

Deployable ultraviolet systems for environmental surface disinfection in healthcare: a scoping review linking dose delivery, room-scale performance and infection-prevention outcomes

Cristiano Salata

`cristiano.salata@unipd.it`

University of Padua

Ilenia Crozzoletti

University of Padua

Paola Brun

University of Padua

Claudia Del Vecchio

University of Padua

Ignazio Castagliuolo

University of Padua

Systematic Review

Keywords: ultraviolet-C, pulsed xenon, surface disinfection, scoping review, environmental cleaning, antimicrobial resistance, multidrug-resistant organisms, healthcare-associated infection, disinfection robot, implementation

Posted Date: October 12th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11228171/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Ultraviolet (UV) systems are increasingly used as no-touch adjuncts to environmental cleaning, but healthcare evidence spans heterogeneous sources, deployment configurations, room geometries and outcome types. The practical question for infection prevention is therefore not only whether UV is germicidal, but whether an effective surface dose can be delivered under healthcare conditions and translated into environmental and patient-level benefit.

Methods

We conducted a scoping review of deployable UV-based surface-disinfection systems in healthcare. PubMed was searched on 1 September 2026 for publications from 1 January 2010 through 1 September 2026 using a structured high-sensitivity query combining controlled vocabulary and title/abstract terms for ultraviolet radiation, healthcare settings, surfaces/rooms and disinfection. The search returned 643 records. Review-type records were identified and removed in PubMed using the Review publication-type filter ($n = 437$), leaving 206 records for reviewer assessment. Two reviewers completed title/abstract screening and full-text eligibility assessment. Eligible reports then underwent data extraction, descriptive analysis and evidence mapping. Eligibility followed a Population–Concept–Context framework and focused on portable/mobile automated systems or operator-positioned UV sources used for a defined treatment cycle in routine healthcare, healthcare rooms or full-scale simulated hospital rooms. Permanently fixed wall/ceiling systems, handheld devices and dosimetry-only studies without a direct microbiological surface endpoint were excluded.

Results

Seventy distinct studies were represented by 71 reports: 43 R1, 17 R2, and 10 R3 studies. The additional report was a prespecified secondary analysis of the Benefits of Enhanced Terminal Room (BETR) disinfection trial and was not counted as a separate study. Directly exposed surfaces often showed substantial microbial reductions, whereas distance, shadowing, organic soil, spores and difficult geometry reduced performance. Nineteen R1 studies reported infection, acquisition, or healthcare-associated infection outcomes attributed to environmental transmission, including program-level measures. Randomized evidence was mixed: BETR disinfection found benefit for UV-C added to standard terminal cleaning, whereas the cancer/transplant cluster-randomized study and the sham-controlled LAMP trial found no clinical reduction. No evaluation measured the complete pathway from delivered surface dose through environmental reduction to patient outcome.

Conclusions

UV surface disinfection is best understood as a deployment system in which source, positioning, delivered dose, room geometry, organism, target surfaces and workflow jointly determine performance. Environmental bioburden findings were most consistently favorable, while patient-level effects were context dependent. Linking dosimetry, microbiology, implementation coverage and clinical outcomes within the same evaluation is a major priority for future infection-prevention research.

Background

Environmental surfaces can contribute to persistence and transmission of healthcare-associated pathogens, particularly when high-touch sites remain contaminated after manual cleaning. Manual cleaning is indispensable, but performance varies with staffing, training, contact time, surface accessibility and local workflow. Ultraviolet (UV)-based systems are therefore used as adjunctive, no-touch interventions intended to reduce residual contamination after routine or terminal cleaning [1–5].

Several reviews have addressed ultraviolet or broader no-touch environmental disinfection in healthcare from complementary perspectives, including healthcare-associated infection prevention, UV-C efficacy and safety, high-touch-surface performance, whole-room implementation and device-specific evidence [6–8]. For example, Marra et al. synthesized no-touch UV and hydrogen-peroxide strategies [6], Ramos et al. reviewed hospital UV-C efficacy and safety [7], and Resendiz et al. focused on germicidal effectiveness across high-touch surfaces in the immediate patient environment [8]. More recent syntheses have examined automated decontamination and implementation [9, 10], healthcare-associated infection outcomes [11], pulsed-xenon systems [12], and UV-C device and parameter mapping [13]. A broader 2026 systematic review of randomized and quasi-randomized hospital surface-decontamination interventions also highlighted persistent uncertainty in patient-centred outcomes, including UV comparisons [14]. The present review uses a broader healthcare-relevant evidence architecture while retaining a specific deployment scope: portable/mobile automated or operator-positioned UV systems are mapped across routine care, field-efficacy experiments and full-scale room studies, and interpreted along the pathway from delivered dose to environmental and patient outcomes.

A scoping-review approach is appropriate when the objective is to map a heterogeneous evidence base, describe how a concept has been studied and identify gaps rather than estimate a single pooled intervention effect [15, 16]. The objective of this review was therefore to map deployable UV-emitting technologies evaluated for environmental surface disinfection in healthcare, characterize the settings and experimental designs in which they were tested, compare microbiological, clinical and operational outcomes, and identify technical and implementation factors that explain why germicidal efficacy may not translate directly to room-scale or routine-care performance.

Methods

Review design and questions

The review was structured as a scoping review and reported with reference to the PRISMA extension for Scoping Reviews (PRISMA-ScR) [15]. The Population–Concept–Context framework was defined as follows: Population, healthcare environmental surfaces and microorganisms contaminating those surfaces; Concept, deployable UV-based surface disinfection, including source characteristics, deployment configuration, delivered dose, microbiological performance, clinical outcomes and implementation; Context, routine healthcare environments, genuine occupied or unoccupied patient-care or clinical-service rooms, and full-scale simulated hospital rooms designed to reproduce clinically relevant geometry and operating conditions. Eligible interventions were portable/mobile automated systems or UV sources deliberately positioned by an operator for a defined treatment cycle. Permanently fixed wall- or ceiling-mounted irradiation systems and handheld spot-disinfection devices were outside the review scope. This deployment boundary was chosen to focus on systems requiring room-by-room deployment or deliberate operator positioning and therefore directly interacting with environmental-services workflow, treatment coverage and room turnover. High-level disinfection or reprocessing of critical or semicritical medical devices was outside scope; external surfaces of noncritical patient-care equipment were eligible when evaluated as part of environmental hygiene. Eligible studies had to report a microbiological surface outcome, a patient outcome linked to an eligible UV surface intervention, or an operational outcome directly tied to its implementation; dosimetry-only or model-only studies without a directly measured microbiological surface endpoint were excluded.

The review addressed five questions: (1) which UV sources and deployable configurations have been evaluated for healthcare surface disinfection; (2) in which healthcare or full-scale room contexts have they been studied; (3) which environmental, clinical and operational outcomes have been reported; (4) which technical and contextual factors modify performance; and (5) where do evidence and reporting gaps remain for infection prevention and antimicrobial-resistance control?

A prospective protocol for this scoping review was not written, registered, or publicly posted.

Search strategy and study selection

PubMed (National Library of Medicine, National Institutes of Health) was searched on 1 September 2026 for publications dated from 1 January 2010 through 1 September 2026. The 2010 lower date limit was chosen to focus the review on contemporary deployable UV technologies and their implementation in healthcare. A structured high-sensitivity query combined controlled vocabulary and title/abstract terms for ultraviolet radiation, healthcare settings, surfaces/rooms and disinfection and returned 643 records. Review-type records were then identified and removed directly in PubMed using the Review publication-type filter (n = 437), leaving 206 records for reviewer assessment. The complete reproducible query is provided in Additional file 1.

Two reviewers independently screened the 206 records remaining after removal of review-type publications and assessed full text when a record was potentially eligible. Study selection was conducted with disagreements resolved by discussion. Eligibility was restricted to primary studies

evaluating portable/mobile automated UV systems or operator-positioned UV sources used for a defined treatment cycle for environmental surface disinfection in healthcare or full-scale simulated healthcare rooms. Air-only interventions, permanently fixed wall/ceiling installations, handheld spot-disinfection devices, high-level reprocessing of critical or semicritical medical devices, and dosimetry- or model-only studies without a directly measured microbiological surface endpoint were excluded. After study selection, data were extracted from the included reports and used for descriptive analysis and evidence mapping.

After completion of study selection, 71 reports representing 70 distinct studies met the eligibility criteria. Anderson et al. 2018 was retained as a companion secondary analysis of the Benefits of Enhanced Terminal Room disinfection (BETR) trial and was not counted as a separate study. The final study-selection process is summarized in Fig. 1.

Figure 1. Study-selection flow and evidence strata. The structured PubMed search run on 1 September 2026 returned 643 records. Review-type records were identified and removed in PubMed using the Review publication-type filter (n = 437), leaving 206 records for screening by two reviewers. Seventy-one reports representing 70 distinct studies met the eligibility criteria; one BETR companion report was not counted as a separate study.

Of the 206 records assessed by the reviewers, 135 were excluded during title/abstract screening or full-text eligibility assessment, leaving 71 included reports representing 70 distinct studies. The final evidence base comprised 43 R1 routine-care studies represented by 44 reports, 17 R2 healthcare field-efficacy studies represented by 17 reports, and 10 R3 healthcare-room/full-scale studies represented by 10 reports.

Data charting and evidence mapping

Following completion of study selection, data charting and extraction were performed by one reviewer using a structured evidence map. For each included study, charted variables included healthcare setting, study design, contamination model, UV source and wavelength, deployment configuration, target surfaces, occupancy conditions, comparator, exposure time or delivered dose, positioning, microorganisms, quantitative outcomes, operational findings, limitations and sponsorship. No independent duplicate data extraction was performed. Because study designs and outcome metrics were heterogeneous, findings were summarized descriptively rather than statistically pooled. No formal critical appraisal or risk-of-bias assessment of the included studies was performed. Consistent with the evidence-mapping objective of the scoping review, methodological characteristics relevant to interpretation were instead descriptively charted, including study design, comparator structure, outcome directness, co-interventions, precision, dose verification and implementation coverage.

Generative AI support. OpenAI ChatGPT was used to assist with refinement of the structured PubMed search strategy, organization of evidence tables, manuscript formatting and language editing. The tool was not used as an autonomous eligibility decision-maker; study-selection decisions and scientific

interpretation were made by the authors, who retain responsibility for verification of extracted data, references and final manuscript content.

The included studies were stratified by proximity to routine use. R1 comprised routine-care studies using natural surface contamination, clinical outcomes or operational outcomes. R2 comprised field-efficacy studies in genuine healthcare settings that combined natural sampling with inoculated carriers, controlled challenges or mixed laboratory components. R3 comprised microbiological room-scale studies performed in unoccupied healthcare rooms or full-scale simulated hospital rooms using eligible mobile or operator-positioned sources. These strata were not treated as a hierarchy of methodological quality; they describe different forms of evidence and answer different questions.

