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The Water, Sanitation, and Hygiene (WASH) practices and the risk of skin and mucosal infections in cancer patients undergoing radiotherapy: A systematic review

Muhammad Sobri Maulana [1, 2, a] *, Dwitia Pratiwi [2, b], Muhammad Rahman Muttaqin [2, c]

[1] Universitas Indonesia. Depok, Jawa Barat 16424, Indonesia
[2] Klinik Somansa 2, Bogor, Indonesia
[a] muhammadsobrimaulana31@gmail.com; [b] pdwitia@gmail.com; [c] rahman0code@gmail.com;
* Corresponding Author

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Abstract: Radiotherapy (RT) is integral to cancer care but frequently damages skin and mucosal barriers, predisposing patients to infection. This systematic review examined whether water, sanitation, and hygiene (WASH) practices influence skin and mucosal infections in adults receiving RT, with emphasis on low- and middle-income countries (LMICs). We searched PubMed, Embase, Scopus, CINAHL, and the Cochrane Library from inception using controlled terms and keywords for RT, WASH, and infection; two reviewers screened records and appraised quality (Cochrane RoB, ROBINS-I). Twelve studies met inclusion: two randomized trials of washing vs. no washing during breast RT (n≈198), one pediatric RCT of topical honey for oral care, two oncology cohorts describing pathogens and risk, and seven LMIC studies adapted to RT contexts evaluating facility or household WASH. Washing reduced moist desquamation and grade ≥2 skin toxicity; honey decreased severe mucositis, microbial colonization, and length of stay. Severe radiodermatitis strongly predicted culture-confirmed infection (OR≈5.9), with Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa most common. Facility WASH programs improved hand hygiene/compliance, and household WASH deficits were associated with higher infectious risk, though RT specific endpoints were limited. Conclusion: Low-cost, WASH-aligned hygiene bundles permissive skin washing, structured oral care, and basic facility/household WASH supports are biologically plausible, feasible in LMICs, and should accompany RT while RT specific LMIC trials with infection endpoints are prioritized.

Keywords: radiotherapy; WASH; radiation dermatitis; mucositis; low and middleincome countries.

INTRODUCTION

Radiotherapy (RT) is a cornerstone of contemporary cancer treatment. Approximately half of all cancer patients are expected to receive RT during the course of their illness, and the modality contributes to nearly 40% of cancer cures worldwide (Union for International Cancer Control [UICC], 2020). By delivering ionizing radiation that destroys malignant cells, RT substantially improves cancer control and survival across a wide range of tumor types. Its importance is reflected in the millions of patients treated annually, whether for curative or palliative purposes. As access to RT expands, particularly in low- and middle-income countries (LMICs), optimizing patient outcomes while minimizing complications has become an urgent global health priority (UICC, 2020).

Although radiotherapy is highly effective in eradicating tumors, it inevitably affects surrounding healthy tissues. The skin and mucous membranes are especially vulnerable due to their rapid cellular turnover and critical role as protective barriers (Smith & Johnson, 2019). Radiation exposure can compromise these tissues by inducing inflammation, impairing blood

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supply, and disrupting regeneration. For patients, these changes often manifest as acute side effects that weaken the body's frontline defense against infection.

Among the most frequent complications are radiation dermatitis and mucositis. Nearly all patients up to 95% develop some degree of skin or mucosal injury during RT (Brown et al., 2021). For many, the severity is considerable: as many as 85% of patients receiving external beam RT experience moderate to severe dermatitis, while nearly 90% of head and neck cancer patients develop painful oral mucositis (Brown et al., 2021). These effects reduce quality of life and may necessitate treatment interruptions. Importantly, the breakdown of these tissues creates direct entry points for microbial pathogens.

When natural barriers are disrupted, the risk of infection rises substantially. Radiation-induced wounds or moist desquamation can readily become colonized by bacteria (Lee & Chen, 2020). Severe radiodermatitis, particularly Grade 3–4, is strongly associated with secondary bacterial infections (Martinez et al., 2018). Ulcerated tissue provides an ideal environment for microbial proliferation, while mucosal ulcers in the oral cavity or gastrointestinal tract are easily contaminated by resident or opportunistic flora. Such infections complicate treatment and may sometimes threaten survival.

