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Integrated clinical, environmental, and healthcare-worker hand surveillance for unit-level infection prevention prioritisation in a Mongolian tertiary hospital: a two-component observational study

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Abstract

Background

Integrating clinical surveillance with environmental cultures and healthcare-worker (HCW) hand sampling may help target infection prevention and control (IPC) action, but environmental or hand recovery alone does not establish transmission. We assessed unit-level IPC priorities in a Mongolian tertiary hospital and contextualised the institutional profile using national surveillance.

Methods

We combined a retrospective analysis of anonymised, IPC-reviewed, laboratory-positive healthcare-associated infection (HAI) records from 28 December 2022 to 31 December 2025 with a cross-sectional survey conducted in six units from 16 June to 3 July 2025. The survey sampled 131 high-touch surfaces, nine field-negative controls, and 68 HCW hand imprints. Cross-sectional isolates underwent MALDI-TOF mass spectrometry identification and VITEK 2 susceptibility testing. Monthly phenotype-confirmed MDRO-positive HAI records were analysed by negative-binomial regression with patient-days as an offset.

Results

Across 43,922 admissions and 275,922 patient-days, 2,458 HAIs were recorded (8.91 per 1,000 patient-days). Of 1,819 IPC-classified MDRO-positive HAI cases, 91.6% occurred in four service categories. Among 1,999 organisms recovered from these records, MRSA (32.3%) and ESBL-producing *Escherichia coli* (23.4%) predominated; *Acinetobacter baumannii* was most frequent in intensive care. After exclusion of six data-incomplete 2023 months, the temporal model did not provide evidence of an increase (incidence-rate ratio per year 1.08, 95% confidence interval 0.98–1.18; p = 0.11). Twenty-two of 131 surfaces (16.8%) were MDRO-positive, and 23 of 68 HCW hand imprints (33.8%) were MRSA-positive. Surgery Unit I and the intensive care unit were ranked top priority, and the Stroke Unit high priority.

Conclusions

Integrated surveillance identified a small number of units where clinical burden overlapped with environmental-surface and HCW-hand contamination. These findings support risk-stratified IPC and antimicrobial stewardship while remaining insufficient to infer directional transmission or clonal linkage.

Background

Antimicrobial resistance (AMR) and healthcare-associated infections (HAIs) remain major threats to patient safety, particularly in tertiary hospitals where invasive care, broad-spectrum antimicrobial

exposure, and high patient acuity concentrate risk [1–5]. Within these settings, multidrug-resistant organisms (MDROs) may be distributed unevenly across clinical units, making local surveillance essential for targeted infection prevention and control (IPC).

High-touch surfaces, shared equipment, and healthcare-worker (HCW) hands can form an ecological interface through which clinically important organisms persist or are transiently redistributed [6–11]. Environmental or hand cultures can therefore identify priorities for IPC verification, but they cannot establish source-reservoir relationships or direction of transmission without molecular epidemiology [12]. High-touch frequency is also an imperfect proxy for transmission relevance because mobile shared items and network-central surfaces may be more important than touch counts alone [13].

Mongolian national surveillance indicates substantial antimicrobial resistance pressure. The ARMOR-MN 2019–2023 report documented high resistance among major healthcare-associated pathogens and identified *Acinetobacter baumannii* as a leading organism in critical care [14]. Earlier Mongolian studies have reported under-recognised HAI burden, elevated device-associated infection rates, resistant ICU pathogens, and substantial Gram-negative MDRO carriage among hospitalised patients [15–19].

However, adult tertiary-hospital studies integrating longitudinal clinical surveillance with environmental and HCW-hand microbiology at unit level remain scarce, particularly in resource-constrained settings. We therefore combined three years of IPC-reviewed HAI surveillance with an epidemiologically directed cross-sectional survey of high-touch surfaces and HCW hands. Our objectives were to describe institutional and unit-level HAI and MDRO burden, identify environmental and hand contamination in selected units, and use converging signals to inform transparent operational IPC prioritisation. This integration addresses a practical gap: how routine and targeted surveillance can guide unit-level action without treating environmental concordance as proof of transmission. National surveillance was used only for qualitative contextualisation.

Methods

Study design and setting

This two-component observational study was conducted in an anonymised tertiary referral hospital in Ulaanbaatar, Mongolia. The retrospective component used laboratory-positive records reviewed and classified by the hospital IPC service as part of routine HAI/MDRO surveillance from 28 December 2022 to 31 December 2025. The study team received the IPC-validated dataset and performed secondary analyses of case counts, organism composition, unit distribution, and temporal patterns. Units for cross-sectional sampling were selected before microbiological results were known, using approximately 30 months of available surveillance data, clinical burden, patient acuity, invasive-care density, and feasibility. Sampling was undertaken from 16 June to 3 July 2025 in Anaesthesiology-Intensive Care (ICU), Isolation, Stroke, Surgery Unit I, Surgery Unit II, and the Sterilization Unit.

