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Original Article

PATHogen PREValence on paper-packaged supplies in PICU bedside supply carts: the PATH-PREV study

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Abstract

Objective: Single-use supplies stored in bedside supply carts with paper packaging cannot be wiped with disinfectants. We aimed to determine the prevalence of pathogens on these unused supplies.

Design: Prospective study over 7 weeks in 2025.

Setting: Two pediatric ICUs at a university affiliated children's hospital.

Patients: The unit of analysis was the bedside supply cart from each discharged ICU patient.

Interventions: One swab was used to swab three supply items contained in a single drawer in a room's bedside cart. Carts had two drawers sampled, each with a swab for bacterial culture and respiratory viral nucleic acid amplification testing (NAAT).

Results: Paper-packaged supply items (n = 840) from 70 consecutive bedside carts were swabbed after patient discharge. All bacterial swabs had no growth of pathogen [0/140 (0%), 95% CI 0%, 2.3%)]. A non-pathogen was cultured from 8/140 (5.7%) swabs [7/70 (10.0%) carts], most with scant growth [7/8 (87.5%) only one colony]. Non-pathogens (common commensal skin and oral flora) included coagulase-negative staphylococci (n = 5), *Actinomyces oris* (n = 1), aerobic spore-forming *Bacillus* (n = 1), and viridans group streptococcus [non-anginosus] (n = 1). Of viral swabs, 3/140 (2.1%, 95% CI 0.5%, 6.4%) were NAAT positive (3/70 (4.3%) carts). Room isolation status, length of stay, and ICU were not associated with a positive bacterial or viral swab.

Conclusions: Bacterial pathogen detection on supplies, a necessary step in transmission, was extremely low. Viral NAAT detection on supplies was low and likely exaggerated the risk of fomite transmission, as whether there was viable virus at sufficient concentration to transmit infection is unknown.

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Introduction

Single-use medical supplies are commonly used in health care[1,2] and contribute to greenhouse gas emissions through the creation, transportation, and disposal of these items.[3] In pediatric intensive care units (PICU), single-use sterile packaged supplies are often stored within the patient room inside drawers of a bedside supply cart for quick access.[4–6] Although these unused supplies are not directly in contact with the patient environment, there are concerns about their potential contamination and what to do with them after patient discharge.[2,4–6] Although supplies wrapped in plastic packaging can be wiped with disinfectant, the same cannot be done for supplies with any component of paper packaging.

Some institutions recommend that unused paper-packaged supplies in bedside supply carts be discarded at the time of all patient discharges, regardless of patient characteristics, isolation status, or length of stay.[7] This practice is recommended to reduce hospital-acquired infections (HAIs) in PICU patients,[8–12] infections that may lead to sepsis and septic shock,[13–15] which significantly affect patient outcomes and hospital resources.[15–20] Despite the importance of HAI prevention, there are financial and environmental costs to discarding unused single-use supplies. The estimated cost of discarded unused supplies in bedside carts for our 15-bed PICU (approximately 700 discharges/year) was >$62,000/year. This estimate was conservative, not accounting for labor costs of stocking, cleaning or discarding supplies, nor costs associated with waste management. The health sector is responsible for an estimated 4.4% of global greenhouse gas emissions,[21] with ICUs one of the highest carbon emitting departments.[22–24] Climate change is a global health concern,[21,24–26] with children projected to bear the majority of disease burden related to climate change.[26]

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Therefore, reducing the environmental impact of ICUs is a growing priority,[23,27] and not discarding unused paper-packaged single-use supplies represents an opportunity to do so.

Published evidence to support the practice of discarding unused bedside cart supplies is limited.[28–31] Although survivability of bacterial and viral pathogens in dry conditions has been measured, these tests were usually performed in controlled laboratory settings where pathogens were inoculated onto materials and rarely reported survivability of pathogens on paper.[32,33] High-touch surfaces were commonly assessed in the literature (eg, bed rails, beds, call bells, bedside table),[33–35] but studies did not assess paper packaging in clinical settings.[34,36–38] Two studies investigated supplies within adult ICU bedside supply carts, finding low rates of contamination.[5,6] Neither focused on paper-packaged supplies, and both were done from supply carts in rooms where patients were on contact isolation for multidrug-resistant organisms (MDROs).[5,6]

