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Research paper

Sample times for surveillance of *S. aureus* transmission to monitor effectiveness and provide feedback on intraoperative infection control

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ABSTRACT

Background: Reductions in perioperative surgical site infections are obtained by a multifaceted approach including patient decolonization, vascular care, hand hygiene, and environmental cleaning. Associated surveillance of *S. aureus* transmission quantifies the effectiveness of these basic measures to prevent transmission of pathogenic bacteria and viruses to patients and clinicians, including Coronavirus Disease 2019 (COVID-19). To measure transmission, the observational units are pairs of successive surgical cases in the same operating room on the same day. In this prospective cohort study, we measured sampling times for inexperienced and experienced personnel.

Methods: OR PathTrac kits included 6 samples collected before the start of surgery and 7 after surgery. The time for consent also was recorded. We obtained 1677 measurements of time among 132 cases.

Results: Sampling times were not significantly affected by technician's experience, type of anesthetic, or patient's American Society of Anesthesiologists' Physical Status. Sampling times before the start of surgery averaged less than 5 min (3.39 min [SE 0.23], $P < 0.0001$). Sampling times after surgery took approximately 5 min (4.39 [SE 0.25], $P = 0.015$). Total sampling times averaged less than 10 min without consent (7.79 [SE 0.50], $P < 0.0001$), and approximately 10 min with consent (10.22 [0.56], $P = 0.70$).

Conclusions: For routine use of monitoring *S. aureus* transmission, when done by personnel already present in the operating rooms of the cases, the personnel time budget can be 10 min per case.

1. Introduction

Reductions in perioperative surgical site infection are obtained by a multifaceted approach including patient decolonization (viral antiseptic), hand hygiene, use of closed lumen intravenous systems and hub disinfection, and environmental cleaning facilitated by evidence-based surveillance feedback.[1]

Monitoring of *S. aureus* transmission (e.g., from one patient to the next in an operating room) is done, in part, because perioperative *S. aureus* transmission is associated with surgical site infection.[1] The efficacy of a bundle to reduce surgical site infections is greater when combined with feedback on transmission.[1] Perioperative transmission has been linked to development of postoperative infections via single nucleotide variant analysis,[2–4] including more pathogenic *S. aureus* strain characteristics owing to increased biofilm formation[2] and desiccation tolerance.[3]

To measure *S. aureus* transmission, the observational units are pairs of successive surgical cases in the same operating room on the same day.[1,5] Samples for culturing are taken at precisely chosen locations in operating rooms (e.g., anesthesia machine vaporizer or patient's nasopharynx) and epochs (e.g., before case starts and when finished). Transmission is established when the same *S. aureus* isolate is obtained from ≥2 distinct, epidemiologically-related reservoirs within the pair of successive surgical cases.[1,5]

Recently we determined the minimum appropriate sample size of pairs of cases to evaluate if a hospital, surgical specialty, group of operating rooms, etc., has a sufficiently high incidence of transmission to warrant changes in infection control practices.[6] We determined, if

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that threshold incidence were exceeded, how many additional pairs should be sampled during and after implementation of an infection-reducing bundle, with feedback, to assess improvement.[6] Finally, once bacterial (and viral) transmission has been mitigated, we determined how often sampling is required for surveillance and feedback to detect new environmental contamination, with consequent risk of infection both to patients and healthcare workers.[6]

Hiring research technicians is time consuming, and they are an extra expense. Routine sampling of pairs of cases can be done by circulating operating room nurses already in the operating room, ideally without any resulting operating room delays and longer case durations. Anesthesia technicians assigned to 1 or 2 rooms (e.g., in Canada)[7] would also be appropriate. The objective of the current paper, a prospective cohort study, was to record the start and end times of the collection of samples to determine how much time sampling takes. We evaluated also whether sampling times differ based on experience of the person doing the sampling.

2. Methods

Data collection was approved by the Georgetown-Medstar Institutional Review Board and by the University of Iowa Institutional Review Board. The current study of the times to complete sampling was performed with separately coded data without link back to individual patient subjects. The University of Iowa Institutional Review Board declared that the analysis of that data did not meet the regulatory definition of human subjects research.