Case definitions and denominators

The IPC service classified laboratory-positive records using institutional criteria aligned with CDC/NHSN HAI definitions: the admission day was counted as day 1, infections meeting criteria on or after day 3 were classified as healthcare-associated, and surgical-site infections used the relevant 30- or 90-day surveillance window [20]. Present-on-admission or community-onset infections, asymptomatic colonisation, duplicate records, and records with insufficient classification data were excluded during routine IPC review. For case-level analyses, each IPC-validated MDRO-positive HAI record was counted once. For isolate-level summaries, all clinically reported pathogenic organisms from the same microbiology result were retained separately; therefore, polymicrobial records could contribute more than one organism. Admissions and patient-days were obtained from hospital statistics. Incidence density was standardised to total patient-days because unit-level device-days were not consistently available. The surveillance system retained the admitting unit after transfer, which could shift apparent burden toward admitting services.

Environmental and hand sampling

High-touch surfaces were sampled from patient-zone, staff-contact, and shared-equipment categories using a sterile 10 x 10 cm template and a pre-moistened sterile nylon-flocked swab applied in horizontal, vertical, and diagonal strokes with rotation. Swabs were transported in Amies medium at 2-8 °C and processed within two hours. Field-negative controls were sterile swabs opened at the sampling site without surface contact and processed identically. Hand imprints were collected immediately after patient care and before hand hygiene by pressing the fingertips and palm of the dominant hand onto nutrient agar for five seconds. They were interpreted as point-in-time transient contamination rather than persistent colonisation. Participation was voluntary and based on written informed consent.

Microbiology

For the cross-sectional survey, primary culture used 5% sheep-blood agar, MacConkey agar, Endo agar, nutrient agar, mannitol-salt agar, and CHROMagar MRSA, incubated at 37 °C and read at 18-24 h; CHROMagar MRSA was extended to 48 h when required. Representative morphotypes were subcultured to purity. Species identification was performed by MALDI-TOF MS (VITEK MS), and antimicrobial susceptibility testing by VITEK 2, interpreted according to CLSI M100 (35th edition, 2025) [21]. For phenotypic classification, MRSA, ESBL-producing Enterobacterales, carbapenem-resistant Enterobacterales (CRE), and carbapenem-resistant *A. baumannii* (CRAB) were assigned from species identification and available susceptibility results. Formal MDR/XDR/PDR classification was not assigned because the routine susceptibility panels did not consistently cover all antimicrobial categories required by Magiorakos et al. [22]. In retrospective isolate-level descriptions, *A. baumannii* and *P. aeruginosa* were retained as species labels when a standardised resistance phenotype was not available; accordingly,

these labels were not treated as phenotype-confirmed MDRO categories in the primary temporal analysis.

Statistical analysis and national contextualisation

Burden, organism composition, and unit-level distribution were summarised descriptively. Monthly IPC-classified MDRO-positive records from January 2023 to December 2025 were modelled using a conservative phenotype-based definition: MRSA, ESBL-producing Enterobacterales, CRE, and VRE when reported. Negative-binomial regression was used because of marked overdispersion, with the natural logarithm of monthly patient-days as an offset; results are reported as incidence-rate ratios (IRRs) with 95% confidence intervals (CIs). Data completeness was checked against the official infection register. Six 2023 months had implausibly low counts, and an incomplete February–June 2025 microbiology export was recovered from a secondary extract that matched the register. The complete-month model, excluding the six data-incomplete months, was treated as the primary interpretable temporal analysis; the full 36-month model and the 2024–2025 restriction were sensitivity analyses. Unit-level prioritisation descriptively juxtaposed clinical-burden categories used during the interim surveillance review with surface MDRO positivity and MRSA-positive HCW hand imprints. Priority tiers reflected convergence of operational signals and were intended to guide IPC verification, not to provide a validated risk score or infer transmission. For national contextualisation, annual organism–antibiotic resistance proportions were extracted from the ARMOR-MN 2019–2023 consolidated report [14] and visualised by the authors in R version 4.5.2. Only organism–antibiotic–year combinations with at least 30 tested isolates were displayed (Additional file 1: Figure S1); the corresponding machine-readable data are provided in Additional file 2. Institutional and national findings were compared qualitatively because the data sources differed in denominator and unit of analysis.

Use of generative artificial intelligence

ChatGPT (OpenAI) was used to support English-language editing, structural revision, and journal formatting during manuscript preparation; it was not used to generate the study data. All authors reviewed and revised the resulting text and take full responsibility for the manuscript.

Ethics

The retrospective component used anonymised routine surveillance and laboratory records without direct patient contact; individual consent was not required. The cross-sectional component was approved by the study hospital's Research Department (approval no. 2025/06/05/01; 5 June 2025), and participating HCWs provided written informed consent. All data were anonymised and reported in aggregate.

Results

Institutional and unit-level HAI and MDRO burden

During the surveillance period, the hospital recorded 43,922 admissions and 275,922 patient-days. A total of 2,458 HAIs were recorded, corresponding to an incidence density of 8.91 per 1,000 patient-days and a cumulative incidence of 5.60 per 100 admissions (Table 1). There were 1,819 IPC-classified MDRO-positive HAI cases. The associated records yielded 1,999 clinically reported organisms. MDRO-positive HAI burden was concentrated in General Surgery (632 cases, 34.7%) and Anaesthesiology-ICU (529, 29.1%), followed by Other wards (264, 14.5%) and the Emergency Department (241, 13.2%); together, these services accounted for 91.6% of all MDRO-positive HAI cases (Figure 1). General Surgery was recorded as an aggregate service in retrospective surveillance, whereas Surgery Units I and II were sampled separately by ward location.