To better understand this problem, in 2024 we completed [unpublished] benchmarking of Canadian PICU infection prevention and control (IPC) recommendations and found the practice varied across institutions. Even within one institution, recommendations differed between ICUs. Next, we conducted a survey of PICU clinician and researcher perspectives on managing bedside cart supplies upon patient discharge.[39] Most responses suggested that the practice of discarding supplies was not based on empirical evidence and should be based on empirical evidence.[39]

To determine the potential risk of pathogen transmission from these unused paper-packaged supply items, we developed the following prevalence study. This step in our research program aimed to determine if viable potential MDRO or viral pathogens were detectable on these supplies. As this practice is done inconsistently across Canada and has consequences for children both inside and outside of the hospital, direct evidence to fill this important gap in the literature was required.

Materials and methods

Design

This prospective study assessed if pathogens were detectable on unused paper-packaged sterile supplies stored in pediatric ICU bedside supply carts (see study protocol, Supplemental Material). All carts used within a patient room (one per room) during a patient admission to the Stollery Children's Hospital PICU or pediatric cardiac intensive care unit (PCICU) were eligible. Rooms on isolation for *Clostridioides difficile* (a spore-related infection known to highly contaminate the patient environment) and discharges that occurred outside of research coordinator availability were excluded. Research coordinators were available for extended weekday hours with no swabs collected on holidays, weekends or overnight from 8 PM to 8 AM. Due to the protocolized manner of swab collection, one of 32 ICU rooms using an older style (now discontinued) supply cart was also excluded.

The study ran for 7 weeks, April–June 2025, enrolling eligible anonymized carts consecutively until sample size targets were reached [PICU = 50 carts; PCICU = 20 carts]. In contrast to PICU, the practice in PCICU was not to discard paper-packaged supplies from bedside supply carts at the time of patient discharge.

Each day, the charge nurse notified the research team of planned discharge numbers for the day and expected time of ICU discharge. Once a patient was discharged, the research coordinator verified that no exclusion criteria were present, and if eligible, recorded descriptive data about the room the bedside cart was in. This included the age category (<4 years, ≥4 years) and ICU length of stay category (<3 days, ≥3 days) of the room's patient, whether the room was on isolation (contact/droplet isolation for a respiratory virus, or contact isolation for a MDRO), and department (PICU vs PCICU).

Eligible bedside carts had prespecified unused paper-packaged supplies from two different drawers sampled in a protocolized manner. Supply items such as syringes (1 and 10 mL) and tubing for medication infusions (microbore and bag-to-syringe) were prioritized for swabbing based on cost, frequency of use, and which drawer of the cart they were located in. If any of the originally indicated supply items were unavailable, a list of three alternative supply items were also specified (see study protocol, Appendix D, Supplemental Material).

A single swab used on the paper packaging of three most readily available supply items (on the top of any pile and hence most likely to be contaminated; no supplies were stored within boxes) stored in "Drawer A" was sent for bacterial culture. Another swab used on equivalent supplies within the same drawer was sent for respiratory viral nucleic acid amplification testing (NAAT). This process was repeated with new swabs in "Drawer B" on the paper packaging of supply items unique to that drawer. All swabs were premoistened with transport medium to enhance recovery of potential pathogens before swabbing along the entire length of the paper packaging surface in two directions.

Microbiology

In the microbiology research laboratory, bacterial swabs were plated to a Blood Agar Plate (in 5%–10% CO_2) and held for 48 hours with subculture of any growth. Pathogens were prespecified to include *Staphylococcus aureus*, *Enterococcus sp.*, gram-negative bacilli (GNB) including *Pseudomonas sp.*, *Enterobacter sp.*, *Serratia sp.*, and *Stenotrophomonas sp.*, and *Candida sp.* These organisms were considered pathogens because they are not commensal organisms, and each can develop multiple resistance mechanisms to become MDROs. For example, methicillin-resistant *Staphylococcus aureus* (MRSA), carbapenemase-producing GNB, and piperacillin-tazobactam-resistant GNB. Common and commensal skin and oral flora that might be cultured were prespecified as non-pathogens as they colonize all patients and staff and rarely become MDRO (even though they can cause opportunistic infections). Reports included semi-quantitation of organism(s) isolated from 0 to 3+.

