American Journal of Infection Control ■■ (2017) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Dynamics of intraoperative *Klebsiella*, *Acinetobacter*, *Pseudomonas*, and *Enterobacter* transmission

Brent Hadder MD [a,*], Hetal M. Patel BS [b], Randy W. Loftus MD [a]

[a] *Department of Anesthesiology, University of Iowa Hospitals and Clinics, Iowa, IA*
[b] *Department of Anesthesiology, Dartmouth-Hitchcock Medical Center, Lebanon, NH*

Key Words:
Klebsiella
Acinetobacter
Pseudomonas
Enterobacter
transmission
dynamics

Background: Our primary objective was to examine anesthesia work area reservoir isolation of *Klebsiella*, *Acinetobacter*, *Pseudomonas*, and *Enterobacter* spp (KAPE) pathogens. This is a retrospective analysis of a randomized, prospective, and observational study involving 3 academic medical centers.

Methods: Patients included adults undergoing general anesthesia. Gram-negative isolates (N = 2,682) were collected from anesthesia work area reservoirs in 274 randomly selected operating room case pairs. Nine hundred and forty-five isolates were included in this study. Chi square tests were used to examine the association of anesthesia work area reservoirs with KAPE genera isolation.

Results: *Acinetobacter* pathogens were more likely to be isolated from anesthesia provider hands (risk ratio [RR], 1.07; 95% confidence interval [CI], 1.04-1.10; corrected $P = .004$) and less likely to be isolated from patients (RR, 0.2; 95% CI, 0.08-0.50; corrected $P < .0001$). *Enterobacter* pathogens were more likely to be isolated from patients (RR, 3.34; 95% CI, 1.92-5.81; corrected $P = 0.001$) and less likely to be isolated from provider hands (RR, 0.89; 95% CI, 0.83-0.97; corrected $P = .007$).

Conclusions: Anesthesia provider hands are important reservoirs for *Acinetobacter* spp, whereas patient skin surfaces are key reservoirs for *Enterobacter* spp. Future work should examine the impact of a multimodal program in controlling the intraoperative spread of *Acinetobacter* and *Enterobacter* pathogens.

Health care–associated infections (HAIs) affect up to 7% of all patients undergoing surgery and are associated with a significant increase in patient morbidity and mortality.[1-3] National organizations such as the Centers for Disease Control and Prevention, World Health Organization, and the White House consider HAIs to be a devastating and persistent problem linked to antibiotic resistance. These organizations have called for improved basic preventive measures, such as surveillance, to reduce bacterial spread.[4-6]

Bacterial transmission events arising from anesthesia work area reservoirs, including anesthesia provider hands before, during, and after care, patient nasopharyngeal and axillary skin sites, and anesthesia machine surfaces (adjustable pressure-limiting valve and agent dial), have been directly linked to increased risk of open lumen stopcock contamination events. In turn, open lumen stopcock contamination events have been associated with increased risk of patient morbidity and mortality.[7-9]

The intraoperative spread of *Klebsiella*, *Acinetobacter*, *Pseudomonas*, and *Enterobacter* spp (KAPE) is of particular concern because of ongoing acquisition of genetic traits which are associated with antibiotic resistance and virulence.[10] These traits include extended spectrum β-lactamase (ESBL) production that is associated with increased antibiotic resistance, treatment failure, and increased patient morbidity and mortality.[11]

Our primary aim for this study was to examine the relative contribution of anesthesia work area reservoir sites to KAPE isolation, including ESBL-positive strains. Our secondary aims were to characterize a typical transmission pattern for KAPE isolates and to examine the association of KAPE reservoir isolation with postoperative HAI development. Our hope is that this work will provide guidance for intraoperative infection control measures targeting more pathogenic gram-negative organisms.

* Address correspondence to Brent Hadder, MD, Department of Anesthesiology, University of Iowa Hospitals and Clinics, 200 Hawkins Dr, Iowa City, IA 52242.
E-mail address: brent-hadder@uiowa.edu (B. Hadder).

Funding/support: Supported by The University of Iowa and Dartmouth-Hitchcock Medical Center.

Conflicts of interest: R.W.L. is a shareholder in RDB Bioinformatics, LLC, has one or more patents pending, and has received research funding from Sage and B.Braun Medical Inc. No other conflicts to report.

Author contributions: B.H. helped conduct the study, analyze the data, and write the manuscript; H.M.P. helped conduct the study; and R.W.L. helped design the study, conduct the study, analyze the data, and write the manuscript. All authors approved the final version of the manuscript.

