Surgeon	Treatment group	No. Cases	Isolates Transmission N (% group total)	Any Transmission N (% group total)	Between Transmission N (% group total)	Surgical Site Infection N (% group total)
7	1	41	23 (46)	10 (43.5)	2 (66.7)	1 (100)
8	1	27	15 (30)	7 (30.4)	0	0
9	1	4	7 (14)	2 (8.7)	0	0
10	1	16	4 (8)	3 (13)	1 (33.3)	0
11	1	6	0 (0)	0 (0)	0	0
12	1	6	0 (0)	0 (0)	0	0
14	1	3	0 (0)	0 (0)	0	0
16	1	1	0 (0)	0 (0)	0	0
18	1	1	1 (2)	1(4.3)	0	0
19	1	1	0 (0)	0 (0)	0	0
Group Total		106	50	23	3	1
1	0	45	41 (25)	19 (38)	3 (16)	5 (50)
2	0	26	42 (26)	12 (24)	7 (37)	2 (20)
3	0	19	35 (22)	7 (14)	6 (32)	2 (20)
4	0	6	4 (3)	2 (4)	0	0
5	0	20	12 (7)	5 (10)	1 (5)	0
6	0	8	13 (8)	3 (6)	1 (5)	1 (10)
15	0	1	0 (0)	0 (0)	0	0
17	0	2	7 (4)	0 (0)	0	0
13	0	3	8 (5)	2 (4)	1 (5)	0
Group Total		130	162	50	19	10

Treatment 0=usual practice, 1= program, 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 one transmission event was detected with or between cases; and between transmission is that which occurred between patient care environments.