Results

Evidence map and device architectures

The final evidence map contains 70 distinct studies represented by 71 reports: 43 R1 (61.4%), 17 R2 (24.3%) and 10 R3 (14.3%) studies (Table 1). Within R1, 19 of 43 studies (44.2%) reported clinical, acquisition or program-level healthcare-associated infection (HAI) outcomes, whereas 24 (55.8%) were primarily environmental or operational. Pulsed-xenon systems were evaluated in 23 of 70 studies (32.9%), and robotic or autonomous configurations in 12 (17.1%); source/configuration categories were not mutually exclusive.

Table 1
Evidence-map summary for the 70 distinct included studies

Evidence stratum	N / (%)	Typical setting/design	Primary interpretive role
R1 – Routine-care surface effectiveness	43 / (61.4%)	Routine healthcare; natural contamination, implementation programs, acquisition/infection studies	Operational effectiveness; environmental and patient/program outcomes
R2 – Healthcare field efficacy	17 / (24.3%)	Genuine healthcare settings with carriers/inocula or mixed laboratory components	Efficacy modifiers under real healthcare geometry
R3 – Healthcare-room/full-scale performance	10 / (14.3%)	Unoccupied genuine rooms or full-scale simulations; eligible mobile/operator-positioned sources	Room geometry, shadowing, distance and delivered-dose translation

At least 38 of 71 reports (53.5%) documented direct commercial involvement, defined as manufacturer/company funding, provision or loan of devices, materials or data, company technical support, or company/developer authorship; generic unrelated industry disclosures alone were not counted. Only one study evaluated operator-positioned 222-nm far-UVC [17] and one used a near-UV/UV-A LED robotic system at 340–385 nm (peak approximately 365 nm) [18], underscoring the predominance of conventional germicidal UV-C evidence. The additional report is a companion secondary analysis of

BETR disinfection [19] and is not counted as an independent study. Mobile continuous UV-C and pulsed-xenon systems account for most of the evidence, with robotic, multi-emitter, targeted/articulating and operator-positioned configurations also represented. The near-UV/UV-A study used SARS-CoV-2 RNA as its principal surface endpoint and is interpreted separately from the germicidal UV-C evidence.

Table 2 summarizes a multiaxial framework in which each system is described by source and spectrum, deployment configuration, evidence setting, surface target and dose-control strategy.

Table 2
Multiaxial description of deployable UV surface-disinfection systems represented in the 70 included studies

Axis	Categories represented in the included studies	Comparative implication
Source and spectrum	Low-pressure mercury UV-C; pulsed-xenon UV; other continuous germicidal UV-C; operator-positioned filtered 222-nm far-UVC; one near-UV/UV-A LED robotic system (340–385 nm, peak ~ 365 nm)	Determines spectral output, pulse structure, organism susceptibility, dose and safety requirements. The near-UV/UV-A study is sparse and should not be generalized to UV-C.
Deployment configuration	Mobile stationary whole-room; targeted/articulating; multi-emitter; autonomous or semi-autonomous robot; operator-positioned portable luminaires	Determines positioning, shadow management, setup burden, repeatability, traceability and dependence on staff. Permanent wall/ceiling installations and handheld devices are outside scope.
Evidence setting	R1 routine healthcare; R2 genuine healthcare field efficacy; R3 unoccupied healthcare room or full-scale simulated hospital room	Separates operational effectiveness, field efficacy and room-scale performance without discarding realistic empty-room evidence.
Surface target and coverage	High-touch surfaces; whole-room surfaces; selected equipment; direct and indirect sites	Defines which surfaces actually receive the measured dose and to which locations the microbiological result applies.
Dose-control strategy	Fixed time; reflected-dose endpoint; radiometer/sensor mapping; multiple placements; navigation/path-planning algorithm	Determines whether intended dose reaches direct and shaded locations and whether cycle completion can be verified.

Routine-care surface effectiveness (R1)

Based on the primary outcome domain, 24 of the 43 R1 studies (55.8%) focused primarily on environmental or operational outcomes. Additional UV treatment frequently reduced residual surface contamination, but the expanded map also contains neutral comparisons and strong context dependence. Anderson et al. reported a 1.35-log10 overall reduction in target pathogens across 39 patient rooms [20]. In a cystic-fibrosis outpatient clinic, Allen et al. found that UV-C produced significant

colony-forming unit (CFU) reductions across sampled surfaces after inconsistent effects of manual cleaning, with 10–20-min treatments and repositioning in some rooms [21]. Armellino et al. reported 90-second focused multivector UV cycles with approximately 92–99.6% reductions on patient-care equipment [22], while Jinadatha et al. found larger methicillin-resistant *Staphylococcus aureus* (MRSA) and heterotrophic-count reductions with pulsed-xenon UV than with manual cleaning in 20 post-discharge rooms [23]. Choi et al. evaluated a 340–385-nm UV-LED robot in COVID-19 rooms and observed lower SARS-CoV-2 RNA positivity after irradiation, but no viable virus was recovered and performance varied by room geometry [18]. During the Rwanda Marburg outbreak, Uwayo et al. reported that two equipment sites remaining RT-PCR-positive after chemical disinfection became negative after 254-nm UV-C robot deployment [24]. Dexter et al. contributed operational rather than microbiological evidence from 133,927 treatments in 700 rooms, showing a pooled mean duration of 18.3 min and substantial room-specific variability [25]. These findings reinforce that efficacy, coverage and workflow must be interpreted together rather than assuming uniform benefit from device deployment.

The remaining 19 R1 studies (44.2%) reported infection, acquisition or program-level HAI outcomes, represented by 20 reports because BETR disinfection has both a primary and a prespecified secondary report (Table 3). Randomized clinical evidence was mixed. In the BETR disinfection pragmatic cluster-randomized multicentre crossover trial, adding UV-C to standard terminal cleaning reduced the composite target-organism acquisition/infection outcome (RR 0.70, 95% CI 0.50–0.98), whereas adding UV-C to bleach did not reduce *Clostridioides difficile* infection [26]. Its prespecified hospital-wide secondary analysis found a borderline composite effect for the UV period (RR 0.89, 95% CI 0.79–1.00; $P = 0.052$), with lower *C. difficile* and vancomycin-resistant enterococci (VRE) acquisition [19]. In a separate cluster-randomized crossover trial in cancer and transplant units, daily plus discharge UV-C did not reduce VRE or *C. difficile* [27]. The Lowering the Acquisition of Multidrug-resistant organisms with Pulsed-xenon (LAMP) double-blinded cluster-randomized crossover trial likewise found no reduction in HAIs with pulsed-xenon UV versus sham after terminal cleaning (3.49 vs 3.17 infections/1000 patient-days; RR 1.10, 95% CI 0.94–1.29; $P = 0.23$) [28]. Large observational evidence was also mixed: Hodges et al. found no reduction in pathogen transfer from prior room occupants [29], whereas Haas et al. [30] and Pegues et al. [31] reported favorable associations in different settings. An early two-resident long-term-care case report linked UV decontamination with reduced residual environmental *C. difficile* and no further reported recurrences, but its design does not support causal inference [32].

Table 3

Clinical, acquisition and program-level findings from all 19 R1 studies reporting these outcomes

Study	Setting/design + UV deployment	Clinical/acquisition/program finding	Main interpretive limitation
Sitzlar et al. [32]	Two-resident case report; long-term-care shared room; automated UV room/bathroom treatment to a reflected-dose endpoint.	After UV treatment, only one bedrail colony of <i>C. difficile</i> was recovered; both residents subsequently had negative rectal swabs and no further CDI during the reported follow-up.	Only two residents; uncontrolled case report; recurrence cannot be causally attributed to UV.
Haas et al. [30]	Retrospective acute-care implementation study; portable/mobile UV room-disinfection units deployed after discharge cleaning.	MDRO + <i>C. difficile</i> rate decreased from 2.67 to 2.14/1000 patient-days; rate ratio 0.80 (95% CI 0.73–0.88).	Historical comparison; 76% coverage; residual confounding and concurrent changes possible.
Napolitano et al. [33]	Facility-wide pre-post intervention pilot; mobile continuous UV-C delivered by trained dedicated personnel with coverage monitoring.	HAI incidence decreased by 1.3/1000 patient-days (34.2%) after implementation, with lower overall infection burden during higher treatment coverage.	Uncontrolled pre-post design; no concurrent control; possible co-interventions and secular trends.
Nagaraja et al. [34]	Before/during acute-care implementation analysis; pulsed-xenon UV mobile room disinfection after routine cleaning.	Hospital-acquired CDI was 22% lower during UV use, but the difference did not reach conventional statistical significance ($P = 0.06$).	Historical before-after design; limited causal attribution.
Vianna et al. [35]	Community-hospital before-after implementation; pulsed-xenon UV using three 5-min positions after cleaning.	Combined <i>C. difficile</i> /MRSA/VRE rate decreased 29% facility-wide ($P = 0.01$) and 61% in ICU ($P = 0.01$); organism-specific effects were heterogeneous.	Uncontrolled historical comparison; concurrent infection-prevention changes and industry involvement.
Anderson et al. [19, 26]	Pragmatic cluster-randomized multicentre crossover trial; mobile continuous UV-C added to terminal cleaning; companion hospital-wide secondary analysis.	Primary report: UV + standard cleaning RR 0.70 (95% CI 0.50–0.98); UV + bleach did not reduce <i>C. difficile</i> infection (RR 1.00, 95% CI 0.57–1.75). Secondary report: UV period RR 0.89 (95% CI 0.79–1.00; $P = 0.052$), with lower <i>C. difficile</i> and VRE acquisition.	Randomized multicentre design supports causal interpretation for specified comparisons, but effects varied by pathogen/strategy and no linked room-level dosimetry or environmental mediator was measured.