Table 1. Institutional HAI and MDRO burden, December 2022–December 2025.

Indicator	Value
Admissions	43922
Patient-days	275922
Total HAIs	2458
HAI incidence density (per 1,000 patient-days)	8.91
HAI cumulative incidence (per 100 admissions)	5.60
MDRO-positive HAI cases	1819
Organisms from MDRO-positive HAI records	1999

MDRO, multidrug-resistant organism. Each IPC-validated MDRO-positive HAI record was counted once in case-level analyses. All clinically reported pathogenic organisms from the same microbiology result were retained in isolate-level summaries; therefore, case and organism counts differ. Incidence density was standardised to total patient-days because unit-level device-days were not consistently recorded.

Among organisms recovered from MDRO-positive HAI records, pus/wound specimens (699, 35.0%) and the heterogeneous 'other' category (610, 30.5%) predominated, followed by urine (286, 14.3%) and sputum (170, 8.5%). The most frequent organism/phenotype groups were MRSA (646, 32.3%), ESBL-producing *Escherichia coli* (468, 23.4%), *Acinetobacter baumannii* (295, 14.8%), *Pseudomonas aeruginosa* (196, 9.8%), and CRE (135, 6.8%) (Table 2). The species-only labels *A. baumannii* and *P. aeruginosa* represent organisms recovered from IPC-classified MDRO-positive records and should not be interpreted as uniformly phenotype-confirmed MDRO categories. The strongest specimen-organism intersection was pus/wound-MRSA (412 isolates; 58.9% of pus/wound isolates and 63.8% of all MRSA). Urine was dominated by ESBL-producing *E. coli* (171 isolates), whereas sputum was dominated by *A. baumannii* (56

isolates). In General Surgery, MRSA (309) and ESBL-producing *E. coli* (262) predominated; in the ICU, *A. baumannii* (237), MRSA (120), and CRE (59) were most frequent.

Table 2. Specimen types and leading organisms from MDRO-positive HAI records.

Category	n	%
Specimen type		
Pus / wound	699	35.0
Other	610	30.5
Urine	286	14.3
Sputum	170	8.5
Bile	96	4.8
Peritoneal fluid	64	3.2
Swab / smear	20	1.0
Blood	20	1.0
Leading organism/phenotype groups		
Methicillin-resistant Staphylococcus aureus (MRSA)	646	32.3
ESBL-producing Escherichia coli	468	23.4
Acinetobacter baumannii	295	14.8
Pseudomonas aeruginosa	196	9.8
Carbapenem-resistant Enterobacterales (CRE)	135	6.8
Mixed / multiple	89	4.5
ESBL-producing Klebsiella spp.	62	3.1
Stenotrophomonas maltophilia	27	1.4

ESBL, extended-spectrum beta-lactamase. Acinetobacter baumannii and Pseudomonas aeruginosa were retained as species-level labels when standardised resistance phenotypes were unavailable; they were not included in the conservative temporal definition.

Across the 30 data-complete months, conservative-definition MDRO incidence averaged 7.5 records per 1,000 patient-days (range 4.9–12.0). Six 2023 months contained implausibly low official counts; a separate February–June 2025 export gap was recovered from a secondary extract. In the complete-month model, there was no evidence of a temporal increase (IRR per year 1.08, 95% CI 0.98–1.18; p=0.11). The full-period model produced a positive estimate (IRR 1.35, 95% CI 1.28–1.43; p<0.001), but this estimate was driven by the six data-incomplete months. The 2024–2025 restriction was also non-

significant (IRR 1.12, 95% CI 0.97–1.31; p=0.13; Table 3; Figure 2). The temporal findings therefore do not support a robust increase in phenotype-confirmed MDRO-positive HAI records.

Table 3. Temporal models of monthly phenotype-confirmed MDRO-positive HAI records.

Specification	Months	IRR per year	95% CI; p
Excluding data-incomplete months	30	1.08	0.98–1.18; p=0.11
Full period	36	1.35	1.28–1.43; p<0.001
2024–2025 only	24	1.12	0.97–1.31; p=0.13

IRR, incidence-rate ratio; CI, confidence interval. The complete-month model excluding six data-incomplete 2023 months is the primary interpretable analysis. The full-period estimate is shown to demonstrate the effect of incomplete surveillance capture.

Environmental and hand contamination

All nine field-negative controls showed no growth, arguing against systematic contamination during collection or transport. Of 131 high-touch surfaces, 44 (33.6%) were culture-positive and 22 (16.8%) were MDRO-positive, yielding 65 organisms (mean 1.48 organisms per positive surface). Fourteen of 44 positive surfaces (31.8%) were polymicrobial. Surface MDRO positivity was highest in the Stroke Unit (7/16, 43.8%) and lowest in the Sterilization Unit (0/11) (Figure 3; Table 4). MRSA was the most frequent environmental MDRO (21/65 organisms, 32.3%), followed by *Pseudomonas aeruginosa*, *Acinetobacter nosocomialis*, and *Staphylococcus hominis* (five each); one CRAB isolate was recovered in the Stroke Unit.