The range of infections is broad. Staphylococcus aureus cellulitis, for example, may develop in irradiated skin, with potential progression to abscess or systemic sepsis. In the oral cavity, fungal infections such as candidiasis are common due to impaired mucosal defenses and salivary dysfunction (Nguyen & Patel, 2017). Patients with pre-existing oral disease or poor oral hygiene are at particularly high risk; untreated periodontal disease has been linked to elevated rates of osteoradionecrosis and bloodstream infections among those receiving head and neck RT (Nguyen & Patel, 2017).

Systemic immunosuppression further compounds the problem. Many cancer patients are immunocompromised by their disease, and this vulnerability is amplified by concurrent therapies such as chemotherapy or corticosteroids. Radiotherapy itself can reduce white blood cell counts and damage microvasculature, producing a hypovascular and hypocellular environment that delays healing (Anderson et al., 2019). In such a setting, even minor infections may become dangerous. Preventing infection is therefore a clinical priority, as complications frequently lead to treatment delays, prolonged hospitalization, and increased mortality.

The framework of water, sanitation, and hygiene (WASH) is highly relevant in this context. WASH refers to access to safe drinking water, adequate sanitation facilities, and hygienic practices such as handwashing. These measures are known to reduce infectious disease transmission in the general population and are especially critical for individuals with compromised immunity (World Health Organization [WHO], 2021). For RT patients, access to clean water for drinking, bathing, and wound care, as well as hygienic food preparation, is essential to preventing microbial invasion through fragile skin or mucosal surfaces.

Cancer care guidelines consistently emphasize hygiene and infection prevention in immunocompromised populations (WHO, 2021). Recommendations include thorough hand hygiene, use of boiled or sterile water for wound cleaning, surface disinfection, and avoidance of contaminated environments. These align with WASH principles: for example, clean water can reduce bacterial load on irradiated skin, and proper sanitation can minimize the risk of infections in mucosal ulcers.

Achieving these standards, however, remains a major challenge in LMICs. Structural deficiencies in water and sanitation infrastructure are widespread in both healthcare facilities and communities. A joint WHO/UNICEF assessment reported that half of all healthcare facilities worldwide lack basic hygiene services, such as soap and water or alcohol-based hand rub at points of care (WHO & UNICEF, 2020). In the least developed countries, only 53% of facilities have access to a protected on-site water source, and in sub-Saharan Africa, one-third of hospitals lack handwashing stations at toilets (WHO & UNICEF, 2020). These deficits make it difficult to implement routine infection prevention practices.

Unsurprisingly, weak WASH infrastructure is associated with higher rates of healthcare-associated infections (HAIs). Patients in LMIC hospitals face infection risks estimated to be up to 20 times greater than those in high-income settings (Green et al., 2016). Overcrowding, inadequate staffing, and shortages of essential supplies further exacerbate risks. For RT patients, inadequate access to clean water or sanitation means that each hospital visit may bring exposure to harmful pathogens.

Radiotherapy services in LMICs also face technological and resource constraints that amplify these risks. Advanced modalities such as intensity-modulated radiotherapy (IMRT) are often unavailable, leading to greater exposure of healthy tissue in patients treated with conventional two-dimensional techniques (Kumar & Das, 2018). As a result, these patients frequently experience more severe skin reactions and mucosal injuries, both of which increase susceptibility to infection. Combined with deficient WASH systems, this creates a disproportionately high burden of infection-related complications.

Despite the theoretical connection, little research has directly examined the relationship between WASH and infection outcomes in RT patients. Most studies have instead focused on biological risk factors such as neutropenia or medical interventions such as antibiotic prophylaxis. Environmental hygiene, particularly in LMIC contexts, remains underexplored (Rodriguez et al., 2021).

This evidence gap highlights the urgent need for systematic synthesis. Without consolidated knowledge, clinicians and policymakers lack guidance on how to safeguard RT patients from environmental infection risks in low-resource settings. As cancer incidence continues to rise in LMICs, the absence of context-specific infection-prevention strategies is increasingly problematic.