Study	Setting/design + UV deployment	Clinical/acquisition/program finding	Main interpretive limitation
Kovach et al. [36]	Single-site nursing-home before-after study with environmental/clinical surveillance; pulsed-xenon UV whole-room treatment after discharge cleaning.	Environmental positivity fell from 33% at baseline to 7.1% after cleaning and 4.4% after UV; infections and infection-related hospitalizations also decreased during the intervention.	Uncontrolled single-site pre-post design; temporal confounding and regression to the mean possible.
Pegues et al. [31]	Interrupted time series in hematology-oncology units; no-touch mobile UV-C terminal disinfection targeted through an electronic patient-flow system.	<i>C. difficile</i> incidence IRR 0.49 (95% CI 0.26–0.94; P = 0.03), with no corresponding decrease on non-study units.	Non-randomized unit-level design; only 21.1% of eligible discharges received UV.
Pavia et al. [37]	Pediatric long-term-care before-after study; a mobile continuous UV-C device rotated among rooms approximately three times weekly.	Viral infection incidence IRR 0.56 (95% CI 0.37–0.84).	No concurrent control or environmental endpoint; device donation and company authorship.
Raggi et al. [38]	Community-hospital pre-post cohort with operational/cost analysis; facility-wide mobile continuous UV-C terminal-disinfection service.	HAI rate decreased from 4.87 to 3.94/1000 patient-days (–19.2%; P = 0.006); USD 1.22 million direct savings were reported.	Uncontrolled; financial estimate did not fully subtract intervention costs; residual confounding possible.
Brite et al. [39]	Interrupted time series in a bone-marrow-transplant unit; mobile terminal-room UV environmental disinfection.	No significant reduction in VRE or <i>C. difficile</i> acquisition/incidence after UV implementation.	Single specialized unit; no linked environmental mediator.
Schaffzin et al. [40]	High-occupancy implementation program; two pulsed-xenon UV robots operated by dedicated technicians with coverage monitoring.	Coverage reached 85.7% of isolation rooms and 87.7% of priority rooms; HAI rates decreased 16.2% after implementation.	Program evaluation with concurrent cleaning initiatives; cannot isolate a causal UV effect.
Morikane et al. [41]	ICU before-after clinical/environmental study; pulsed-xenon UV mobile unit added to terminal cleaning.	MRSA incidence decreased from 13.8 to 9.9/10,000 patient-days (IRR 0.71); drug-resistant <i>Acinetobacter</i> from 48.5 to 18.1 (IRR 0.37); environmental counts also declined.	Single centre; co-interventions and temporal trends possible.

Study	Setting/design + UV deployment	Clinical/acquisition/program finding	Main interpretive limitation
Kitagawa et al. [42]	Quasi-experimental before-after study; pulsed-xenon UV adjunct to manual terminal cleaning with routine terminal-cycle deployment.	MRSA acquisition decreased from 3.56 to 2.21/1000 patient-days; adjusted IRR 0.556 (95% CI 0.309–0.999).	Non-randomized; borderline confidence interval; possible secular/co-intervention effects.
Hodges et al. [29]	Retrospective cohort across six hospitals; adjunct mobile UV-C after chlorine-based terminal cleaning.	Prior-room pathogen transfer: adjusted OR 1.06 (95% CI 0.84–1.32; P = 0.64).	Non-random treatment allocation; no demonstrated benefit.
Rock et al. [27]	Cluster-randomized crossover in cancer/transplant units; mobile UV-C integrated into daily and discharge room cleaning.	VRE IRR 0.98 (95% CI 0.78–1.22); <i>C. difficile</i> IRR 1.43 (95% CI 0.93–2.21).	Five clusters; high-risk population; no linked dosimetry/environmental mediator.
Dhar et al. [28]	Cluster-randomized, double-blinded crossover trial in two hospitals/15 wards; pulsed-xenon UV versus visually indistinguishable sham after terminal cleaning.	Environmentally implicated HAIs: 3.49 vs 3.17/1000 patient-days; RR 1.10 (95% CI 0.94–1.29; P = 0.23).	Large sham-controlled randomized null result; no linked room-level mediator; manufacturer provided equipment/technical support.
de la Rosa-Zamboni et al. [43]	Four-period before-after bundle study in a NICU; UV-C terminal disinfection combined with subsequent copper-surface intervention and other IPC measures.	HAIs decreased from 11.03 to 5.35/1000 patient-days; bacterial-isolate HAIs from 5.39 to 1.79; combined UV-C/copper association RR 0.49.	UV-C cannot be separated from hand-hygiene bundles and copper; non-random sequential periods.
Ishikawa et al. [44]	Single-centre before-after outbreak-control bundle in NICU/GCU; pulsed-xenon UV within enhanced cleaning and hand-hygiene measures.	MRSA infection decreased from 2.81 to 0.90/1000 patient-days; environmental positives decreased from 12/137 to 0.	Outbreak setting; simultaneous enhanced cleaning and hand-hygiene measures confound the UV contribution.

CDI, *Clostridium difficile* infection; CI, confidence interval; HAI, healthcare-associated infection; ICU, intensive care unit; IPC, Infection Prevention and Control; IRR, incidence rate ratio; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; OR, odds ratio; RR, risk ratio; VRE, vancomycin-resistant enterococci.

Healthcare field efficacy (R2)

The 17 R2 studies were conducted in genuine healthcare environments but incorporated controlled carriers, inoculated surfaces or mixed laboratory components (Table 4). Boyce et al. showed significant reductions in aerobic counts across five high-touch surfaces in 25 patient rooms [45], while Havill et al. found UV-C faster but less sporicidal and less reliable out of direct line of sight than hydrogen-peroxide vapor [46]. Nerandzic et al. demonstrated distance-sensitive pulsed-xenon performance [47]. Mustapha et al. added floor-specific evidence: manual cleaning markedly reduced natural floor contamination, with residual MRSA positivity decreasing from 9% after manual cleaning to 1% after adjunctive UV-C, although the incremental difference was not statistically significant; controlled MRSA carriers confirmed UV-C activity [48]. These field studies reinforce organism, matrix, distance and delivered dose as determinants of performance rather than source label alone.

These newer additions reinforce the same field-efficacy modifiers seen in the original corpus. Rutala et al. reported > 99.9% reductions for vegetative bacteria with longer exposure required for *C. difficile* spores [1]; Wong et al. showed device-to-device differences under difficult placement and protein load [2]; and heavy organic soil, organism susceptibility and shadowing repeatedly reduced performance [4, 47, 49–54]. Villacís et al. likewise documented additional environmental reduction after pulsed-xenon UV in patient and operating-room environments [55]. Field efficacy is therefore best interpreted as a function of organism, matrix, distance and delivered dose rather than source label alone.

Table 4
Healthcare field-efficacy studies (R2): deployment, findings and principal modifiers

Study	Setting/design + UV deployment	Field-efficacy finding	Key efficacy modifier / interpretive limitation
Rutala et al. [1]	Standard hospital room plus rooms previously occupied by MRSA/VRE patients; prospective field study with inoculated carriers and natural contamination; mobile automated continuous UV-C with reflected-dose endpoint.	Vegetative bacteria decreased by > 99.9%; in patient rooms, MRSA-positive samples fell from 20.3% to 0.5% and mean total CFU from 384 to 19.	<i>C. difficile</i> spores required a substantially longer/higher-dose cycle than vegetative bacteria; efficacy was organism- and dose-dependent.
Wong et al. [2]	Post-discharge MRSA/VRE/ <i>C. difficile</i> isolation rooms; paired environmental cultures plus carrier comparison of two mobile automated UV-C devices.	Contaminated rooms decreased to 3.3% for MRSA, 4.9% for VRE and 0% for <i>C. difficile</i> ; mean non-floor CFU fell from 19.6 after manual cleaning to 1.3 after UV-C.	Carrier performance differed between devices and under difficult placement/protein-load conditions, limiting interchangeability of device labels.
Nerandzic et al. [3]	Rooms of hospitalized patients; laboratory dose study plus paired hospital-room cultures; mobile automated continuous UV-C using reflected-dose targets.	Hospital-room positive cultures decreased by 93% for MRSA/VRE and 80% for <i>C. difficile</i> .	Higher reflected dose was required for reliable spore reduction; organism susceptibility affected performance.
Ali et al. [4]	Contaminated patient rooms after terminal cleaning; in-use comparison of two whole-room continuous UV-C systems with natural sampling and inoculated indicators.	Both systems produced large MRSA and <i>K. pneumoniae</i> reductions under low-soil conditions.	Heavy organic soil, <i>C. difficile</i> spores and shadowing reduced efficacy; careful source positioning improved coverage.
Yui et al. [49]	Hospital room and bathroom; in-vitro challenge plus in-use sequential sampling; rapid targeted mobile continuous UV-C with multiple short positions.	MRSA/ <i>K. pneumoniae</i> reductions ranged from 2.97–4.87 log under low soil; natural contamination also decreased after treatment.	High soil markedly reduced reductions; <i>C. difficile</i> was less responsive, especially in synthetic faeces, and some natural contamination persisted.
Füszl et al. [50]	Waiting areas of two hospital outpatient clinics; field study plus controlled <i>C. auris</i> carriers; autonomous mobile UV-C robot after routine cleaning.	Natural environmental contamination decreased after robot use.	Standard cycles did not reliably eliminate high-load/stationary-phase <i>C. auris</i> or shielded/rim locations, emphasizing coverage limitations.

Study	Setting/design + UV deployment	Field-efficacy finding	Key efficacy modifier / interpretive limitation
Casini et al. [51]	Real hospital high-touch surfaces plus controlled laboratory tests; mixed study of an experimental autonomous UV-C robot.	Average total viable-count reduction was 67% after SOP alone and 96% after SOP plus UV-C.	Higher dose was required in hospital use than in vitro, showing that laboratory dose-response does not directly translate to room deployment.
Villacís et al. [55]	Patient rooms and operating-room environments; in-vitro validation plus paired environmental sampling; pulsed-xenon UV after terminal manual cleaning.	Environmental CFU fell from 3569 after manual cleaning to 889 after PX-UV; reductions were about 87% in operating rooms and 76% in patient rooms.	Environmental before/after endpoint only; incremental benefit was evaluated after manual cleaning and no patient outcome was linked.
Rózańska et al. [52]	Six hospital rooms/wards plus laboratory conditions; mixed carrier and hospital before/after study using mobile UV-C robots.	Laboratory reductions ranged from about 1 to 6 log; hospital sampling confirmed a marked decrease in bacterial contamination.	Performance varied by organism, material and sampling location, limiting transfer of a single efficacy estimate across surfaces.
Yang et al. [56]	Hospital rooms plus laboratory pathogen tests; mixed laboratory/in-use study using a mobile automatic UV-C robot.	> 3-log reduction occurred for most vegetative organisms at practical distances, and hospital-room contamination decreased after a typical 15-min cycle.	VRE, <i>Mycobacterium abscessus</i> and <i>Aspergillus fumigatus</i> were less susceptible, demonstrating organism-specific response.
Russo et al. [53]	Two hospital outpatient rooms plus laboratory tests; mixed field/in-vitro study of a mobile UV-C robotic system.	Bacteria, molds and yeasts decreased at each high-touch site compared with manual sanitization; laboratory reductions reached about 5–6 log.	Reductions varied by material and test condition; laboratory performance exceeded some field results.
Chen et al. [54]	Central, microbiology and immunology laboratories in a hospital; mixed biofilm and real-environment study using pulsed-xenon UV.	PX-UV reduced biofilm-forming pathogens and eliminated detectable bioburden on sampled high-touch surfaces after treatment.	Clinical-laboratory setting and mixed air/surface endpoints limit direct generalization to patient rooms.
Boyce et al. [45]	25 post-discharge patient rooms; prospective before/after study with natural cultures plus <i>C. difficile</i> carriers; mobile automated continuous UV-C with one- or two-stage positioning.	All five high-touch surfaces showed significant reductions; two-stage treatment reduced mean aerobic counts to 0 CFU on all five sites.	Cycles were long, and one-versus two-stage positioning materially changed dose distribution and <i>C. difficile</i> reduction.