Among 68 HCW hand imprints, 34 (50.0%) showed growth and 23 (33.8%) were MRSA-positive. Because samples were collected after patient care and before hand hygiene, they represent transient point-in-time contamination rather than persistent colonisation. MRSA positivity was highest in Surgery Unit I (10/25, 40.0%) and the ICU (10/27, 37.0%). By profession, positivity was 14/36 (38.9%) among nurses and 7/22 (31.8%) among physicians; comparisons are descriptive because denominators were small and uneven. One *Klebsiella pneumoniae* isolate was recovered from an ICU physician's hand.

Table 4. Cross-sectional surface and hand sampling outcomes by unit.

Unit	Surfaces n	Culture-positive	MDRO-positive	Hand MRSA-positive
Surgery Unit I	24	9 (37.5%)	8 (33.3%)	10/25 (40.0%)
Anaesthesiology–ICU	22	10 (45.5%)	3 (13.6%)	10/27 (37.0%)
Stroke Unit	16	10 (62.5%)	7 (43.8%)	2/6 (33.3%)
Isolation Unit	18	5 (27.8%)	3 (16.7%)	1/7 (14.3%)
Surgery Unit II	40	8 (20.0%)	1 (2.5%)	0/3 (0.0%)
Sterilization Unit	11	2 (18.2%)	0 (0.0%)	—
Total	131	44 (33.6%)	22 (16.8%)	23/68 (33.8%)

All nine field-negative controls showed no growth. Hand-imprint and surface denominators differ. The 68 hand imprints comprised samples from nurses (n=36), physicians (n=22), and residents (n=10). Hand sampling was a convenience sample with uneven per-unit numbers, limiting between-unit comparison.

Unit-level integration and operational prioritisation

Integration of the three data sources produced an exploratory four-tier operational prioritisation (Figure 4). Surgery Unit I and the ICU combined high clinical burden with measurable environmental-surface and HCW-hand contamination and were ranked top priority. The Stroke Unit, which had the highest environmental-surface MDRO positivity (43.8%) despite lower clinical burden, was ranked high priority. The Isolation Unit and Surgery Unit II were assigned to the watch tier, and the Sterilization Unit served as a baseline reference. Because the final retrospective dataset reported General Surgery as an aggregate service while cross-sectional sampling distinguished Surgery Units I and II, the matrix should be interpreted as a descriptive IPC planning tool rather than a validated comparative score. It does not establish transmission or clonal linkage.

Comparison with national surveillance

The institutional profile was qualitatively consistent with ARMOR-MN national surveillance. National data identified *Staphylococcus aureus* and *Escherichia coli* as dominant organisms and *A. baumannii* as a leading critical-care pathogen [14]. Similarly, MRSA and ESBL-producing *E. coli* predominated overall in this study, while *A. baumannii* was most frequent in the ICU. The cross-sectional recovery of MRSA and one CRAB isolate also occurred against a national background of substantial resistance among these organisms [14]. This contextual comparison is qualitative only because the national report is laboratory-based isolate surveillance, whereas the present study analysed IPC-reviewed HAI records and a targeted cross-sectional survey. The annual organism–antibiotic resistance landscape used for this qualitative contextualisation is provided in Additional file 1: Figure S1.

Discussion

This single-centre study combined three years of IPC-reviewed surveillance with an epidemiologically directed survey of high-touch surfaces and HCW hands. Three findings are most relevant for practice. First, IPC-classified MDRO-positive HAI burden was concentrated in a small number of services. Second, the organism profile differed by setting, with MRSA and ESBL-producing *E. coli* prominent in surgery and *A. baumannii* prominent in intensive care. Third, triangulation of clinical, surface, and hand signals identified Surgery Unit I, the ICU, and the Stroke Unit as priorities for IPC verification. This integrated profile would not have been visible from clinical or environmental data alone.

Concentration in surgical and intensive-care services is clinically plausible because these settings combine invasive procedures, wound burden, devices, high antimicrobial exposure, and frequent staff-patient contact. The observed organism pattern is consistent with national surveillance and with major healthcare-associated priority pathogens [12, 14, 23]. These findings support unit-specific microbiology review, locally tailored empirical-therapy guidance, and focused IPC audits rather than a uniform response across all wards.

The temporal analysis does not demonstrate a robust increase in phenotype-confirmed MDRO burden. The full-period association was driven by six data-incomplete 2023 months and was not sustained after their exclusion or in the 2024–2025 restriction. The time series should therefore be interpreted as evidence of surveillance-data fragility rather than a confirmed temporal rise. Future prospective surveillance should incorporate standardised case capture, antimicrobial-use data, staffing and occupancy measures, device-days, carriage surveillance, and molecular typing.

The cross-sectional results also require caution. Negative field controls support that observed growth reflected the sampled clinical environment rather than systematic collection or transport contamination. However, surface or hand recovery does not establish patient-to-environment, environment-to-hand, or hand-to-patient transmission [6–11, 24]. Hand imprints were collected after patient care and before hand hygiene; they therefore provide a high-risk process signal, not evidence of persistent carriage. The ICU *Klebsiella pneumoniae* hand isolate should be interpreted as a prompt for IPC verification, not as a transmission chain.