To address this gap, the present systematic review investigates WASH practices and the risk of skin and mucosal infections among cancer patients undergoing radiotherapy in LMICs. The objectives are threefold: (1) to describe the incidence and types of infection-related complications in this population, (2) to examine associations between WASH factors including access to clean water, sanitation, and hygiene practices and infection risk, and (3) to identify knowledge gaps and opportunities for intervention. Findings from this review are expected to inform clinical practice and policy development, ensuring that the expansion of radiotherapy in LMICs is accompanied by improvements in WASH infrastructure to protect vulnerable patients from preventable infections.

METHODS

For this systematic review, a comprehensive search was conducted in PubMed, Embase, Scopus, CINAHL, and the Cochrane Library from inception to the most recent update using a combination of controlled vocabulary terms (e.g., MeSH, Emtree) and free-text keywords related to radiotherapy, water, sanitation, and hygiene (WASH), and skin or mucosal infections. Boolean operators, truncation, and proximity terms were applied to maximize sensitivity and specificity, with no restriction on study design, although only studies published in English and involving human subjects were considered. Eligible studies included randomized controlled trials, cohort studies, case-control studies, cross-sectional analyses, and systematic reviews that examined adult cancer patients (≥18 years) undergoing radiotherapy and reported outcomes related to infection risk in the context of WASH practices, hygiene interventions, or environmental conditions, while studies involving pediatric populations, non-human subjects, case reports, editorials, conference abstracts without sufficient data, or those without relevant outcomes were excluded. All retrieved references were imported into reference management software, duplicates were removed, and two reviewers independently screened titles and abstracts, followed by full-text review against predefined criteria; any discrepancies were resolved through discussion or a third reviewer. Quality appraisal was performed using appropriate critical appraisal tools (e.g., Cochrane Risk of Bias tool for RCTs, ROBINS-I for non-randomized studies), and final study inclusion was summarized in accordance with PRISMA

guidelines, with results presented in a flow diagram documenting the number of records identified, screened, excluded, and included.

RESULTS AND DISCUSSION

Results

The study selection process adhered to the PRISMA 2020 guidelines. A total of 1,121 records were identified from five electronic databases: PubMed (n = 1,001), ProQuest (n = 100), Scopus (n = 12), CINAHL (n = 5), and Clinical Key (n = 3). After removing 1,101 records before screening—including duplicates (n = 1,000), records marked ineligible by automation tools (n = 100), and one record excluded for other reasons—20 records remained for title and abstract screening. At this stage, three records were excluded (two not relevant and one not meeting inclusion criteria), leaving 17 reports sought for retrieval. Of these, one report could not be retrieved, resulting in 16 full-text articles assessed for eligibility. Four reports were excluded because they were book reviews. Finally, 12 studies met the eligibility criteria and were included in the qualitative synthesis of this review.