Study	Setting/design + UV deployment	Field-efficacy finding	Key efficacy modifier / interpretive limitation
Havill et al. [46]	15 patient rooms; prospective comparison of hydrogen-peroxide vapor versus mobile whole-room UV-C.	UV-C reduced room contamination and had a shorter mean cycle than hydrogen-peroxide vapor.	UV-C was less sporicidal and less reliable outside direct line of sight, particularly for <i>C. difficile</i> .
Nerandzic et al. [47]	Two acute-care hospitals; mixed carrier and hospital-room surface study using pulsed-xenon UV.	Native pathogen positivity on high-touch surfaces decreased; carrier reductions confirmed activity against MRSA, VRE and <i>C. difficile</i> .	Distance strongly reduced efficacy, and reductions were smaller for <i>C. difficile</i> /VRE than for MRSA under the tested conditions.
Hosein et al. [57]	40 isolation rooms in a UK hospital; before/after environmental study plus controlled MDRO challenge; mobile pulsed-xenon UV.	PX-UV produced a further 78.4% reduction after manual cleaning and about 5-log reduction on spiked MDRO plates.	Controlled challenge and natural-room endpoints differed; operational turnaround was about 1 h.
Mustapha et al. [48]	Post-discharge rooms of MRSA-contact-precaution patients; natural floor sampling plus controlled MRSA carriers; mobile UV-C with multi-position room/bathroom cycles.	Residual MRSA positivity decreased from 9% after manual cleaning to 1% after adjunctive UV-C; controlled carriers confirmed UV-C activity.	The incremental reduction in natural floor contamination was not statistically significant despite clear carrier inactivation.

CFU, colony-forming unit; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; PX-UV, pulsed-xenon ultraviolet; SOP, Standard Operating Procedure; VRE, vancomycin-resistant enterococci.

Healthcare-room and full-scale evidence (R3)

The 10 R3 studies were included because unoccupied healthcare rooms and full-scale simulations reproduce geometry, distance, furnishings and shadowing that are absent from bench experiments while retaining a direct microbiological surface endpoint (Table 5). Boyce et al. showed orders-of-magnitude variation in irradiance with distance and orientation [5], and Jelden et al. demonstrated line-of-sight/material effects and benefits from reflective room surfaces [58, 59]. Kanamori et al. compared one versus two fixed-time source positions in an unoccupied patient room: additional positioning improved overall reduction, while distance remained strongly associated with poorer performance [60]. Rock et al. exposed 133 carbapenem-resistant *Enterobacteriaceae* (CRE)-inoculated high-touch carriers in an actual empty patient room and bathroom; only two remained CRE-positive after a 15-min multi-position cycle, with failures concentrated at difficult/shadowed sites [61]. These additions strengthen the room-scale evidence that positioning and line of sight are as important as nominal source output.

Full-scale simulations showed the same dose-distribution problem. In a furnished 1:1 hospital-room simulation, reduction decreased with distance and shadowing and areas under the bed received little effective radiation unless power or exposure time was increased [62]. In a simulated intensive care unit (ICU) room, an autonomous mobile robot achieved at least 99.99% SARS-CoV-2 inactivation at direct wall sites, whereas floor and under-table positions received lower dose and showed less consistent reduction [63]. The evidence base includes an operator-positioned 222-nm far-UVC room study. In two unoccupied patient rooms, Vincent et al. reported dose-dependent reductions, with the largest reductions observed for *Candida auris* under low-soiling conditions, whereas reductions were less pronounced under high-soiling conditions and for MRSA and bacteriophage T1 [17]. These room-scale studies support the use of measured dose and deliberately selected source positions rather than relying on nominal source output.

Table 5

Healthcare-room/full-scale performance studies (R3): deployment, findings and translational modifiers

Study	Room setting/design + UV deployment	Room-scale performance finding	Key translational modifier / interpretive limitation
Boyce et al. [5]	Unoccupied ICU and surgical-ward rooms; mobile continuous UV-C single emitter; 5- and 15-min exposures with six UV sensors.	Log reductions ranged from > 4 at directly exposed sites to minimal/no reduction at some distant or shaded locations.	Irradiance varied by orders of magnitude with distance and orientation; <i>C. difficile</i> was particularly difficult at low-dose sites.
Jelden et al. [58]	Hospital biocontainment room; portable UVGI generator compared with standard versus UV-reflective wall coating; 10-min cycle.	Reflective paint improved decontamination at indirect/shadowed locations, with > 4-log reductions at some sites versus < 2 log without reflective coating.	Room-surface reflectivity materially altered delivered dose, showing that room construction can modify performance.
Jelden et al. [59]	Unoccupied hospital/biocontainment room; portable UVGI generator; 10-min cycle with measured dose spanning 0–688 mJ/cm ² .	Average reductions were about 4.6 log for MRSA and 3.9 log for VRE.	Line of sight, delivered dose and surface material produced substantial location-to-location variability.
Tholany et al. [64]	Empty hospital rooms; three mobile continuous UV-C emitters; median runtime about 29 min.	Mean recovery was 0.4 CFU on exposed plates versus 87.4 CFU on controls; only 7.1% of exposed plates showed growth.	Residual growth occurred more often at distant or shielded sites, indicating incomplete coverage despite multi-emitter deployment.
Arkusz et al. [62]	Laboratory and furnished 1:1 simulated hospital room; stationary operator-positioned open-type UV-C source; up to 60 min at 10–300 cm.	In the furnished room, > 90% reduction generally required short distance or high power/long exposure.	Distance and shadowing strongly attenuated performance; areas under the bed received little or no effective radiation.
Lorca-Oró et al. [63]	11-m ² simulated ICU room; autonomous mobile UV-C robot; 12- and 20-min runs.	Direct wall sites achieved ≥ 99.99% SARS-CoV-2 inactivation after 12–20 min.	Floor and under-table sites received lower dose and showed less consistent reduction, demonstrating navigation/geometry limits.

Study	Room setting/design + UV deployment	Room-scale performance finding	Key translational modifier / interpretive limitation
Rutala et al. [65]	Hospital patient-room experiment; mobile continuous UV-C evaluated with standard versus UV-reflective wall coating.	Reflective coating shortened time to target decontamination from 25 min 13 s to 5 min 3 s for MRSA and from 43 min 42 s to 9 min 24 s for <i>C. difficile</i> spores.	Time-to-target dose depended strongly on wall reflectivity; performance cannot be inferred from source output alone.
Vincent et al. [17]	Two unoccupied two-bed patient rooms; operator-positioned 222-nm far-UVC luminaires behind beds and in bathroom; 24-h exposure with measured dose 5–637 mJ/cm ² .	UV-C222 reduced <i>C. auris</i> by 2.6 log at low soil and 1.0 log at high soil; MRSA by 1.0 log and T1 by 0.6 log at low soil.	High soil and organism type reduced response; the prolonged 24-h exposure limits direct comparison with short-cycle room systems.
Kanamori et al. [60]	Unoccupied patient room and bathroom; portable fixed-cycle UV-C device; one central position versus sequential positions on both sides of the bed.	Two positions produced greater reductions than one for both carbapenem-resistant <i>K. pneumoniae</i> and MRSA.	Distance strongly correlated with lower reduction, and additional positioning improved coverage.
Rock et al. [61]	Empty patient room and bathroom; portable UV-C device; 5 min on each side of the bed plus 5 min in the bathroom.	Only 2 of 133 inoculated high-touch carrier plates remained CRE-positive after the 15-min multi-position cycle.	Residual growth was confined to difficult/shadowed locations, reinforcing geometry and line-of-sight dependence.

CFU, colony-forming unit; ICU, intensive care unit; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant enterococci.

Cross-cutting determinants of translation

Across R1–R3, the most consistent cross-study message was that emitted radiation is not equivalent to delivered surface dose. Distance, source orientation, room geometry, furniture, reflectivity, number of positions and navigation strategy determine dose at a specific site [2, 4, 5, 19, 20, 23, 47–49, 60–67]. Microbial susceptibility and contamination matrix then modify the response: vegetative bacteria are generally more readily inactivated than spores, while high organic soil, high inoculum, biofilm and some materials reduce performance [1, 3, 4, 17, 47, 49, 50, 52–54, 56]. The 365-nm robotic study [18] additionally illustrates why wavelength-specific evidence should not be generalized across the UV spectrum.

The evidence can therefore be read as a causal chain from source and deployment, to delivered surface dose, microbial response, change in environmental burden, and finally patient acquisition or infection. No included evaluation measured every link in this chain within the same deployment. Several R2/R3 studies

quantified dose and microbiological response without patient outcomes, whereas clinical studies generally measured acquisition or infection without linked room-level dosimetry. BETR disinfection provides randomized evidence at the patient-outcome end of the pathway [26], while Rock et al. provide randomized null evidence in a different high-risk context [27]. This disconnect is itself a major evidence gap: future evaluations should connect dosimetry, environmental microbiology, treatment coverage and patient outcomes rather than infer one link from another. This translation pathway and the relationship among the three evidence strata are summarized in Fig. 2.

Figure 2. Translation framework from UV source characteristics to infection-prevention outcomes.

The same source can produce different outcomes when delivered dose, room geometry, organism, contamination matrix or implementation coverage differ. R3, R2 and R1 represent different evidentiary vantage points rather than a formal quality hierarchy; no single included study spans the entire translation pathway.

Implications for infection prevention and antimicrobial-resistance control

The evidence is most directly relevant to environmental reservoirs of MRSA, VRE, *C. difficile* and resistant Gram-negative organisms, with additional studies addressing *C. auris* and viral contamination. The expanded clinical evidence argues against a simple “UV works/does not work” interpretation. BETR disinfection found benefit when UV-C was added to standard terminal cleaning [26], with its hospital-wide secondary report showing a more modest and pathogen-specific pattern [19]. By contrast, Rock et al. found no reduction in VRE or *C. difficile* in cancer/transplant units [27], the large sham-controlled LAMP trial found no reduction in environmentally implicated HAIs [28], Hodges et al. found no reduction in prior-room-occupant pathogen transfer [29], and Brite et al. found no significant change in VRE or *C. difficile* [39]. Fourman et al. likewise found no significant additional *C. difficile* surface reduction after bleach [66]. Organism, baseline chemical disinfection, patient population, treatment frequency and coverage therefore modify the likely infection-prevention value of UV.