The Stroke Unit finding is operationally important because the highest surface MDRO positivity occurred despite a lower clinical case count. Potential explanations include shared-equipment use, patient dependency, cleaning-cycle effects, or unmeasured colonisation pressure. The appropriate response is targeted verification: observe cleaning practice and disinfectant contact time, review shared-equipment workflows, audit hand hygiene, and repeat sampling after corrective feedback. High-touch selection is a practical proxy, but it does not identify contact-network hubs; future work should combine microbiology with hand-to-surface network methods and genotyping [13].

Recent ICU contact-network work reinforces this distinction: surfaces most relevant to transmission may not be those touched most often, particularly when shared mobile items act as network hubs [13]. Our

study did not measure contact structure, and its single-timepoint surface survey cannot capture the full cleaning-recontamination cycle. These limitations define a practical next step rather than weaken the immediate value of targeted IPC verification.

Operationally, the findings support horizontal IPC foundations across all units, including hand-hygiene performance, environmental-cleaning reliability, and device-care bundles [25–27]. These should be paired with unit-specific microbiology review and antimicrobial stewardship [28]. For Surgery Unit I and the ICU, priorities are hand-hygiene audit and feedback, validation of cleaning for shared equipment, and review of empirical therapy. For the Stroke Unit, environmental cleaning and shared-equipment workflows warrant priority attention. Watch-tier units should undergo repeat review if clinical surveillance or follow-up sampling escalates.

Strengths include the integration of three years of IPC-reviewed laboratory-positive surveillance, prespecified negative-binomial sensitivity analyses, epidemiologically directed environmental sampling, HCW hand sampling with informed consent, and qualitative comparison with contemporary national surveillance. The study separates operational prioritisation from claims of transmission and reports data-completeness limitations transparently.

The limitations are substantial. This observational, single-centre design cannot establish transmission, clonal linkage, or the absence of pseudo-outbreaks. The retrospective dataset included only laboratory-positive, IPC-reviewed records and may not represent the full HAI burden. The temporal series was affected by data-completeness artefacts, while the broad sensitivity definition included species labels without uniformly coded resistance phenotypes. The surveillance system retained the admitting unit after transfer, which may misallocate burden. Surface sampling was a single snapshot, hand sampling was a convenience sample with uneven unit denominators, and baseline hand-hygiene compliance, cleaning audits, staffing ratios, device-days, and nasal MRSA carriage were not systematically measured. Carbapenem resistance was AST-derived, carbapenemase genes were not investigated, formal MDR/XDR/PDR classification was not assigned, and national comparison was qualitative rather than a numerical benchmark. The findings therefore identify priorities for targeted IPC verification, not baseline IPC performance or directional spread.

Conclusions

In this tertiary hospital, IPC-classified MDRO-positive HAI burden was concentrated in a small number of services and overlapped with environmental-surface and HCW-hand contamination in selected units. This integrated pattern supports risk-stratified IPC: maintain horizontal prevention foundations across the hospital, then intensify targeted cleaning, hand-hygiene, equipment-workflow, microbiology-review, and antimicrobial-stewardship measures in the highest-priority units. Because transmission was not confirmed molecularly, the findings provide operational priorities and a baseline for prospective, genotyping-enabled multi-centre work rather than proof of directional spread.

Abbreviations

AMR, antimicrobial resistance; AST, antimicrobial susceptibility testing; CI, confidence interval; CRAB, carbapenem-resistant *Acinetobacter baumannii*; CRE, carbapenem-resistant Enterobacterales; ESBL, extended-spectrum beta-lactamase; HAI, healthcare-associated infection; HCW, healthcare worker; ICU, intensive care unit; IPC, infection prevention and control; IRR, incidence-rate ratio; MALDI-TOF MS, matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry; MDR, multidrug-resistant; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; PDR, pandrug-resistant; VRE, vancomycin-resistant Enterococcus; XDR, extensively drug-resistant.

Declarations

Ethics approval and consent to participate

The retrospective component used anonymised routine surveillance and laboratory records without direct patient contact; individual consent was not required. The cross-sectional component was approved by the study hospital's Research Department (approval no. 2025/06/05/01; 5 June 2025), and participating HCWs provided written informed consent. All data were anonymised and reported in aggregate.

Consent for publication

Not applicable.

Availability of data and materials

Aggregated data supporting the findings are available from the corresponding author on reasonable request. Individual-level routine surveillance and hand-sampling records are not publicly available because of confidentiality undertakings. National surveillance data used for contextualisation are published in the ARMOR-MN consolidated report [14]. The author-generated visualisation and its filtered machine-readable dataset are included as Additional files 1 and 2.

Competing interests

OT and GT are affiliated with Medclean LLC, which funded the study. The remaining authors declare that they have no competing interests.

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Medclean LLC provided financial and material support for the study. OT and GT, who are affiliated with Medclean LLC, contributed as investigators as described below. Beyond those investigator contributions, the funding organisation had no additional role in data analysis, interpretation, manuscript preparation, or the decision to submit the manuscript.

Authors' contributions

OT contributed to conceptualisation, methodology, formal analysis, data curation, visualisation, writing the original draft, review and editing, and project administration. TD contributed to conceptualisation, methodology, investigation, formal analysis, data curation, and review and editing. GT contributed to conceptualisation, resources, supervision, project administration, and review and editing. UT, OM, KB, TT, SEA, ABa (Aminaa Bayaraa), and ABd (Anudari Badral) contributed to investigation, resources, data curation, and review and editing. All authors read and approved the final manuscript.