0196-6553/
https://doi.org/10.1016/j.ajic.2017.10.018

MATERIALS AND METHODS

Overview

We previously collected 2,682 gram-negative isolates from 274 randomly selected study units (first and second case of the day in each of 548 operating room environments) across 3 major academic medical centers over a 12-month period (March 2009-February 2010).[9] Isolates of the same genera found in at least 2 distinct reservoirs within a study unit were included in this analysis. Because the activity was limited to analysis of deidentified data from a previous institutional review board–approved project (no. 201507774, Assessment of Routine Intraoperative Horizontal Transmission of Potentially Pathogenic Bacterial Organisms II), the University of Iowa declared that the additional analysis did not meet the definition of human subjects research.[9]

Institutional infection control policies were tracked and recorded during the study period. Routine cleaning of environmental surfaces between cases at 1 site involved surface disinfection wipes in addition to a quaternary ammonium compound, whereas 2 sites used only a quaternary compound. Providers at all sites had access to wall-mounted, 62% alcohol dispensers and to 70% alcohol dispensers located on the anesthesia carts. A machine-mounted, foam-based alcohol dispenser was also available at 1 of 3 sites. Gloves were immediately available for use at all sites. Use of preoperative chlorhexidine baths or nasal mupirocin by patients was infrequent for any site. There were no changes in these standardized procedures during the study period.[9]

KAPE anesthesia work area reservoir isolation (primary outcome)

We systematically sampled anesthesia provider hands (attending and resident physicians and certified registered nurse anesthetists) before, during, and after patient care, environmental sites proven to reliably represent the magnitude of contamination of the anesthesia work environment which included the adjustable pressure-limiting valve and agent dial,[7-9] patient skin sites strongly correlated with surgical site infections including the nasopharynx and axilla,[7-9,12,13] and the internal lumen of open lumen intravascular stopcock sets.[7-9] The intent of this model was to include reservoirs that could be addressed by infection control improvements by anesthesia providers and technologists. Distal reservoirs, such as the patient's rectum, are addressed by the model when pathogens are transmitted from distal to proximal reservoirs contacted by the anesthesia provider. For example, rectal colonization with bacterial organisms is assessed indirectly because it commonly occurs in conjunction with skin colonization,[14,15] including the antecubital fossa.[14,15] The antecubital fossa is often in contact with the blood pressure cuff, which frequently contacts the patient axilla and provider hands, clothing, or skin of anesthesia providers, a rationale for why the antecubital fossa and blood pressure cuff have been shown to be significant predictors of bacterial transmission in colonized patients.[15] Air is a constant in the model that potentially impacts all reservoirs in parallel through settling of aerosolized particles; all reservoirs measure settling of aerosolized particles as baseline cultures are obtained and compared with case-end cultures. This model has been previously validated.[7-9,16,17]

Sampling for the first case in a given observational unit involved the following sequence of activities. Environmental sites (adjustable pressure-limiting valve and agent dial of the anesthesia machine) were decontaminated and subsequently cultured to establish a baseline. Anesthesia provider hands were then sampled on operating room entry. After induction of anesthesia and patient stabilization, the patient nasopharynx and axilla were sampled. Provider hands (any provider that entered the anesthesia workspace outside of the sterile field including but not limited to anesthesia providers and technologists) were sampled during care. The same environmental sites were sampled at case end along with the internal lumen of the patient intravenous stopcock set, and provider hands were again sampled at case end.[7-9]

Sampling for the second case in an observational unit was similar to the case 1 process except that environmental sites were not decontaminated before sampling. This was executed in this manner so residual contamination after routine cleaning procedures between cases could be assessed.[7-9]

Culture acquisition and handling methodology

Hand sampling

Using a previously validated, modified glove juice technique, provider hands were sampled before, during, and after patient care.[7-9]

Patient sampling

The patient's nasopharynx was sampled to assess the patient reservoir because nasopharyngeal pathogens have been strongly associated with postoperative surgical site infections. The patient's axilla was also sampled because the axilla harbors up to 15%-30% of pathogens colonizing patient skin.[7-9]

Environmental sampling

Two sites on the anesthesia machine, the adjustable pressure-limiting valve and the agent dial, are proven representatives of the anesthesia environment that have been associated with an increase in the probability of bacterial contamination of the intravenous stopcock set.[7] These sites were sampled at baseline (after active decontamination at case start for case 1 and after routine decontamination at case start for case 2) and at end of the case via a standardized method. Active decontamination involved targeted cleaning of the study sites by the study investigators using a quaternary ammonium compound (Dimension III; Butcher's, Sturtevant, WI) strictly according to the manufacturer's protocol, whereas routine decontamination was performed by the usual operating room personnel according to their standard procedure applied to the environment between operative cases. Routine decontamination also involved use of the same quaternary ammonium compound, but personnel were not asked to specifically target the adjustable pressure-limiting and agent dial.[7-9]

Identification of ESBL-positive isolates

Determination of antibiotic susceptibility

Two to 3 colonies of each of 304 *Enterobacteriaceae* isolates were selected and introduced into 2 mL of sterile saline contained within a 5-mL vial and whisked to bring the bacteria into suspension. The suspensions were briefly vortexed (15 seconds) and compared with a 0.5 McFarland turbidity standard and the turbidity adjusted to match the 0.5 McFarland standard. A sterile swab was then inserted into the bacterial suspension to saturation, and excess liquid was removed from the swab by pressing to the side of the vial. Each swab was then used to coat the surface of a 150-mm Mueller Hinton agar plate in 3 directions using the zig-zag technique, the plate rimmed to collect excess liquid, and the plate allowed to air dry. Antibiotic disks (ampicillin, cefazolin, cefepime, ceftazidime, cefuroxime, ciprofloxacin, clindamycin, gentamicin, meropenem, penicillin, piperacillin-tazobactam, and sulfamethoxazole-trimethoprim) were placed and incubated at 35°C for 16-18 hours. Antibiotic susceptibility was recorded as sensitive (0), 1 (intermediate), or resistant (2).[18,19]