Local implementation remains central. Treatment coverage is a system-level variable: Haas et al. treated 76% of contact-precaution discharges [30], Pegues et al. treated only a subset of eligible hematology-oncology discharges while still observing an association with lower *C. difficile* incidence [31], and dedicated teams and explicit priority rules improved utilization in other high-occupancy settings [11, 38]. Robots may improve repeatability and traceability, but autonomy does not eliminate shielding or user-interface burden [50, 51, 53, 67–69]. In outbreak or multidrug-resistant organism (MDRO)-control programs, apparent clinical benefit should be interpreted within the complete infection-prevention bundle, including manual cleaning, hand hygiene, antimicrobial stewardship and concurrent environmental interventions.

Positioning relative to previous reviews and evidence gaps

The contribution of this scoping review is not a new claim that UV is germicidal. Previous syntheses span no-touch disinfection and HAI outcomes [6], hospital UV-C efficacy and safety [7], high-touch-surface effectiveness [8], automated device implementation and whole-room performance [9, 10], UV-associated HAI outcomes [11], pulsed-xenon meta-analysis [12], randomized surface-decontamination evidence [14], and UV-C device/parameter mapping [13]. The present map comprises 70 distinct healthcare-relevant studies represented by 71 reports and is differentiated by its deployment boundary and evidence architecture: portable/mobile automated and operator-positioned systems are linked across routine-care, field-efficacy and room-scale evidence to the translation pathway from dose delivery to environmental and patient outcomes.

Several evidence gaps are consistent across the map. No study measured source/dose delivery, environmental response, implementation coverage and patient outcome within one complete causal evaluation. Dose and irradiance remain inconsistently reported at indirect sites; room layout, number of source positions, treatment coverage and failed cycles are often incompletely described; and safety, material compatibility and economic outcomes are less frequently reported than microbiological endpoints. Based on these recurrent gaps, we propose a minimum reporting framework for future evaluations of deployable UV surface-disinfection systems (Table 6). The framework is an author-derived synthesis of the reporting deficiencies observed in this review and should not be interpreted as a formally validated reporting guideline.

Table 6
Proposed minimum reporting framework for studies of deployable UV surface-disinfection systems in healthcare

Domain	Minimum information to report
Technology identity	Manufacturer/model; source type; wavelength or spectral distribution; continuous or pulsed emission; number and orientation of emitters.
Dose specification	Irradiance measurement method; target and delivered dose; sensor locations and calibration; distance; exposure time; cycle-control algorithm or endpoint.
Healthcare environment	Room type and dimensions; furniture/layout; occupied or unoccupied status; environmental conditions relevant to UV delivery.
Positioning and coverage	Number and location of device positions; direct and indirect sites; line of sight; eligible rooms; completed cycles; treatment coverage and failed/incomplete cycles.
Cleaning context	Sequence relative to manual cleaning; chemical products and contact time; terminal, daily or outbreak use; concurrent infection-prevention interventions.
Microbiology and outcomes	Natural or artificial contamination; organism and matrix; baseline burden; sampling method/timing; environmental, acquisition, clinical and operational outcomes.
Operations and safety	Setup and cycle time; room downtime; staffing; training; failures; maintenance; adverse events; material compatibility.
Transparency	Funding; device donation/loan; manufacturer or developer roles; conflicts of interest; protocol deviations; missing data and study limitations.

Limitations

This review has important limitations. The bibliographic search was restricted to PubMed and to a single structured query run on 1 September 2026; relevant evidence not indexed in PubMed or described using terminology outside the query may therefore have been missed. Review-type publications were removed using the PubMed Review publication-type filter before reviewer screening. Study selection of the remaining 206 records was conducted by two reviewers, whereas data charting and extraction were performed by a single reviewer without independent duplicate extraction, which may have increased the risk of transcription or classification error. Study designs, baseline contamination, microbiological methods, effect measures and technical reporting were heterogeneous, precluding quantitative pooling. No formal critical appraisal or risk-of-bias assessment was performed. Publication and selective-reporting bias remain possible. The final scope intentionally excludes permanently fixed wall/ceiling installations and handheld spot-disinfection devices. At least 38 of 71 reports (53.5%) documented direct commercial involvement through manufacturer/company funding, provision or loan of devices, materials or data, company technical support, or company/developer authorship; this should be considered when interpreting a device-oriented evidence base.

Eligibility adjudication also clarified the operational boundary. Dosimetry-only or model-only evaluations without a directly measured microbiological surface endpoint were excluded, as were permanently

installed wall/ceiling systems and handheld spot-treatment devices. These decisions were applied consistently during the selection process and are documented in Additional file 1.

Conclusions

Across the final 70-study map (71 reports), deployable UV surface-disinfection systems show their most consistently favorable findings at the environmental level: directly exposed, adequately dosed sites often demonstrate substantial reductions in microbial burden. Translation is less reliable when dose is attenuated by distance, shadowing, organic material, spores or difficult room geometry. Patient-level evidence is materially more heterogeneous. BETR disinfection demonstrated a reduction in a composite acquisition/infection outcome when UV-C was added to standard terminal cleaning [26], but randomized null findings in cancer/transplant units [27] and in the large sham-controlled LAMP trial [28], together with null observational/environmental results in other settings [29, 39, 66], argue against assuming a uniform causal effect across pathogens, populations and cleaning contexts.

For healthcare implementation, the practical unit of analysis should therefore be the deployment system rather than the lamp or wavelength alone. Device selection should consider source, positioning or navigation, target surfaces, delivered-dose control, occupancy requirements, treatment coverage and integration with environmental-services workflow. UV should supplement, not replace, validated manual cleaning and disinfection. Future studies should connect all major links of the translation pathway—dose, surface microbiology, implementation coverage and patient outcomes—within the same evaluation so that germicidal efficacy can be meaningfully translated into infection-prevention benefit.

Abbreviations

BETR

Benefits of Enhanced Terminal Room disinfection

CDI

Clostridium difficile infection

CFU

colony-forming unit

CI

confidence interval

CRE

carbapenem-resistant *Enterobacteriaceae*

HAI

healthcare-associated infection

ICU

intensive care unit

IRR

incidence rate ratio

LAMP

Lowering the Acquisition of Multidrug-Resistant Organisms With Pulsed-xenon

LED

light-emitting diode

MDRO

multidrug-resistant organism

MRSA

methicillin-resistant *Staphylococcus aureus*

OR

odds ratio

PCC

Population–Concept–Context

PRISMA-ScR

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews

PX-UV

pulsed-xenon ultraviolet

R1

routine-care surface effectiveness

R2

healthcare field efficacy

R3

healthcare-room or full-scale evidence

RR

risk ratio

UV-A

ultraviolet-A

UV-C

ultraviolet-C

SOP

Standard Operating Procedure

VRE

vancomycin-resistant enterococci.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Additional file

Additional file 1 (.xlsx). Structured PubMed search strategy and exact query run on 1 September 2026 (643 records retrieved; 437 review-type records removed in PubMed using the Review publication-type filter; 206 records screened by two reviewers); study-selection summary; quantitative evidence-map summary and study-level characteristics for 70 distinct studies represented by 71 reports; funding/manufacture involvement; descriptive methodological characteristics; and device taxonomy.

Funding

This work was supported by the project “Knowledge in cleaning: sviluppo e validazione di tecnologie UV e di tracciamento digitale per la sanificazione e la disinfezione indoor in ambito clinico-ospedaliero” (Bando a Cascata, progetto PNC ANTHEM; capofila: Università degli Studi di Milano-Bicocca), project code PNC0000003. The funding body had no role in the preparation, interpretation, or writing of the manuscript and did not influence its content.

Author Contribution

C.S. finalized the protocol, assisted with paper selection and data extraction/synthesis, wrote the final draft of the article. I.Cr. assisted with paper selection, screened the abstracts, selected publications, extracted data, synthesized data, and revised the final draft of the article. P.B. assisted with data interpretation and revised the final draft of the article. C.D.V. assisted with data interpretation and revised the final draft of the article. I.Ca. drafted the protocol, revised the final draft of the article and led the project.

Acknowledgements

Not applicable.

Data Availability

All data generated or analysed during this review are included in this manuscript and its Additional file 1.

References

1. Rutala WA, Gergen MF, Weber DJ. Room decontamination with UV radiation. *Infect Control Hosp Epidemiol*. 2010;31:1025–9. 10.1086/656244.
2. Wong T, Woznow T, Petrie M, Murzello E, Muniak A, Kadora A, et al. Postdischarge decontamination of MRSA, VRE, and *Clostridium difficile* isolation rooms using 2 commercially available automated ultraviolet-C-emitting devices. *Am J Infect Control*. 2016;44:416–20. 10.1016/j.ajic.2015.10.016.
3. Nerandzic MM, Cadnum JL, Pultz MJ, Donskey CJ. Evaluation of an automated ultraviolet radiation device for decontamination of *Clostridium difficile* and other healthcare-associated pathogens in hospital rooms. *BMC Infect Dis*. 2010;10:197. 10.1186/1471-2334-10-197.
4. Ali S, Yui S, Muzslay M, Wilson APR. Comparison of two whole-room ultraviolet irradiation systems for enhanced disinfection of contaminated hospital patient rooms. *J Hosp Infect*. 2017;97:180–4. 10.1016/j.jhin.2017.08.011.
5. Boyce JM, Farrel PA, Towle D, Fekiet R, Aniskiewicz M. Impact of Room Location on UV-C Irradiance and UV-C Dosage and Antimicrobial Effect Delivered by a Mobile UV-C Light Device. *Infect Control Hosp Epidemiol*. 2016;37:667–72. 10.1017/ice.2016.35.
6. Marra AR, Schweizer ML, Edmond MB. No-Touch Disinfection Methods to Decrease Multidrug-Resistant Organism Infections: A Systematic Review and Meta-analysis. *Infect Control Hosp Epidemiol*. 2018;39:20–31. 10.1017/ice.2017.226.
7. Ramos CCR, Roque JLA, Sarmiento DB, Suarez LEG, Sunio JTP, Tabungar KIB, et al. Use of ultraviolet-C in environmental sterilization in hospitals: a systematic review on efficacy and safety. *Int J Health Sci (Qassim)*. 2020;14:52–65.
8. Resendiz M, Blanchard D, West GF. A systematic review of the germicidal effectiveness of ultraviolet disinfection across high-touch surfaces in the immediate patient environment. *J Infect Prev*. 2023;24:166–77. 10.1177/17571774231159388.
9. Dancer SJ, King MF. Systematic review on use, cost and clinical efficacy of automated decontamination devices. *Antimicrob Resist Infect Control*. 2021;10:34. 10.1186/s13756-021-00894-y.
10. van der Starre CM, Cremers-Pijpers SAJ, van Rossum C, Bowles EC, Tostmann A. The in situ efficacy of whole room disinfection devices: a literature review with practical recommendations for implementation. *Antimicrob Resist Infect Control*. 2022;11:149. 10.1186/s13756-022-01183-y.
11. Maugeri A, Casini B, Esposito E, Bracaloni S, Scarpaci M, Patanè F, et al. Impact of ultraviolet light disinfection on reducing hospital-associated infections: a systematic review in healthcare environments. *J Hosp Infect*. 2025;159:32–41. 10.1016/j.jhin.2025.01.014.
12. Ma L, Yan C, Huang Y, Lv J, Liu S. Does the use of pulsed-xenon ultraviolet light reduce the risk of healthcare-associated infections? An updated systematic review and meta-analysis. *J Infect Chemother*. 2025;31:102729. 10.1016/j.jiac.2025.102729.