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Figures

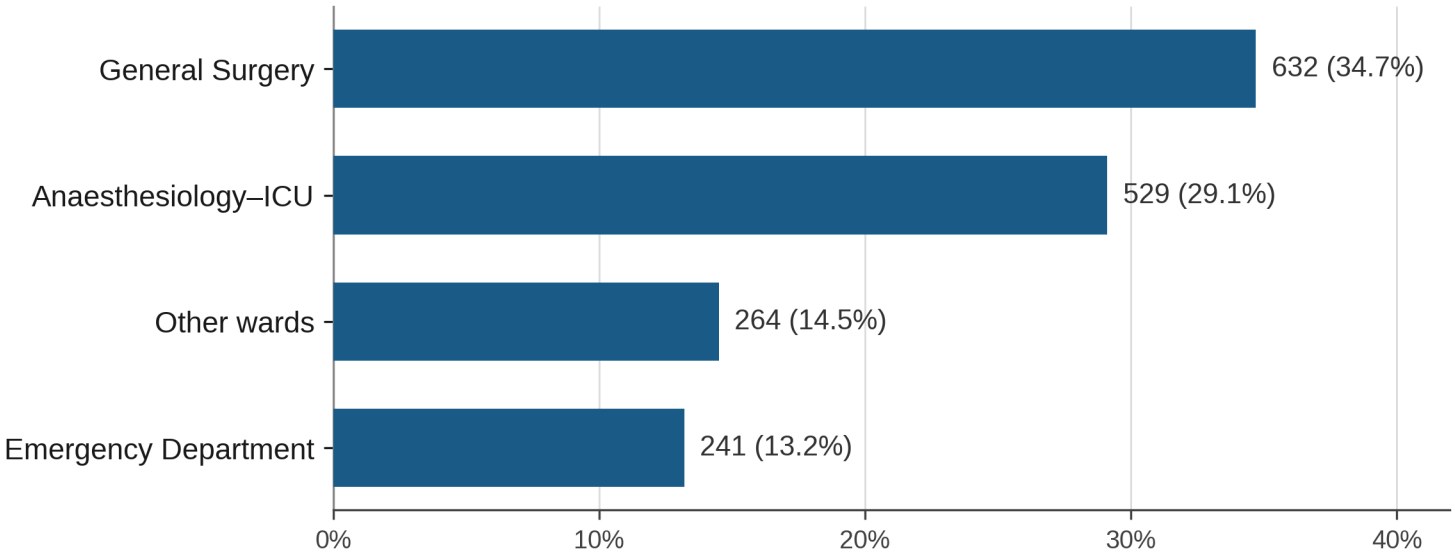


Figure 1

Distribution of MDRO-positive HAI cases across service categories. Four service categories accounted for 91.6% of all 1,819 MDRO-positive HAI cases; General Surgery and Anaesthesiology–ICU alone contributed 63.8%. ‘Other wards’ pools all services other than General Surgery, intensive care, and emergency.