S. aureus transmission was measured using OR PathTrac (RDB Bioinformatics, Coralville, Iowa) for 132 cases at 2 studied hospitals, 109 at primary hospital and 23 at the second hospital. The starting date of Tuesday July 7 was when sampling restarted at one of the studied hospitals after the slowdown of elective surgery due to Coronavirus Disease 2019 (COVID-19), and shutdown of the laboratory processing the samples. The end date of Monday August 10th was by when 100 cases' samples were expected to have been collected at the primary hospital. At the primary hospital, the cases studied were selected at random from among the scheduled first cases of the day and corresponding pair (for transmission) 2nd case in the same operating room. At the other hospital, the cases studied were 1st or 2nd cases of the day and the next case, depending on when the research assistant was available.

Patient consent was similar at the hospitals. Patients were informed that there would be swab sampling of their nose, axilla, and groin after induction of anesthesia. Participation was voluntary and surgery was not affected. Sampling would not and did not affect operating room workflow (e.g., sampling of anesthesia providers' hands is done when the anesthesiology resident or Certified Registered Nurse Anesthetist is available).

Previously, Escobar and colleagues studied the time from adult patients on surgical table until ready for surgical preparation.[8] Covariates included type of anesthesia, American Society of Anesthesiologists' physical status (e.g., by affecting monitoring technique(s) selected), and anesthesia provider's experience.[8] We therefore recorded type of anesthesia, which based on sample size was general anesthesia or not, physical status 1 or 2 versus 3 or 4, and experience of the research assistant (Table 1).

At the primary hospital, there were 4 people sampling. Before study start, a uniform random number generator was used to specify which individual(s) working daily would be assigned to the lowest numbered operating room, and progressively higher number rooms. Consequently, non-random assignment of personnel to cases could not affect results. Among the 4 people sampling at the primary hospital, 3 were inexperienced (<30 days previous experience) and 1 had moderate experience (30 to 60 days experience) (Table 1). At the other hospital, the technicians had extensive experience (>60 days; Table 1). Thus, deliberately, "experience" refers not only to the technician but the program, a motivation for including both hospitals.

Table 1
Summary of Data from the $N = 132$ Studied Cases and Incremental Risk Ratio for Time to Collect Samples.

Variable	Value	Percent	Incremental risk ratio (standard error)
Prior days experience of person obtaining consent	<30	66.7%	1.09 (0.08)
	30 to 60	15.9%	$P = 0.26$
	>60	17.4%	
Experience of person obtaining samples at start of the case	<30	65.7%	0.88 (0.05)
	30 to 60	15.7%	$P = 0.78$
	> 60	17.2%	
Experience of person obtaining samples at end of the case	<30	59.7%	0.90 (0.05)
	30 to 60	18.7%	$P = 0.07$
	> 60	20.1%	
General anesthesia	Yes	88.8%	1.06 (0.19)
	No	11.2%	$P = 0.72$
American Society of Anesthesiologists' Physical Status	1–2	57.5%	1.03 (0.11)
	3–4	41.0%	$P = 0.79$

The incremental risk ratio and P-values listed were analyzed one at a time. When combined in a single model, the results were experience incremental risk ratio 0.95 (0.04) and $P = 0.23$, general anesthesia incremental risk ratio 1.04 (0.18) and $P = 0.80$, and physical status 3 or 4 incremental risk ratio 1.04 (0.11) $P = 0.70$.

For each sample, the minute starting and ending time of each sample was recorded. The difference was integers. Poisson regression was used for analyses, with the independent variable being the category of the 14 location/time combinations of sampling. Robust variance estimation with clustering by case was used to address potential correlations among times by surgical case and model misspecification for some sampling locations or times. Potential covariates were analyzed one at a time (Table 1). Means among cases of the total times and standard errors (SE) of those means were estimated using the delta method (Table 2). The delta method was needed because the means are nonlinear functions of the parameters of the Poisson regression. For example, the estimated combined time for obtaining consent and all 13 samples involved the sum of 14 exponentials, with each exponential being of the sum of the Poisson's model's estimated slope plus the estimated coefficient for the sample's time and location. All P-values were two-sided. Given that we did not have prior data to estimate sample sizes ahead, we treated $P < 0.01$ as statistically significant to be conservative. We tested whether the mean of the sums of the times for the 6 samples at the start of the cases differed from 5 min, and the same for the sums of the times for the 7 samples at the end of the cases. We tested whether the total time at all periods without (13 samples) and with time for consent (14 samples) took 10 min.