13. Elias LAA, Nobukuni MC, Carvalho HEF, Carneiro LM, Batista OMA, Sousa AFL, et al. Germicidal ultraviolet C (UV-C) light for surface disinfection in hospitals: mapping the evidence on devices, parameters, effectiveness, and implementation. *Hygiene*. 2026;6:14. 10.3390/hygiene6010014.
14. Lopez-Alcalde J, Mateos-Mazón M, Oliveira Conterno L, Dancer SJ, Stallings EC, Villanueva G, et al. Decontamination of environmental surfaces in hospitals to reduce hospital-acquired infections: a systematic review. *Infect Prev Pract*. 2026;8:100514. 10.1016/j.infpip.2026.100514.
15. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med*. 2018;169:467–73. 10.7326/M18-0850.
16. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol*. 2018;18:143. 10.1186/s12874-018-0611-x.
17. Vincent RL, Factor SH, Rivera Boudla L, Atkinson D, McDevitt JJ, Camins BC. Efficacy of continuous UV-C222 exposure of *Candida auris*, methicillin-resistant *Staphylococcus aureus*, and T1 bacteriophage at two soil levels in hospital patient rooms. *Infect Control Hosp Epidemiol*. 2026;47:509–16. 10.1017/ice.2026.10414.
18. Choi HK, Cui C, Seok H, Bae JY, Jeon JH, Lee GE, et al. Feasibility of ultraviolet light-emitting diode irradiation robot for terminal decontamination of coronavirus disease 2019 (COVID-19) patient rooms. *Infect Control Hosp Epidemiol*. 2022;43:232–7. 10.1017/ice.2021.95.
19. Anderson DJ, Moehring RW, Weber DJ, Lewis SS, Chen LF, Schwab JC, et al. Effectiveness of targeted enhanced terminal room disinfection on hospital-wide acquisition and infection with multidrug-resistant organisms and *Clostridium difficile*: a secondary analysis of a multicentre cluster randomised controlled trial with crossover design (BETR Disinfection). *Lancet Infect Dis*. 2018;18:845–53. 10.1016/S1473-3099(18)30278-0.
20. Anderson DJ, Gergen MF, Smathers E, Sexton DJ, Chen LF, Weber DJ, et al. Decontamination of targeted pathogens from patient rooms using an automated ultraviolet-C-emitting device. *Infect Control Hosp Epidemiol*. 2013;34:466–71. 10.1086/670215.
21. Allen O, Jadkauskaite L, Shafi NT, Jackson A, Athithan V, Chiu Y-D, et al. Microbiological evaluation of UV disinfection effectiveness in a specialist cystic fibrosis clinic. *J Cyst Fibros*. 2019;18:e37–9. 10.1016/j.jcf.2019.04.019.
22. Armellino D, Walsh TJ, Petraitis V, Kowalski W. Assessment of focused multivector ultraviolet disinfection with shadowless delivery using 5-point multisided sampling of patient care equipment without manual-chemical disinfection. *Am J Infect Control*. 2019;47:409–14. 10.1016/j.ajic.2018.09.019.
23. Jinadatha C, Quezada R, Huber TW, Williams JB, Zeber JE, Copeland LA. Evaluation of a pulsed-xenon ultraviolet room disinfection device for impact on contamination levels of methicillin-resistant *Staphylococcus aureus*. *BMC Infect Dis*. 2014;14:187. 10.1186/1471-2334-14-187.

24. Uwayo HD, Gahamanyi N, Mugisha JC, Kayigi E, Kabalisa E, Umwanankabandi F, et al. Use of robot technology for decontaminating Marburg virus-exposed environments in Rwanda: A promising tool for managing outbreaks in resource-limited settings. *Am J Infect Control*. 2025;53:1080–4. 10.1016/j.ajic.2025.05.018.
25. Dexter F, Birchansky B, Epstein RH, Loftus RW. Average and longest expected treatment times for ultraviolet light disinfection of rooms. *Am J Infect Control*. 2022;50:61–6. 10.1016/j.ajic.2021.08.020.
26. Anderson DJ, Chen LF, Weber DJ, Moehring RW, Lewis SS, Triplett PF, et al. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study. *Lancet*. 2017;389:805–14. 10.1016/S0140-6736(16)31588-4.
27. Rock C, Hsu YJ, Curless MS, Carroll KC, Howard TR, Carson KA, et al. Ultraviolet-C light evaluation as adjunct disinfection to remove multidrug-resistant organisms. *Clin Infect Dis*. 2022;75:35–40. 10.1093/cid/ciab896.
28. Dhar S, Jinadatha C, Kilgore PE, Henig O, Divine GW, Todter EN, et al. Lowering the Acquisition of Multidrug-Resistant Organisms (MDROs) With Pulsed-xenon (LAMP) Study: A Cluster-Randomized, Controlled, Double-Blinded, Interventional Crossover Trial. *Clin Infect Dis*. 2024;79:1024–30. 10.1093/cid/ciae240.
29. Hodges JC, Bilderback AL, Bridge CM, Wagester S, Colaianne BV, Babiker A, et al. Assessment of the effectiveness of ultraviolet-C disinfection on transmission of hospital-acquired pathogens from prior room occupants. *Antimicrob Steward Healthc Epidemiol*. 2022;2:e110. 10.1017/ash.2022.254.
30. Haas JP, Menz J, Dusza S, Montecalvo MA. Implementation and impact of ultraviolet environmental disinfection in an acute care setting. *Am J Infect Control*. 2014;42:586–90. 10.1016/j.ajic.2013.12.013.
31. Pegues DA, Han J, Gilmar C, McDonnell B, Gaynes S. Impact of ultraviolet germicidal irradiation for no-touch terminal room disinfection on *Clostridium difficile* infection incidence among hematology-oncology patients. *Infect Control Hosp Epidemiol*. 2017;38:39–44. 10.1017/ice.2016.222.
32. Sitzlar B, Vajravelu RK, Jury L, Donskey CJ, Jump RLP. Environmental decontamination with ultraviolet radiation to prevent recurrent *Clostridium difficile* infection in 2 roommates in a long-term care facility. *Infect Control Hosp Epidemiol*. 2012;33:534–6. 10.1086/665310.
33. Napolitano NA, Mahapatra T, Tang W. The effectiveness of UV-C radiation for facility-wide environmental disinfection to reduce health care-acquired infections. *Am J Infect Control*. 2015;43:1342–6. 10.1016/j.ajic.2015.07.006.
34. Nagaraja A, Visintainer P, Haas JP, Menz J, Wormser GP, Montecalvo MA. *Clostridium difficile* infections before and during use of ultraviolet disinfection. *Am J Infect Control*. 2015;43:940–5. 10.1016/j.ajic.2015.05.003.
35. Vianna PG, Dale CR Jr, Simmons S, Stibich M, Licitra CM. Impact of pulsed xenon ultraviolet light on hospital-acquired infection rates in a community hospital. *Am J Infect Control*. 2016;44:299–303.

- 10.1016/j.ajic.2015.10.009.
36. Kovach CR, Taneli Y, Neiman T, Dyer EM, Arzaga AJA, Kelber ST. Evaluation of an ultraviolet room disinfection protocol to decrease nursing home microbial burden, infection and hospitalization rates. *BMC Infect Dis*. 2017;17:186. 10.1186/s12879-017-2275-2.
 37. Pavia M, Simpser E, Becker M, Mainquist WK, Velez KA. The effect of ultraviolet-C technology on viral infection incidence in a pediatric long-term care facility. *Am J Infect Control*. 2018;46:720–2. 10.1016/j.ajic.2018.01.014.
 38. Raggi R, Archulet K, Haag CW, Tang W. Clinical, operational, and financial impact of an ultraviolet-C terminal disinfection intervention at a community hospital. *Am J Infect Control*. 2018;46:1224–9. 10.1016/j.ajic.2018.05.012.
 39. Brite J, McMillen T, Robilotti E, Sun J, Chow HY, Stell F, et al. Effectiveness of ultraviolet disinfection in reducing hospital-acquired *Clostridium difficile* and vancomycin-resistant Enterococcus on a bone marrow transplant unit. *Infect Control Hosp Epidemiol*. 2018;39:1301–6. 10.1017/ice.2018.215.
 40. Schaffzin JK, Wilhite AW, Li Z, Finney D, Ankrum AL, Moore R. Maximizing efficiency in a high-occupancy setting to utilize ultraviolet disinfection for isolation rooms. *Am J Infect Control*. 2020;48:903–9. 10.1016/j.ajic.2020.05.004.
 41. Morikane K, Suzuki S, Yoshioka J, Yakuwa J, Nakane M, Nemoto K. Clinical and microbiological effect of pulsed xenon ultraviolet disinfection to reduce multidrug-resistant organisms in the intensive care unit in a Japanese hospital: a before-after study. *BMC Infect Dis*. 2020;20:82. 10.1186/s12879-020-4805-6.
 42. Kitagawa H, Mori M, Kawano R, Hara T, Kashiya S, Hayashi Y, et al. Combining pulsed xenon ultraviolet disinfection with terminal manual cleaning helps reduce the acquisition rate of methicillin-resistant *Staphylococcus aureus*. *Am J Infect Control*. 2021;49:1048–51. 10.1016/j.ajic.2021.01.019.
 43. de la Rosa-Zamboni D, Villa-Guillén M, Bustos-Hamdan A, Rosas-Mateos MI, Medina-Pelcastre M, Torres-García M, et al. Effect of UV-C disinfection and copper plating on healthcare-associated infections in a NICU with high ESBL infections. *Enferm Infecc Microbiol Clin (Engl Ed)*. 2025;43:64–70. 10.1016/j.eimce.2024.02.014.
 44. Ishikawa K, Tsuchida T, Ichiki K, Ueda T, Yamada K, Iijima K, et al. Efficacy of enhanced environmental cleaning/disinfection using pulsed xenon ultraviolet light in preventing outbreaks of methicillin-resistant *Staphylococcus aureus* in neonatal intensive care units. *Epidemiologia (Basel)*. 2025;6:12. 10.3390/epidemiologia6010012.
 45. Boyce JM, Havill NL, Moore BA. Terminal decontamination of patient rooms using an automated mobile UV light unit. *Infect Control Hosp Epidemiol*. 2011;32:737–42. 10.1086/661222.
 46. Havill NL, Moore BA, Boyce JM. Comparison of the microbiological efficacy of hydrogen peroxide vapor and ultraviolet light processes for room decontamination. *Infect Control Hosp Epidemiol*. 2012;33:507–12. 10.1086/665326.