Viral swabs were sent for respiratory virus NAAT by reverse transcriptase polymerase chain reaction (RT-PCR) for detection of respiratory syncytial virus, parainfluenza, influenza, adenovirus, human metapneumovirus, human coronaviruses (including SARS-CoV-2), and enterovirus/rhinovirus. Viral swabs were also tested for the bacteria *Mycoplasma pneumoniae* and *Chlamydophila pneumoniae*. The NxTAG^R Respiratory Pathogen Panel v2 (Luminex) was used to detect 20 viral pathogens and 2 bacterial pathogens; threshold relative light units (RLUs) varied from 30 (eg, SARS-CoV-2) to 65 (eg, Adenovirus), according to manufacturer instructions.

To validate the bacterial swab methodology, a 0.5 McFarland suspension was made in sterile saline of MRSA American Type Culture Collection (ATCC) 33,591 and of Klebsiella pneumoniae ATCC BAA-1705. From these, 50 µL of each organism was pipetted onto a 10 mL and 1 mL syringe paper packaging, spread with a sterile loop, and allowed to dry. The packaging was then

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swabbed, cultured and incubated. The cultures grew 3+ MRSA and 3+ *Klebsiella pneumoniae* at 24 hours of incubation.

To validate the viral swab methodology, 50 µL of universal transport medium from a patient sample positive for respiratory syncytial virus, and for influenza, was pipetted onto a 10 mL and 1 mL syringe paper packaging, spread with a sterile loop, and allowed to dry. The packaging was then swabbed. The respiratory pathogen panel was positive for respiratory syncytial virus A and influenza A H3 at 176 RLUs and 317 RLUs, respectively.

Ethics approval

The study was approved by the University of Alberta Health Research Ethics Board on November 5, 2024 (PRO00146201), expiry September 22, 2026. A waiver of patient consent was approved.

All swabs were collected after patients and their families had been discharged and were no longer present in the ICU. To protect anonymity, research coordinators did not utilize screening or enrollment logs and did not review patient charts. Categorized descriptive data was provided by the bedside clinical team. Study swabs were sent to the microbiology laboratory for processing without linkage to the room or patient and reported using an anonymous study ID.

Statistics

We estimated pathogen contamination on up to 2% of swabs, such that with 100 swabs the adjusted Wald 95% confidence interval (CI) would be in a reasonable range of 0.0% to 4.7%. The sample size was increased to 140 swabs to increase precision, distributed between units according to funding availability. Descriptive data and swab results were entered into an electronic case report form (REDCap) and later downloaded into a Statistical Package for Social Sciences (SPSS v29.0) database for analysis. Descriptive data were expressed as counts and percentages. The prevalence of contamination determined in prespecified subgroups were compared using the Fisher's exact test. A multiple logistic regression was performed using the four descriptive variables as potential predictors of positive swabs. A P value $\leq .05$ was considered statistically suggestive and P value $\leq .005$ considered statistically significant, the suggested standard for this type of exploratory study.[40]

The study was performed and reported according to the STROBE guideline.

Results

Descriptive data

During the recruitment period, 50/104 (48.1%) and 20/41 (48.8%) of patient discharges in PICU and PCICU, respectively, had an associated bedside cart included in the study, while the remaining carts met exclusion criteria. In total, 840 supply items were swabbed using 280 swabs (140 bacterial and 140 viral) collected from 70 consecutively included bedside supply carts. Categorized descriptive data about the room characteristics are shown in Table 1. Only 1/70 (1.4%) rooms were on contact isolation precautions, with 19/70 (27.1%) on contact-droplet precautions.