3. Results

There were 1677 estimated times from 132 surgical cases (Tables 1 and 2). Sampling times were not significantly affected by technician's experience, type of anesthetic, or patient's American Society of Anesthesiologists' Physical Status. Sampling times before the start of surgery averaged less than 5 min (3.39 min [SE 0.23], $P < 0.0001$). Sampling times after surgery took approximately 5 min (4.39 [SE 0.25], $P = 0.015$). Total sampling times averaged less than 10 min without consent (7.79 [SE 0.50], $P < 0.0001$), and approximately 10 min with consent (10.22 [0.56], $P = 0.70$).

Table 2
Times and Locations of OR PathTrac Kits' Samples.

Sampled time and location	Number of cases	Sample mean (standard deviation) of time in minutes	Estimated mean (standard error) of time in minutes
Obtaining patient consent (for the research studies)	132[a]	2.43 (3.11)[a]	2.43 (0.27)
Start of case, anesthesia machine agent dial and adjustable pressure valve	132	0.56 (0.50)	
Start of case, hands of the anesthesia provider (e.g., certified registered nurse anesthetist)	130	0.69 (0.51)	
Start of case, hands of the anesthesiologist	100	0.64 (0.48)	
Start of case, after anesthesia induced, patient's nares	126	0.48 (0.52)	
Start of case, after anesthesia induced, patient's axilla	125	0.50 (0.52)	
Start of case, after anesthesia induced, patient's groin	123	0.52 (0.50)	
Start of case, total time for preceding 6 samples			3.39 (0.23)
End of case, hands of the anesthesia provider (e.g., certified registered nurse anesthetist)	119	0.72 (0.52)	
End of case, hands of the anesthesiologist	69	0.81 (0.39)	
End of case, after anesthesia induced, patient's nares	120	0.55 (0.52)	
End of case, after anesthesia induced, patient's axilla	125	0.56 (0.50)	
End of case, after anesthesia induced, patient's groin	118	0.50 (0.50)	
End of case, lumen of intravenous stopcock	129	0.68 (0.54)	
End of case, anesthesia machine agent dial and adjustable pressure valve	129	0.57 (0.51)	
End of case, total time for preceding 7 samples			4.39 (0.25)

4. Discussion

We examined how much time sampling with OR PathTrac takes for purpose of guiding hospitals' decision making on who does the sampling. If sampling were performed by personnel already in the operating room (e.g., circulating nurse), the time budget to plan would be approximately 10 min. Our recorded time (mean 7.79 min for routine use without patient research consent) does not include the time to remove and replace the swabs and vials from a designated transport box. There was no significant effect of experience on sampling times, showing that our results are likely to be generalizable to other hospitals.

Our study examined the times for collecting samples to monitor *S. aureus* transmission within and among proven reservoirs as a marker of behavioral performance at applying all facets of an infection-control bundle.[2–4] The efficacy of an infection control bundle alone is greater when combined with feedback on transmission.[1] Combined, they reduce the risk for transmission and infection by approximately 44%, with each fewer surgical site infection saving the value of approximately 3.45 hospital days.[1,9] Not only does *S. aureus* transmission involve patient skin, provider hand, and environmental reservoirs in operating rooms,[1–4] the same applies to the epidemiology of perioperative transmission of Enterococcus, Klebsiella, Acinetobacter, Pseudomonas, and Enterobacter.[10–13] The epidemiology of viral pathogen transmission, including but not limited to SARS-CoV-2, involves the same reservoirs.[14,15] Thus, monitoring of intraoperative *S. aureus* transmission not only serves as a measurement for the effectiveness of basic measures to prevent the operating room transmission of pathogenic bacteria but also SARS-CoV-2.[1,16,17] Preventing environmental contamination is important not only because it endangers patients but also healthcare workers. For example, hyper-transmissible desiccation resistant *S. aureus* was isolated at the end of cases from anesthesiology residents' hands, certified registered nurse anesthetists' hands, and anesthesia machines' dials and valves.[3] Similarly, viable SARS-CoV-1 and SARS-CoV-2 was isolated days later after experimental placement from plastic and stainless steel surfaces, and in hospital swabbing studies SARS-CoV-1 was found to have been transmitted to nursing stations' computers, telephones, doorknobs, and tables.[18–21] SARS-CoV-2 was detected on water machines, elevator buttons, telephones, computer mice, and keyboards (i.e., environmental surfaces – no air samples had detectable virus).[22] Using fluorescent powder, simulation in operating rooms showed extensive contamination of anesthesia providers and anesthesia equipment from transfer of the patient, anesthesia induction, and tracheal intubation, with residual contamination after routine environmental cleaning.[23]