47. Nerandzic MM, Thota P, Sankar CT, Jencson A, Cadnum JL, Ray AJ, et al. Evaluation of a pulsed xenon ultraviolet disinfection system for reduction of healthcare-associated pathogens in hospital rooms. *Infect Control Hosp Epidemiol*. 2015;36:192–7. 10.1017/ice.2014.36.
48. Mustapha A, Alhmidi H, Cadnum JL, Jencson AL, Donskey CJ. Efficacy of manual cleaning and an ultraviolet C room decontamination device in reducing health care-associated pathogens on hospital floors. *Am J Infect Control*. 2018;46:584–6. 10.1016/j.ajic.2017.10.025.
49. Yui S, Karia K, Muzsly M, Wilson P, Ali S. In-vitro and in-use efficacy of a rapid, targeted UVC decontamination system. *J Hosp Infect*. 2025;155:216–20. 10.1016/j.jhin.2024.10.019.
50. Füzsi A, Zatorska B, Van den Nest M, Ebner J, Presterl E, Diab-Elschahawi M. The use of a UV-C disinfection robot in the routine cleaning process: a field study in an academic hospital. *Antimicrob Resist Infect Control*. 2021;10:84. 10.1186/s13756-021-00945-4.
51. Casini B, Scarpaci M, Chiovelli F, Leonetti S, Costa AL, Baroni M, et al. Antimicrobial efficacy of an experimental UV-C robot in controlled conditions and in a real hospital scenario. *J Hosp Infect*. 2025;156:72–7. 10.1016/j.jhin.2024.11.010.
52. Róžańska A, Walkowicz M, Bulanda M, Kasperski T, Synowiec E, Osuch P, et al. Evaluation of the efficacy of UV-C radiation in eliminating microorganisms of special epidemiological importance from touch surfaces under laboratory conditions and in the hospital environment. *Healthc (Basel)*. 2023;11:3096. 10.3390/healthcare11233096.
53. Russo C, Bartolini D, Corbucci C, Stabile AM, Rende M, Gioiello A, et al. Effect of a UV-C Automatic Last-Generation Mobile Robotic System on Multi-Drug Resistant Pathogens. *Int J Environ Res Public Health*. 2021;18:13019. 10.3390/ijerph182413019.
54. Chen LH, Li Y, Qi Y, Wang SN, Gao CQ, Wu Y. Evaluation of a pulsed xenon ultraviolet light device for reduction of pathogens with biofilm-forming ability and impact on environmental bioburden in clinical laboratories. *Photodiagnosis Photodyn Ther*. 2020;29:101544. 10.1016/j.pdpdt.2019.08.026.
55. Villacís JE, Lopez M, Passey D, Santillán MH, Verdezoto G, Trujillo F, et al. Efficacy of pulsed-xenon ultraviolet light for disinfection of high-touch surfaces in an Ecuadorian hospital. *BMC Infect Dis*. 2019;19:575. 10.1186/s12879-019-4200-3.
56. Yang JH, Wu UI, Tai HM, Sheng WH. Effectiveness of an ultraviolet-C disinfection system for reduction of healthcare-associated pathogens. *J Microbiol Immunol Infect*. 2019;52:487–93. 10.1016/j.jmii.2017.08.017.
57. Hosein I, Madeloso R, Nagaratnam W, Villamaria F, Stock E, Jinadatha C. Evaluation of a pulsed xenon ultraviolet light device for isolation room disinfection in a United Kingdom hospital. *Am J Infect Control*. 2016;44:e157–61. 10.1016/j.ajic.2016.01.044.
58. Jelden KC, Gibbs SG, Smith PW, Hewlett AL, Iwen PC, Schmid KK, et al. Ultraviolet (UV)-reflective paint with ultraviolet germicidal irradiation (UVGI) improves decontamination of nosocomial bacteria on hospital room surfaces. *J Occup Environ Hyg*. 2017;14:456–60. 10.1080/15459624.2017.1296231.

59. Jelden KC, Gibbs SG, Smith PW, Hewlett AL, Iwen PC, Schmid KK, et al. Comparison of hospital room surface disinfection using a novel ultraviolet germicidal irradiation (UVGI) generator. *J Occup Environ Hyg.* 2016;13:690–8. 10.1080/15459624.2016.1166369.
60. Kanamori H, Rutala WA, Gergen MF, Weber DJ. Patient Room Decontamination against Carbapenem-Resistant Enterobacteriaceae and Methicillin-Resistant *Staphylococcus aureus* Using a Fixed Cycle-Time Ultraviolet-C Device and Two Different Radiation Designs. *Infect Control Hosp Epidemiol.* 2016;37:994–6. 10.1017/ice.2016.80.
61. Rock C, Curless MS, Nowakowski E, Ross T, Carson KA, Trexler P, et al. UV-C Light Disinfection of Carbapenem-Resistant Enterobacteriaceae from High-Touch Surfaces in a Patient Room and Bathroom. *Infect Control Hosp Epidemiol.* 2016;37:996–7. 10.1017/ice.2016.111.
62. Arkusz K, Pasik K, Jędrzejewska A, Klekiel T, Woźniak W, Nycz M, et al. Shedding light on the problem: Influence of the radiator power, source-sample distance, and exposure time on the performance of UV-C lamps in laboratory and real-world conditions. *PLoS ONE.* 2024;19:e0302258. 10.1371/journal.pone.0302258.
63. Lorca-Oró C, Vila J, Pleguezuelos P, Vergara-Alert J, Rodon J, Majó N, et al. Rapid SARS-CoV-2 inactivation in a simulated hospital room using a mobile and autonomous robot emitting ultraviolet-C light. *J Infect Dis.* 2022;225:587–92. 10.1093/infdis/jiab551.
64. Tholany J, Suzuki H, Frank AR, Bryant SH, Cunningham Goedken C, Suh D, et al. The use of UV-C radiation for terminal disinfection of pathogenic Gram-negative rods: a pilot study. *Antimicrob Steward Healthc Epidemiol.* 2023;3:e247. 10.1017/ash.2023.514.
65. Rutala WA, Gergen MF, Tande BM, Weber DJ. Rapid hospital room decontamination using ultraviolet (UV) light with a nanostructured UV-reflective wall coating. *Infect Control Hosp Epidemiol.* 2013;34:527–9. 10.1086/670211.
66. Fourman N, Hourli-Levi E, Meltzer E, Mechnik B, Pinas-Zade N, Maizels L, et al. Efficacy of UV-C devices in *Clostridioides difficile* environmental decontamination in a hospital setting: a before-after study. *BMC Infect Dis.* 2026;26:295. 10.1186/s12879-025-12415-y.
67. Casini B, Tuvo B, Scarpaci M, Totaro M, Badalucco F, Briani S, et al. Implementation of an environmental cleaning protocol in hospital critical areas using a UV-C disinfection robot. *Int J Environ Res Public Health.* 2023;20:4284. 10.3390/ijerph20054284.
68. McGinn C, Scott R, Ryan C, Donnelly N, Cullinan MF, Beckett M. Rapid disinfection of radiology treatment rooms using an autonomous ultraviolet germicidal irradiation robot. *Am J Infect Control.* 2022;50:947–53. 10.1016/j.ajic.2021.11.022.
69. McGinn C, Scott R, Donnelly N, Roberts KL, Bogue M, Kiernan C, et al. Exploring the applicability of robot-assisted UV disinfection in radiology. *Front Robot AI.* 2021;7:590306. 10.3389/frobt.2020.590306.
70. Carlisle MG, Rutala WA, Cadnum JL, Wilson BM, Deshpande A, Donskey CJ. A randomized trial of ultraviolet-C light versus sodium hypochlorite delivered by an electrostatic sprayer for adjunctive

- decontamination of hospital rooms. *Infect Control Hosp Epidemiol*. 2023;44:1025–8. 10.1017/ice.2022.132.
71. Casini B, Tuvo B, Cristina ML, Spagnolo AM, Totaro M, Baggiani A, et al. Evaluation of an Ultraviolet C (UVC) Light-Emitting Device for Disinfection of High Touch Surfaces in Hospital Critical Areas. *Int J Environ Res Public Health*. 2019;16:3572. 10.3390/ijerph16193572.
 72. Kitagawa H, Mori M, Hara T, Kashiyaama S, Shigemoto N, Ohge H. Effectiveness of pulsed xenon ultraviolet disinfection for *Clostridioides (Clostridium) difficile* surface contamination in a Japanese hospital. *Am J Infect Control*. 2021;49:55–8. 10.1016/j.ajic.2020.05.032.
 73. Kitagawa H, Mori M, Kashiyaama S, Sasabe Y, Ukon K, Shimokawa N, et al. Effect of pulsed xenon ultraviolet disinfection on methicillin-resistant *Staphylococcus aureus* contamination of high-touch surfaces in a Japanese hospital. *Am J Infect Control*. 2020;48:139–42. 10.1016/j.ajic.2019.08.033.
 74. Sathitakorn O, Jantarathaneewat K, Weber DJ, Apisarnthanarak P, Rutjanawech S, Apisarnthanarak A. Efficacy of Environmental Cleaning Protocol Featuring Real-Time Feedback with and without PX-UV in Reducing the Contamination of Gram-Negative Microorganisms on High-Touch Surfaces in Four Intensive Care Units in Thailand. *Antibiot (Basel)*. 2023;12:438. 10.3390/antibiotics12030438.
 75. Jinadatha C, Villamaria FC, Restrepo MI, Ganachari-Mallappa N, Liao IC, Stock EM, et al. Is the pulsed xenon ultraviolet light no-touch disinfection system effective on methicillin-resistant *Staphylococcus aureus* in the absence of manual cleaning? *Am J Infect Control*. 2015;43:878–81. 10.1016/j.ajic.2015.04.005.
 76. Simmons S, Dale C Jr, Holt J, Passey DG, Stibich M. Environmental effectiveness of pulsed-xenon light in the operating room. *Am J Infect Control*. 2018;46:1003–8. 10.1016/j.ajic.2018.02.027.
 77. Su WL, Lin CP, Huang HC, Wu YK, Yang MC, Chiu SK, et al. Clinical application of ultraviolet C inactivation of severe acute respiratory syndrome coronavirus 2 in contaminated hospital environments. *Viruses*. 2021;13:2367. 10.3390/v13122367.
 78. Bosco R, Cevenini G, Gambelli S, Nante N, Messina G. Improvement and standardization of disinfection in hospital theatre with ultraviolet-C technology. *J Hosp Infect*. 2022;128:19–25. 10.1016/j.jhin.2022.07.006.
 79. Kitagawa H, Tadera K, Mori M, Kashiyaama S, Nomura T, Omori K, et al. The effect of pulsed-xenon ultraviolet disinfection on surfaces contaminated with vancomycin-resistant enterococci in a Japanese hospital. *J Infect Chemother*. 2021;27:1665–8. 10.1016/j.jiac.2021.08.011.
 80. Ghantaji SS, Stibich M, Stachowiak J, Cantu S, Adachi JA, Raad II, et al. Non-inferiority of pulsed xenon UV light versus bleach for reducing environmental *Clostridium difficile* contamination on high-touch surfaces in *Clostridium difficile* infection isolation rooms. *J Med Microbiol*. 2015;64:191–4. 10.1099/jmm.0.000004-0.
 81. Zeber JE, Pfeiffer C, Baddley JW, Cadena-Zuluaga J, Stock EM, Copeland LA, et al. Effect of pulsed xenon ultraviolet room disinfection devices on microbial counts for methicillin-resistant *Staphylococcus aureus* and aerobic bacterial colonies. *Am J Infect Control*. 2018;46:668–73. 10.1016/j.ajic.2018.02.001.