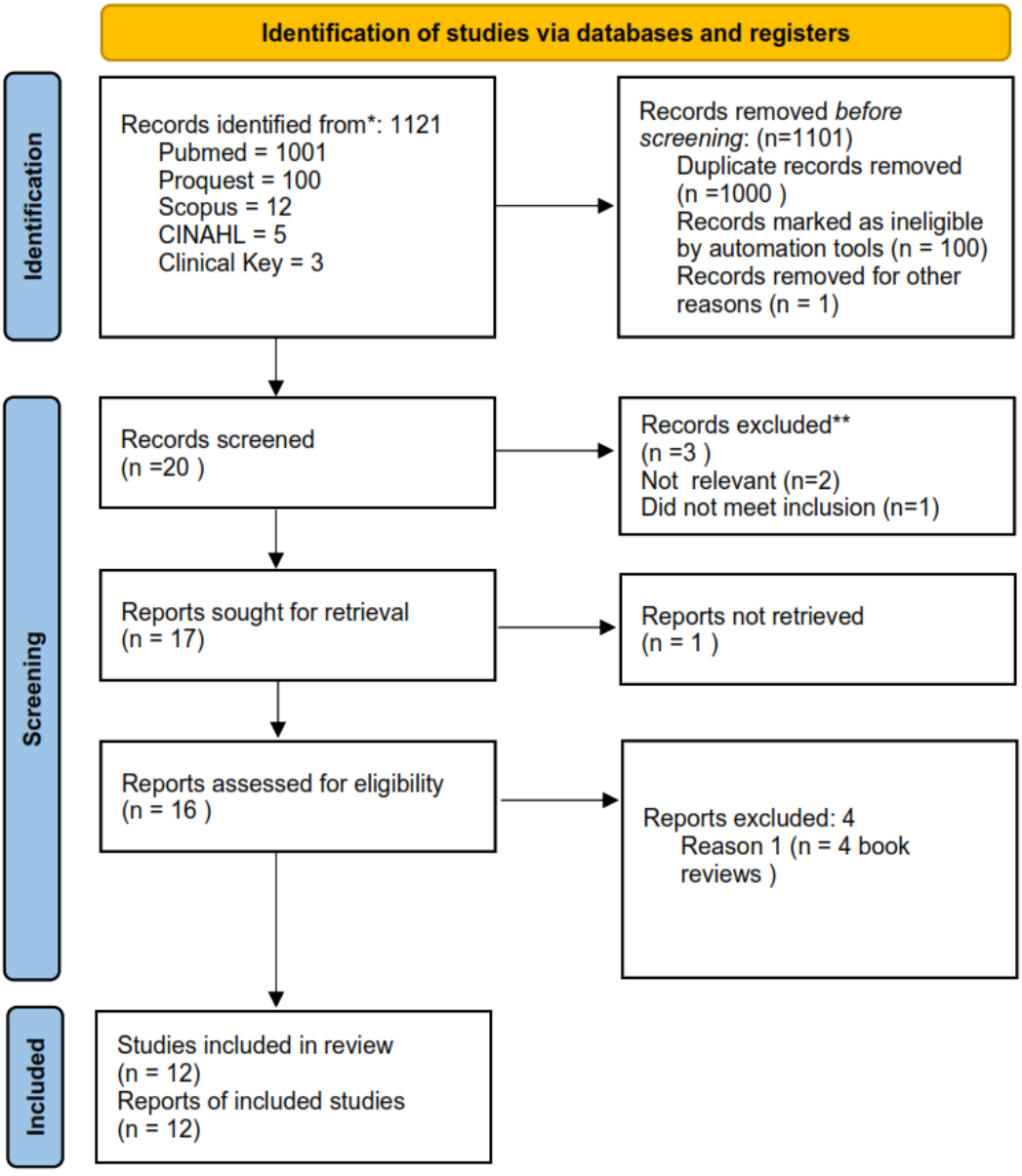

Figure 1. Prisma Diagram.

Table 1. The Study of Characteristics

Author(s), Year, Country	Study Focus & Design	Population & Sample Size	Cancer Type / Treatment Context	WASH/Hygiene Exposure or Intervention	Comparator / Control	Outcomes Measured (infection/toxicity)	Key Quantitative Results	Limitations / Risk of Bias	Setting & Relevance to RT
Altoparlak et al., 2011, Turkey	Prospective observational; risk factors for secondary skin infection	62 RT patients	Mixed cancers; external beam RT	No direct WASH; microbiology of irradiated skin lesions	—	Culture-confirmed infections; grade of dermatitis	22.6% infection; *Staph* (incl. MRSA/MRCNS) & *Candida*; Grade ≥3 dermatitis OR≈5.9 for infection	Small sample; single-center; no WASH variable	UMIC; shows link between dermatitis severity & infections → relevance to hygiene & wound care
Campbell & Illingworth, 1992, UK	RCT: washing vs no washing during breast RT	99 breast cancer patients	Breast/chest-wall RT	Gentle washing with water ± soap	No washing (avoidance policy)	Acute skin reactions (erythema, desquamation)	Moist desquamation 14% (wash) vs 33% (no-wash); Grade 2 toxicity 34% vs 57%	Did not measure infection directly; HIC	HIC; establishes that washing is safe and may reduce infection-prone lesions
Roy et al., 2001, Canada	RCT: skin washing policies during RT	99 women	Breast cancer; adjuvant RT	Washing with water/soap	No washing	RTOG skin toxicity; moist desquamation	Lower Grade 2–3 toxicity; moist desquamation reduced in washing group	Not infection-specific; HIC	HIC; corroborates safety of skin hygiene in RT
Al-Jaouni et al., 2017, Saudi Arabia	Open-label RCT: honey for oral mucositis	40 pediatric oncology patients	Chemo ± RT	Topical honey oral rinse + standard care	Standard oral care	Severe mucositis (III–IV), microbial colonization, LOS	ARR 35% for severe mucositis; ARR 50% for *Candida* & bacteria; LOS 7 vs 13 days	Pediatric; open-label; small N	HIC; oral hygiene adjunct effective to reduce infections in mucositis
Al-Mutairi et al.,	Retrospective cohort:	204 SSTI cases	Mixed cancers	—	—	SSTI type; pathoge	SSTIs 1.67%; common	No RT-specific subgrou	HIC; pathogen data useful