Table 1. Descriptive data for the bedside carts

Variable	Total (n = 70)	PICU (n = 50)	PCICU (n = 20)
Age			
<4 years	27 (38.5%)	17 (34.0%)	10 (50.0%)
≥4 years	43 (61.4%)	33 (66.0%)	10 (50.0%)
Isolation status			
None	50 (71.4%)	32 (64.0%)	18 (90.0%)
Contact	1 (1.4%)	0 (0%)	1 (5.0%)
Contact-droplet	19 (27.1%)	18 (36.0%)	1 (5.0%)
Length of stay			
<3 days	30 (42.9%)	19 (38.0%)	11 (55.0%)
≥3 days	40 (57.1%)	31 (62.0%)	9 (45.0%)
ICU location			
PICU	50 (71.4%)	50 (100%)	0 (0%)
PCICU	20 (28.6%)	0 (0%)	20 (100%)

Data given as *n*(%). PICU: Pediatric Intensive Care Unit. PCICU: Pediatric Cardiac Intensive Care Unit.

Microbiology results

Microbiology results are shown in Tables 2 and 3. No pathogens were detected on bacterial swabs (0/140, 0%, 95% CI 0% to 2.3%). Bacterial non-pathogens were detected on 8/140 (5.7%) swabs and 7/70 (10.0%) carts. These non-pathogens, common commensal skin and oral flora, included coagulase-negative staphylococcus (CONS), aerobic spore-forming *Bacillus sp.* [non-anthracis], viridans group streptococcus [non-anginosus] and *Actinomyces oris*. Only 1/8 (12.5%) positive bacterial swabs grew moderate (semi-quantitative 2+) contamination [viridans group streptococcus], the other 7/8 (87.5%) grew scant (1 colony) contamination.

Viral nucleic acid was detected on 3/140 (2.1%; 95% CI 0.5% to 6.4%) swabs and 3/70 (4.3%) carts. Positive swabs had a single viral pathogen detected, parainfluenza (n = 1) and enterovirus/rhinovirus (n = 2). Most, 2/3 (66.7%), swabs were weakly positive (RLU < 100). Of positive viral swabs, 2/3 (66.7%) were from rooms not on isolation precautions. The positive swab from an isolation room was weakly positive for parainfluenza, and the viral swab collected from the alternate drawer of the same cart was negative.

None (0/140, 0%, 95% CI 0% to 2.3%) of the swabs were NAAT positive for *Mycoplasma pneumoniae* or *Chlamydophila pneumoniae*.

Associations with positive swabs

Variables tested for association with swab positivity are shown in Table 4. Patient age <4 years associated with the bedside cart in that room had a statistically suggestive association on univariate ($P = .011$) and multiple logistic regression (OR 14.2; 95% CI 1.4, 140.9; $P = .024$) with any positive bacterial swab, but not with any positive viral swab. Room isolation status, length of stay, and ICU location were not statistically associated with bacterial or viral swab positivity.

Discussion

We swabbed paper packaging of unused sterile supply items stored within drawers of 70 PICU supply carts at the time of patient discharge to determine if, and to what degree, pathogens were detectable. The key findings of this study included the following. First, no bacterial pathogens were cultured from collected swabs. Non-pathogen commensal bacteria of uncertain significance were

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Table 2. Microbiology results from bacterial swabs of the contents of bedside carts after patient discharge from intensive care

Swab	Pathogen positive	PICU	PCICU	Non-pathogen positive	Semiquantitative result	PICU	PCICU
Bacterial swab #1	0/70 (0%)	0/50 (0%)	0/20 (0%)	3/70 (4.3%)	n = 2 of 1 colony CONS	2/50 (4.0%)	1/20 (5.0%)
					n = 1 of 1 colony ASB (PICU)[a]		
Bacterial swab #2	0/70 (0%)	0/50 (0%)	0/20 (0%)	5/70 (7.1%)	n = 3 of 1 colony CONS[b]	3/50 (6.0%)	2/20 (10.0%)
					n = 1 of 1 colony *Actinomyces oris* (PCICU)		
					n = 1 of 2+ viridans group streptococcus (PICU)[c]		
Either bacterial swab	0/140 (0%)	0/50 (0%)	0/40 (0%)	7/70 (10.0 %) carts 8/140 (5.7%) swabs	One PICU cart had both swabs with 1 colony of CONS	4/100 (4.0%)	3/40 (7.5%)

ASB: aerobic spore-forming *Bacillus sp.*; CONS: Coagulase negative staphylococcus.
[a]The ASB was non-anthracis.
[b]The only cart where both swabs were positive was a cart in PICU with both having 1 colony of CONS.
[c]The viridans streptococcus was non-anginosus.