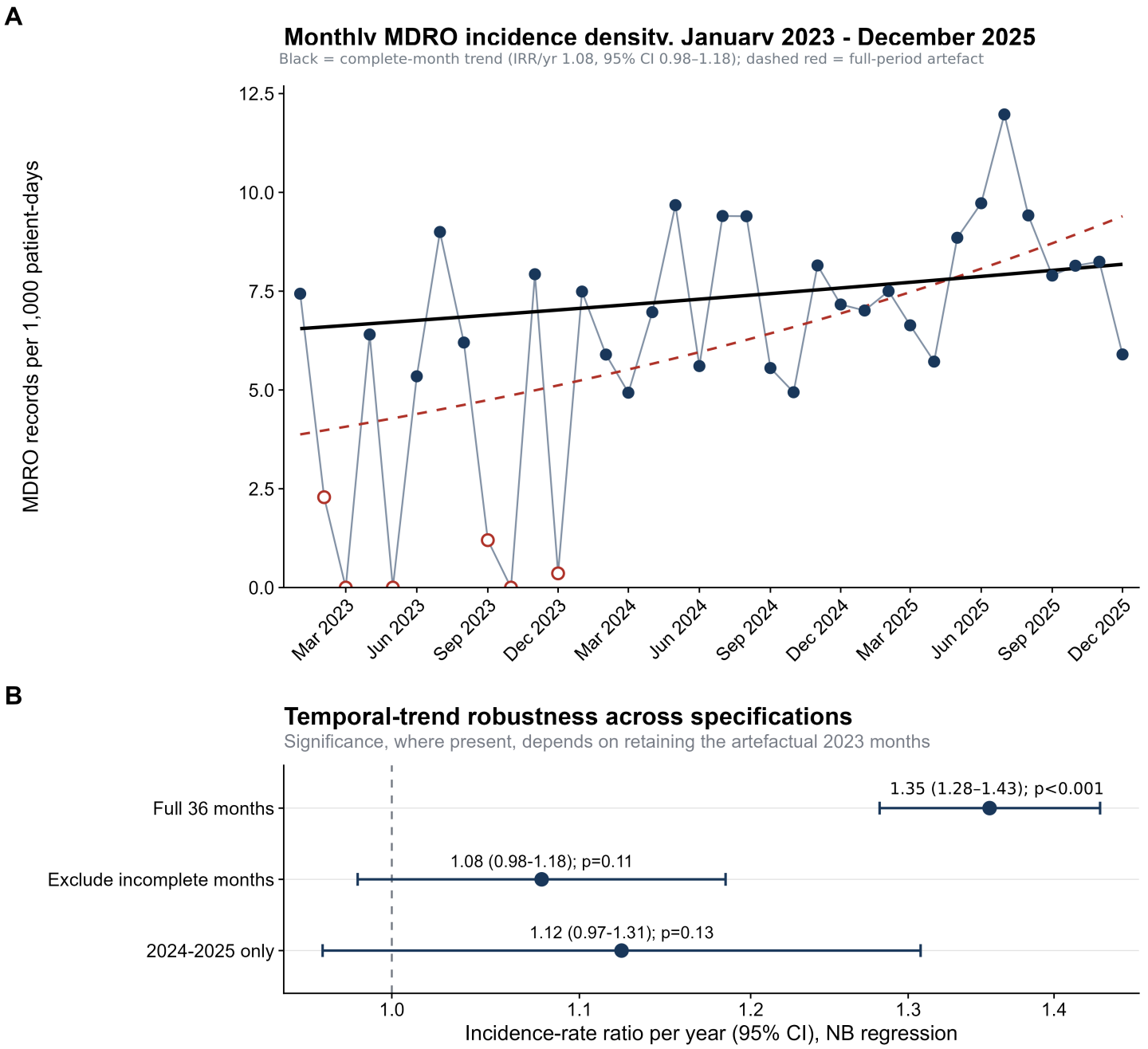


Figure 2

Monthly phenotype-confirmed MDRO incidence density and temporal-model sensitivity. (A) Monthly IPC-classified MDRO-positive HAI records per 1,000 patient-days. Filled points denote data-complete months; open points denote six data-incomplete 2023 months. February–June 2025 are shown after recovery from a secondary extract. The solid line is the complete-month negative-binomial trend; the dashed line is the full-period trend. (B) IRRs per year across the three model specifications. The full-period estimate is driven by incomplete surveillance capture.