82. Zeber JE, Coppin JD, Villamaria FC, Williams MD, et al. Use of ultraviolet irradiation in addition to commonly used hospital disinfectants or cleaners further reduces the bioburden on high-touch surfaces. Open Forum Infect Dis. 2019;6:ofz529. 10.1093/ofid/ofz529.

Figures

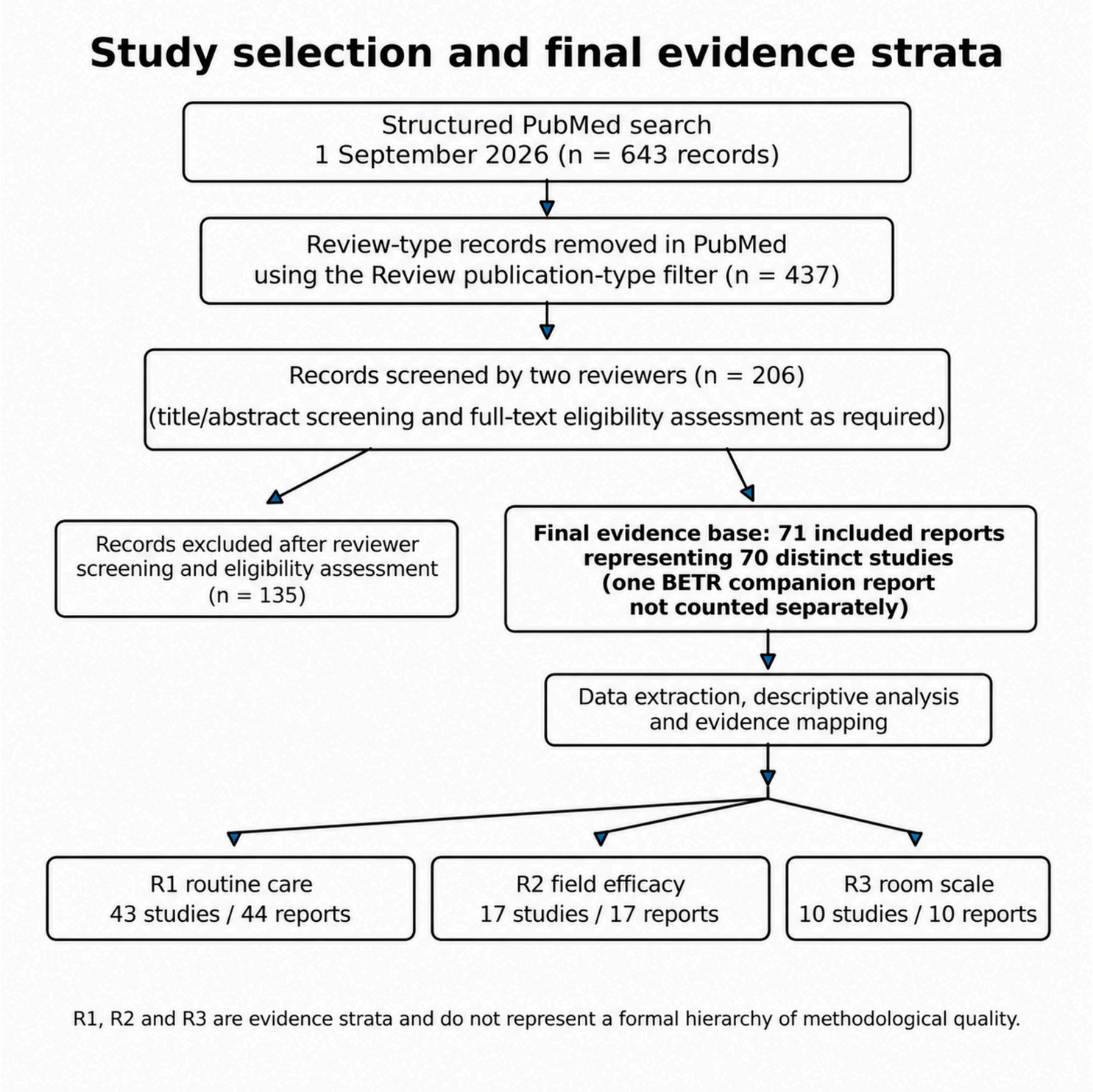


Figure 1

Study-selection flow and evidence strata. The structured PubMed search run on 1 September 2026 returned 643 records. Review-type records were identified and removed in PubMed using the Review publication-type filter (n=437), leaving 206 records for screening by two reviewers. Seventy-one reports representing 70 distinct studies met the eligibility criteria; one BETR companion report was not counted as a separate study.

Of the 206 records assessed by the reviewers, 135 were excluded during title/abstract screening or full-text eligibility assessment, leaving 71 included reports representing 70 distinct studies. The final evidence base comprised 43 R1 routine-care studies represented by 44 reports, 17 R2 healthcare field-efficacy studies represented by 17 reports, and 10 R3 healthcare-room/full-scale studies represented by 10 reports.

From UV emission to infection-prevention impact

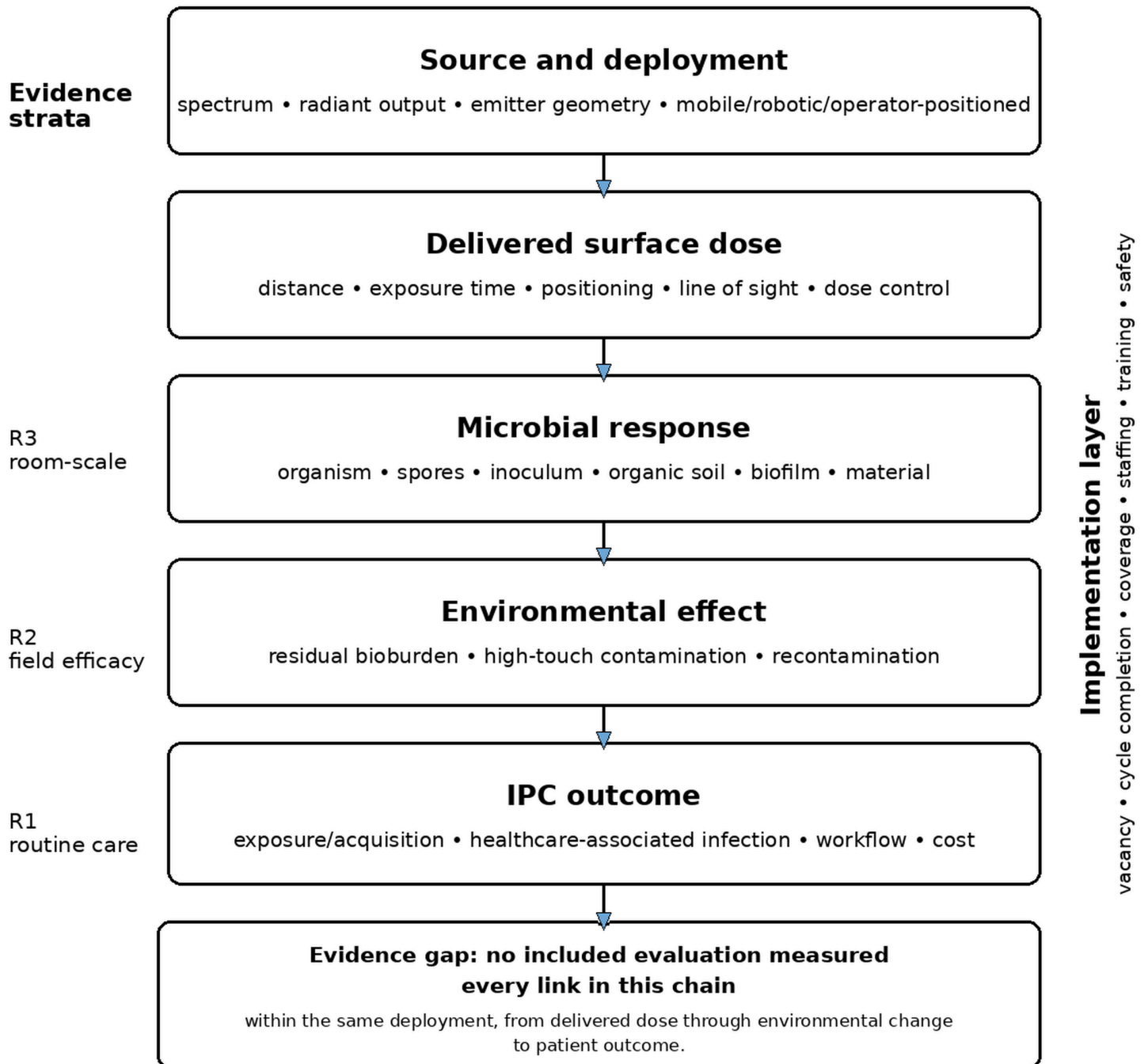


Figure 2

Translation framework from UV source characteristics to infection-prevention outcomes.

The same source can produce different outcomes when delivered dose, room geometry, organism, contamination matrix or implementation coverage differ. R3, R2 and R1 represent different evidentiary vantage points rather than a formal quality hierarchy; no single included study spans the entire translation pathway.

Supplementary Files

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

- [Additionalfile1.xlsx](#)