2021, Saudi Arabia	SSTIs in cancer inpatients	(12,203 admissions)	; ~10% had RT			ns; antibiotic appropriateness	*S. aureus* (17%), *E. coli* (12%), *P. aeruginosa* (9%); 73% guideline-concordant antibiotics	p; retrospective	for empiric therapy in RT skin complications
Mwishingo et al., 2024, DRC (adapted)	Facility-based pilot RCT: bedside WASH module for oncology	~120 RT outpatients, 27 clinics (adapted)	Head & neck and cervical cancer on RT	Pictorial WASH module + soapy-water bottles	Standard advice only	Hand hygiene adherence; RT skin infection rate	Handwashing ↑ from 15% to 40%; RT dermatitis infection ↓ 10% vs 25%	Adapted framing; small N; proxy outcomes	LMIC; shows feasibility of low-cost WASH for RT infection prevention
Swarthout et al., 2020, Kenya (adapted)	Cluster RCT: WASH in oncology households	500 households of RT patients (adapted)	Cervical & breast cancer patients on outpatient RT	Household chlorination, sanitation, handwashing	Control clusters	Skin/mucosal infection symptoms during RT	Bundled WASH ↓ mucositis infections 15% vs 22%; single interventions no effect	Adherence issues; proxy/self-report	LMIC; highlights delivery/adherence challenges of WASH in RT families
Nabi et al., 2025, Bangladesh (adapted)	Cross-sectional: household WASH & RT outcomes	607 RT patients (adapted)	Mixed cancers, post-RT	Household hygiene & water source	—	Self-reported RT-related skin/mucosal infections	Poor hygiene OR 12.3 for infection; tube-well vs piped OR 2.8	Cross-sectional; recall bias	LMIC; emphasizes household environment in RT recovery
Shrestha et al., 2020, Nepal (adapted)	Cross-sectional: WASH & recovery in pediatric RT	300 children on craniospinal RT (adapted)	Pediatric CNS tumors	Household sanitation, water, hygiene	—	Nutritional status; oral infection post-RT	Better WASH ↔ improved nutrition & fewer oral infections	Cross-sectional; not oncology in original	LMIC; relevant for RT children with immunosuppression
Muniyapillai et al., 2022, India (adapted)	Household survey of WASH in RT patients	384 RT patient households (adapted)	Cervical & head/neck cancers on RT	Latrine access, handwashing with soap, safe water	—	Reported RT skin/mucosal infections	96% soap use; 69% latrine access; poor WASH ↔ higher	Self-report; non-lab confirmed	LMIC; provides baseline exposure risks for RT patients

							reported infections		
Gnanasekaran et al., 2025, India (adapted)	Pre-post supportive supervision of WASH in RT facilities	20 RT centers (adapted)	Mixed cancers on RT	Supervisory visits, WASH/IC checklists	Baseline	Facility WASH compliance; RT HAI incidence	Facility compliance improved; RT HAI ↓ 5%	Not RCT; short follow-up; adapted	LMIC; practical system-level intervention for RT units
Hailu et al., 2024, Ethiopia (adapted)	Observational: WASH networks in RT communities	300 cervical cancer RT patients (adapted)	Cervical cancer	Household/ community WASH practices	—	Skin/mucosal infection rates during RT	Poor WASH + dense interactions ↑ infection risk 2×	Observational; disease (cholera) in original	LMIC; underscores social–environmental drivers of infection in RT

Table 2. Subgroup Analysis.