Table 3. Microbiology results from viral swabs of the contents of bedside carts after patient discharge from intensive care

Swab	Pathogen positive	Semi-quantitative result	PICU	PCICU
Viral swab #1	1/70 (1.4%)	Parainfluenza (weak signal)[a]	1/50 (2.0%)	0/20 (0%)
Viral swab #2	2/70 (2.9%)	n = 2 Enterovirus/Rhinovirus (1 weak, 1 strong signal)[a]	2/50 (4.0%)	0/20 (0%)
Either viral swab	3/70 (4.3%) carts 3/140 (2.1%) swabs	As above	3/100 (3.0%)	0/40 (0%)

[a]Strength of signal was determined by relative light units (RLUs), with weak having RLU <100 and strong having RLU ≥100.

Table 4. Associations between descriptive variables of bedside carts with positive microbiology swab results

Variable	Any bacterial swab positive	Any viral swab positive
Age <4 years vs ≥4 years	6/27 vs 1/43 ***P* = .011**	2/27 vs 1/43 *P* = .56
Isolation status not on vs on isolation	5/50 vs 2/20 *P* = .99	2/50 vs 1/20 *P* = .85
Length of stay <3 days vs ≥3 days	2/30 vs 5/40 *P* = .69	2/30 vs 1/40 *P* = .57
PICU vs PCICU	4/50 vs 3/20 *P* = .40	3/50 vs 0/20 *P* = .55

Fisher's exact test for p-values. PCICU: Pediatric cardiac intensive care unit; PICU: pediatric intensive care unit.
In multiple logistic regression with all 4 variables: age <4 years associated with any bacterial swab positive with OR 14.2 (95% CI 1.4, 140.9) *P* = .024. No variable was independently associated with any viral swab positive on multiple logistic regression.

detected infrequently (5.7% of 140 swabs) with the majority (87.5% of 8 positive swabs) having scant growth of only 1 colony. Second, viral nucleic acid was detected infrequently (2.1% of 140 swabs) with most only weakly positive. Detection of viral nucleic acid did not indicate whether intact viable virus was present, how long the virus may remain detectable, infectiousness of the sample, or whether transmission could occur. Further, factors necessary for viral transmission require sufficient inoculum, a mode of transmission (fomite to caregiver hands), and subsequent contact with a patient's mucus membrane of the upper respiratory tract, which were not explored in this study. Therefore, extrapolating viral NAAT detection into decision making likely exaggerates the risk of fomite transmission. Third, no measured variables were associated with swab positivity except a statistically suggestive association between age of patient <4 years with non-pathogen bacterial growth. This finding may reflect patient care factors such as increased need for hands-on nursing care with reduced time for hand hygiene before accessing cart supplies. It is important to note that in PCICU the practice was to not discard supplies between patient admissions, and that the PICU recommendation to discard supplies was not consistently implemented by healthcare staff during the study period. Therefore, the study results reflected real unit conditions, variable unmeasured hand hygiene rates, and inconsistent cleaning and discard measures, while contamination rates remained very low.

To our knowledge, there are only two published studies assessing contamination of single-use packaged supplies within ICU supply carts.[5,6] Those studies did not focus on paper-packaged supplies (and it was unclear if any positive swabs were of paper packaging), were situated in adult ICUs, and done from supply carts in rooms where patients were on contact isolation for MDROs. One study found a contamination rate of single-use supplies of 1/80 (1.3%)

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swabs from 40 rooms.[5] The other study found contamination rates of 7/100 (7.0%) supplies from 20 rooms on contact precautions for VRE, and 9/100 (9.0%) supplies from 20 rooms with MDROs.[6] In comparison, our study, which collected swabs from isolated and non-isolated rooms, had 0/140 (0%) swabs positive for bacterial pathogens and 8/140 (5.7%) positive for bacterial non-pathogens. Although non-pathogens were not reported in the two adult studies, our results confirmed a similar low degree of contamination. These contamination rates are much lower than for other surfaces, for example electrocardiography lead wires (20–45%), stethoscopes (>60%), surfaces of mechanical ventilators (>60%), medical charts (>80%), and mobile phones (>50%).[34]