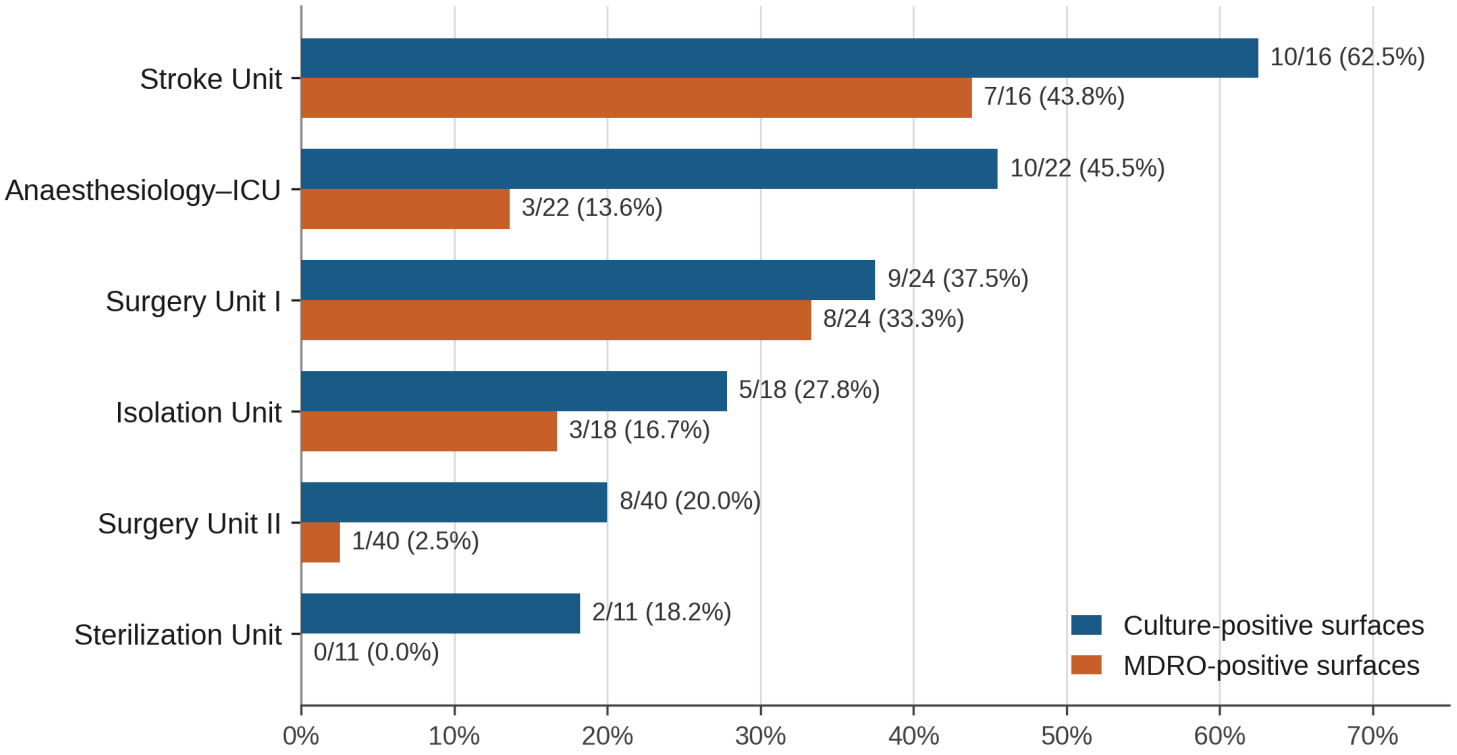


Figure 3

Environmental surface culture and MDRO positivity by unit. Sampling was conducted from 16 June to 3 July 2025. All nine field-negative controls showed no growth. Overall, 44/131 (33.6%) surfaces were culture-positive and 22/131 (16.8%) were MDRO-positive. The Stroke Unit had the highest surface MDRO positivity despite a lower clinical-burden category.

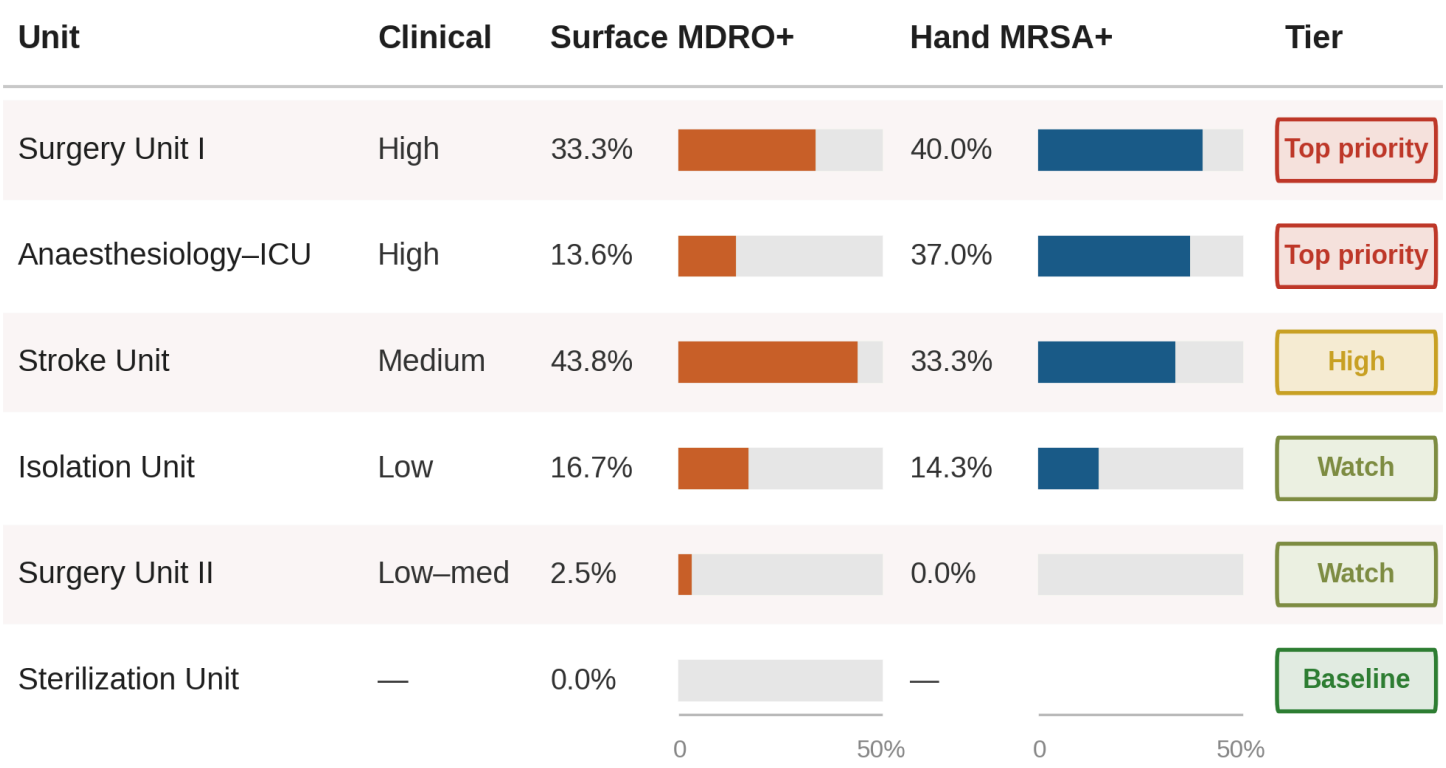


Figure 4

Exploratory unit-level IPC prioritisation matrix. The matrix juxtaposes clinical-burden categories, environmental-surface MDRO positivity, and MRSA positivity in HCW hand imprints. Bars are scaled to 0–50%. Clinical categories derive from the interim surveillance review; final retrospective reporting aggregated General Surgery. Tiers indicate operational priorities and do not imply transmission or molecular linkage.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1FigureS1ARMORMNresistancelandscape.pdf
- Additionalfile2TableS1ARMORMNheatmapdata.csv