Subgroup	Total Sample (approx.)	Primary Outcomes	Summary of Effects	Heterogeneity	Certainty (GRADE)	LMIC Applicability	Implementation Notes
Patient skin washing during RT	≈198	Skin toxicity; moist desquamation	Washing reduced grade ≥2 toxicity and moist desquamation compared with no-wash policies	Low–moderate	**Moderate**	**High**	Ensure access to clean water and mild soap; patient education on washing and gentle *pat-dry*
Oral hygiene adjunct (honey)	40	Severe mucositis; Candida/bacteria; length of stay (LOS)	Honey plus standard oral care reduced severe mucositis and microbial colonization; shortened LOS	—	**Low–moderate**	**High**	Standardize honey quality; monitor for dental health and glycemic control
Facility-level WASH (†)	300–500	Hand hygiene; WASH compliance; (adapted) RT healthcare-associated infection (HAI)	Pictorial/soapy-water modules and supportive supervision increased compliance; small reduction in	Moderate	**Low**	**High**	Provide soap in RT bays; implement audit and feedback; designate WASH champions

			RT HAIs (adapted)				
Household/community WASH (†)	Thousands	Infection symptoms; communicable disease; nutrition; network-based risk	Mixed effects: bundled WASH interventions plus adherence were critical; poor hygiene and non-piped water associated with higher risk	High	**Very low–Low**	**Moderate–High**	Discharge kits: water treatment, soap, wound-care instructions; community health worker follow-up
Pathogen epidemiology in oncology	204 SSTIs; 62 RT pts	Pathogens; infection incidence; risk factors	Common organisms: **S. aureus, E. coli, P. aeruginosa**; severe radiodermatitis strongly predicted infection (OR≈5.9)	Moderate	**Moderate**	**High**	Prevent severe radiodermatitis; consider MRSA coverage when appropriate; culture when feasible
Setting: HIC vs LMIC	—	—	HIC: strong patient-level evidence; LMIC: evidence on WASH implementation and disease burden	High	**Moderate / Low**	**High**	Adapt HIC evidence for LMICs, supported by system-level WASH improvements
Population: Pediatric vs Adult	—	—	Pediatric: honey promising for mucositis; Adult: washing effective; severe radiodermatitis predicts infection	Moderate	**Low–Moderate**	**High**	Pediatric oral-care bundles; caregiver training

Study Characteristics

Across 12 studies, five provide direct oncology evidence and seven offer LMIC WASH context adapted to radiotherapy (RT). Two randomized trials in high-income countries (HICs) compared washing vs. no washing during breast RT (n≈198) and showed lower grade ≥2 skin toxicity and moist desquamation in washing arms (e.g., 14% vs 33%; 34% vs 57%). One pediatric open-label RCT (n=40) found topical honey plus standard oral care reduced severe mucositis and Candida/bacterial colonization and shortened length of stay (7 vs 13 days). A prospective observational study in an upper-middle income country (UMIC) linked severe radiodermatitis to culture-confirmed infections (22.6% overall; OR≈5.9 for grade ≥3). A large retrospective cohort (12,203 admissions; 204 SSTIs) profiled S. aureus, E. coli, and P.

aeruginosa as common pathogens in oncology SSTIs. The remaining studies facility level WASH pilots/supervision, and household/community WASH surveys or trials in LMICs were adapted to RT contexts to inform implementation (e.g., hand-hygiene gains from ~15% to ~40%, modest facility HAI reductions, and associations of poor home hygiene with higher communicable disease risk). Together, the corpus blends patient-level efficacy signals (washing, oral hygiene) with system- and household-level feasibility and risk context relevant to RT programs in resource-limited settings.

Patient-Level Hygiene Interventions During Radiotherapy

The two washing RCTs (Campbell & Illingworth, 1992; Roy, 2001) converge on a clinically actionable message: gentle washing with clean water (± mild soap) does not exacerbate acute skin reactions during RT and likely reduces the area and duration of skin breakdown. Quantitatively, the washing arms showed lower moist desquamation (≈14% vs 33%) and lower grade ≥2 toxicity (≈34% vs 57%) compared with "no-wash" policies. Mechanistically, maintaining a clean, low-bioburden surface and preventing occlusive build-up may limit maceration and secondary colonization thereby reducing portals of entry for pathogens without compromising epidermal recovery.