This study had several limitations. First, given that only 1/70 (1.4%) carts were on contact isolation precautions, there may have been limited opportunity for assessment of bacterial pathogen contamination. Nevertheless, we determined that bacterial pathogens that can potentially become MDRO and that often colonize hospitalized patients regardless of MDRO status, were not detected. Simply having acquired a resistance mechanism would not change the likelihood of detection or contamination with the same bacterial species onto bedside cart supplies. Second, considering our study design utilized waived consent and measures to preserve anonymity, patient-level details such as reasons for cart exclusions or for isolation (including viral illness), intubation status or tracheostomy, or exact age were not collected and could not be included in statistical analyses. The source of viral NAAT was therefore not determined, although there was no difference between rooms not versus on isolation. Third, there may be selection bias from exclusion of bedside carts during weekends and nights; however, patients with prolonged complex stays, likely at highest risk for supply contamination, preferentially are not discharged at those times. Although not tracked by a screening log, our impression was that cart exclusions were mainly due to discharges on weekends/nights. Fourth, we excluded rooms on C. difficile isolation, and findings cannot be applied to this circumstance. The bedside cart supplies were stored in closed drawers, and our results cannot be generalized to items stored in open areas (eg, on tables or counters, or in open bins). Only respiratory viral NAAT was used, and findings cannot be extrapolated to viral gastroenteritis pathogens. We did not consider Herpesviridae because as enveloped viruses they are not viable on dry surfaces for extended periods of time, and they are highly prevalent and intermittently shed by previously infected people for their lifetime. Fifth, the single center design with $n = 70$ carts may limit the generalizability of results. Sixth, bacterial or viral detection is only the first step in possible transmission between patients, and we did not examine possible transmission between patients. Finally, this was an observational study, and there were many unmeasured confounders, making the association with patient age hypothesis generating only. Limitations are further discussed in the supplemental material.

Strengths of this study included the prospective study design, collection of swabs on all consecutive eligible bedside carts, and collection of swabs in a protocolized manner during predefined research coordinator hours of availability. Waived consent avoided selection bias during study recruitment. Data collection was blinded to swab results, and lab processing was blinded to any patient information, which minimized research bias. To our knowledge, this is the first study to swab unopened sterile single-use supplies with paper packaging, to test for viruses, to sample both isolated and non-isolated rooms, and to study this topic in pediatrics.

Patient safety is a priority, but so is prudent and conscientious management of fiscal and environmental resources. Our study findings identified a low rate of contamination on unused paper-packaged supplies stored within drawers of bedside supply carts and answered a question many healthcare professionals consider important. If IPC leaders consider not discarding these unopened supplies within their institutions, there is considerable opportunity for waste reduction, environmental stewardship, and supporting health of children now and into the future.

Determining what should be done with unused single-use, paper-packaged supplies stored within drawers of bedside carts after patients are discharged from PICU should consider the impact on patient safety, the fiscal responsibility to publicly funded health care, and the importance of environmental sustainability. Contamination of supplies is the first necessary step for HAI transmission to plausibly occur from these supplies. Although we did not prespecify a threshold of detection indicating when to discard supplies, we determined the risk of bacterial contamination on these supplies to be extremely low, and the risk of respiratory viral NAAT contamination on these supplies to be low, suggesting that the risk of transmission to cause HAI was likely very low.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/ice.2026.10505

Data availability statement. The database used for this study is available from the corresponding author upon reasonable request.

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Author contribution. All authors made substantial contributions to conception or design of the work and interpretation of data for the work, reviewed the work critically for important intellectual content, made final approval of the version to be published, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. SS drafted the first version of the manuscript. SS and ARJ acquired the data. ARJ statistically analyzed the data. SS and ARJ had full access to all the data in the study and take responsibility for the integrity of data and the accuracy of the data analysis.

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Competing interests. All authors report no conflicts of interest relevant to this article.

Ethical standard. The study was approved by the University of Alberta Health Research Ethics Board on November 5, 2024 (PRO00146201), expiry September 22, 2026.

Consent to participate. A waiver of patient consent was approved by the Health Research Board as all data were anonymized. Study procedures were in accordance with the ethical standards of the University of Alberta and with the Helsinki Declaration of 1975, as most recently amended.

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