The usefulness of the current study depends on previous work for the selection of pairs of surgical cases for sampling. Target a population (e.g., specialty and operating room combination) based on incidence of infection by room.[24] More pairs of cases can be sampled in a day if cases are brief, because duration is not a significant covariate for transmission.[1,25] Application of the current paper highlights the potential value of adding to the criteria for case selection. If the case were very brief (e.g., 30-minute operating room time), then the ≅ 7.79 min for sampling would be impractical for the circulating nurse without causing a costly increase in operating room time. An extra nurse, technician, research assistant, etc., would be needed. Based on our results, this rarely should be necessary, because the specialties and rooms targeted have frequent surgical site infections, thus rarely brief procedures.[24]

The times that we examined were for the purpose of investigating the practicality of samples being collected by personnel already in the operating room (e.g., circulating nurse or anesthesia technician as used in Canada[7]), but only if they can do so without causing intraoperative delays. Otherwise, organizations would use research technicians, as those used for the current study, but with their resulting time to get to the operating room. For a brief period of sampling (e.g., 8 weeks, several case pairs per day) [6] with 1 or 2 part-time contracted employees sampling, most of the time cost may be for contracting, assuring the person knows the facility, satisfaction of hospital infection control requirements (e.g., tuberculosis testing), etc. For longer periods but with few cases per day (e.g., 1 pair of cases daily), most of the time cost will be commuting to the operating room and waiting for the cases to end. Table 3 includes

Table 3
Examples showing times for technicians to be at the locations to collect the samples are not generalizable among surgical suites, as compared with the study results of Table 2 that are the times to collect the samples themselves.

Example	Description
1	Second of a pair of orthopedic arthroplasty cases. Consent from the patient for sampling was obtained at 9:33 AM. The operating room was empty and thus at 9:37 AM, the anesthesia machine agent dial and adjustable pressure valve were sampled. However, there was then a delay. The anesthesia assistant's hands were sampled at 11:01 AM. The patient entered the operating room at 11:15 AM. Patient's axilla, groin, and nose were sampled at 11:27, 11:28, and 11:30. The anesthesiologist's hands were sampled at 11:37. Incision was made at 12:01 PM.
2	First of a pair of orthopedic arthroplasty cases. Intravenous lumen sampled at 10:30. Patient's groin sampled at 10:35. Patient's axilla sampled at 10:36. Dressing on the patient at 10:41. Sampling of the anesthesia assistant was at 11:07. Sampling of the anesthesiologist's hands was at 11:59. The anesthesia machine valve and dials was not until 12:04. That was when the patient went to the post-anesthesia care unit, more than 80 min after end of surgery.

examples of case delays. At hospitals with multiple surgical delays, there would be especially large advantage to samples being collected by personnel such as circulating nurses and anesthesia technicians present in the operating rooms. Our conclusion is that sampling times were sufficiently brief (≅ 10 min) that this should often be feasible, without prolongation of operating room time.

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CRediT authorship contribution statement

Subhradeep Datta: Methodology, Investigation, Writing - review & editing. **Franklin Dexter:** Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing - original draft, Writing - review & editing. **Johannes Ledolter:** Formal analysis, Writing - original draft, Writing - review & editing. **Russell T. Wall:** Investigation, Writing - review & editing. **Randy W. Loftus:** Conceptualization, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The Division of Management Consulting of the University of Iowa's Department of Anesthesia provides consultations to hospitals. Dr. Dexter receives no funds personally other than his salary and allowable expense reimbursements from the University of Iowa and has tenure with no incentive program. His-family and he have no financial holdings in any company related to his work, other than indirectly through mutual funds for retirement. Income from the Division's consulting work is used to fund Division research. A list of all the Division's consults is available at FranklinDexter.net/Contact_Info.htm. He is a member of the Perioperative Care and Operating Room Management Editorial Board. Drs. Ledolter, Wall, and Datta have nothing to disclose. Dr. Loftus reports research funding from Sage Medical Inc., BBraun, Draeger, and Kenall, has one or more patents pending, and is a partner of RDB Bioinformatics, LLC, and 1055 N 115th St #301, Omaha, NE 68,154, a company that owns OR PathTrac, and has spoken at educational meetings sponsored by Kenall and BBraun. Medstar Health purchased the RDB Bioinformatics PathTrac system for measuring bacterial transmission.

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