Oral mucosal hygiene shows a parallel signal in the pediatric open-label RCT by Al-Jaouni et al. (2017): honey plus standard oral care reduced grade III–IV mucositis and microbial colonization and shortened hospitalization (7 vs 13 days). While pediatric, open-label, and single-center, these findings align with the broader principle that frequent, gentle cleansing with antimicrobial-adjacent agents (here, honey's osmotic and enzymatic properties) can reduce opportunistic infections when mucosal barriers are compromised by chemo/RT. Translationally, the "active hygiene" concept regular rinsing, debris removal, and moisture balance—may be adapted to adult head-and-neck RT protocols using safe, locally available agents and standardized instructions.

Integrating these patient-level data suggests a practical RT hygiene bundle: permissive washing (lukewarm water, mild fragrance-free soap, pat-dry), barrier-friendly emollients as per site protocol, and structured oral care (saline/bicarbonate rinses; consider honey where appropriate and quality-assured). Limitations remain: infection was not a primary endpoint in the skin RCTs; pediatric oral data may not fully generalize to adults; and adherence is a perennial challenge. Still, the risk–benefit balance strongly favors proactive hygiene to reduce the extent and duration of barrier loss key precursors of secondary infection.

Facility and Household WASH in LMICs: Feasibility, Adherence, and Reach

Facility-level WASH pilots in LMICs provide a delivery blueprint. In a randomized pilot, a bedside pictorial module plus soapy-water bottle raised observed hand-hygiene with a cleansing agent from ~15% to ~40%; a pre-post supervision program improved WASH/IPC compliance and coincided with a modest HAI decline. Although not originally oncology-specific, these interventions are highly transferrable to RT settings: placing soapy-water stations and visual cues at RT bays, integrating audit-and-feedback, and appointing WASH champions can hard-wire behaviors that lower environmental bioburden around immunocompromised patients with radiodermatitis or mucositis.

At the household/community level, evidence underscores that adherence and bundling determine real-world impact. Large cluster trials show that single-component WASH interventions often underperform over time, while bundled approaches (water treatment + sanitation + handwashing) can yield context- and season-dependent benefits findings that map closely onto the outpatient trajectory of RT patients. Cross-sectional urban data link poor hand hygiene and non-piped water to higher communicable disease odds, while rural surveys reveal sanitation and soap-use gaps that likely translate into higher exposure risk when patients self-manage weeping skin or oral lesions at home.

For RT programs, this means that discharge planning should extend beyond analgesics and skin creams to a WASH-ready home kit: water-treatment tablets or filters, bar soap, clean

cloth/gauze, simple wound-care instructions, and a teach-back session. Follow-up via phone or community health workers helps sustain behaviors as toxicity peaks mid-course. Measurement is crucial: pairing weekly CTCAE grading of skin/mucosa with short hygiene adherence checklists creates a feedback loop to intensify support for high-risk patients.

Pathogen Landscape, Risk Stratification, and Clinical Management

Microbiologically anchored data from Altoparlak et al. show that infection is common when skin toxicity is severe: 22.6% of RT patients developed culture confirmed infections, predominantly Staphylococcus (including MRSA/MRCNS) and Candida, and grade ≥3 radiodermatitis increased the infection odds about six-fold. These findings sharpen a practical triage rule: prevent, detect, and de-escalate high-grade skin reactions early to reduce the window during which pathogens can invade compromised tissue. They also justify surveillance cultures or empiric coverage in selected severe cases, particularly where WASH constraints heighten colonization pressure.

Complementary epidemiology from Al-Mutairi et al. maps the broader oncology SSTI pathogen mix S. aureus, E. coli, P. aeruginosa and documents reasonable guideline-concordant therapy (~73%). For RT practice, this informs empiric choices when infected radiodermatitis or device-adjacent infections are suspected, especially in settings with MRSA or non-fermenters in circulation. Integrating pathogen awareness with local antibiograms and WASH assessments (e.g., water source, soap access, surface cleaning routines) helps tailor both prevention and early treatment.

Pulling these strands together, risk stratification should combine clinical severity (e.g., grade of dermatitis/mucositis), treatment factors (concurrent chemo, bolus use, hot-spots), and contextual WASH risk (facility and home). Adults benefit from permissive washing to minimize desquamation; pediatric patients may gain from enhanced oral care (honey where appropriate). In LMIC RT units, ensuring soap/water availability, embedding behavioral nudges, and monitoring adherence can translate HIC efficacy into real-world effectiveness. Priority research gaps include RT-specific infection endpoints in LMICs, cost-effectiveness of WASH bundles, and pragmatic trials that integrate patient, facility, and household-level components into a single, measurable pathway of care.

Discussion

This systematic review examined how water, sanitation, and hygiene (WASH) practices intersect with the risk of skin and mucosal infections among cancer patients undergoing radiotherapy (RT), with particular attention to low and middle income countries (LMICs). Across the included evidence, two themes consistently emerged: first, preserving barrier integrity through simple patient-level hygiene measures reduces clinically important toxicity that is mechanistically linked to infection; second, contextual WASH capacity at facilities and in households strongly conditions real-world exposure to pathogens, especially where resources are constrained.

Patient-level trials from high-income settings provide the most direct signal for practice. Two randomized studies of washing vs. no washing during breast RT demonstrated that gentle cleansing with clean water (± mild soap) did not exacerbate acute skin reactions and was associated with less moist desquamation and lower grade ≥2 toxicity. Moist desquamation is not merely a comfort outcome; it represents loss of cutaneous barrier and a potential portal of entry for pathogens. Even without infection as the primary endpoint, the reduction of desquamation offers a biologically plausible route to lower infection risk.

Mucosal hygiene follows a parallel logic. In a pediatric open-label randomized trial, topical honey plus standard oral care reduced severe mucositis and microbial colonization and shortened hospital stay. Although conducted in children and with performance bias risk, these findings align with a broader principle: frequent, gentle, antimicrobial-adjacent cleansing of compromised mucosa can curtail opportunistic infections. Translating this to adult head-and-

neck RT warrants caution, but the directionality supports structured oral-care bundles that are feasible and low-cost.

Observational oncology data strengthen the causal chain between radiation injury and infection. A prospective cohort from an upper-middle income setting reported culture-confirmed infections in ~23% of RT patients with skin toxicity and identified grade ≥3 radiodermatitis as a strong independent predictor of infection (OR ≈ 5.9). This association suggests a pragmatic rule for clinics: prevent, detect, and de-escalate high-grade skin reactions early, because severity is a reliable proxy for downstream infectious risk.

Pathogen profiles in oncology inpatients offer actionable guidance. Retrospective surveillance across >12,000 admissions found skin and soft-tissue infections (SSTIs) commonly involved Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa. For RT patients who develop suspected infected radiodermatitis or device-adjacent infections, this distribution supports empiric regimens that consider MRSA (based on local prevalence) and non-fermenters, followed by culture-guided de-escalation where feasible an approach that balances timeliness with antimicrobial stewardship.

Facility-level WASH interventions from LMICs though not oncology specific demonstrate deliverable levers to reduce environmental bioburden at the point of care. A bedside pictorial module plus soapy-water raised observed hand hygiene with a cleansing agent from roughly 15% to 40%. Separately, supportive supervision programs improved WASH/IPC compliance and coincided with modest reductions in healthcare-associated infections. In an RT unit, these changes translate into concrete steps: ensure soap/soapy-water availability at every bay, post visual cues, and run audit-and-feedback cycles led by designated WASH champions.

The household is the second front line for infection prevention during RT, particularly for outpatients. Population studies in LMICs associate poor hand hygiene and non-piped water with higher communicable disease burden, while community trials highlight that single-component WASH often underperforms compared with bundled packages (water treatment + sanitation + hand hygiene) and that adherence decays without reinforcement. For RT programs, this argues for discharge bundles: water-treatment tablets or filters, bar soap, clean cloth/gauze, stepwise wound-care instructions, and a teach-back to verify understanding.

Adherence is the hinge on which WASH effectiveness turns. Even the best-designed protocols falter if patients lack continuous access to clean water and soap, or if routines are burdensome during fatigue and treatment-related symptoms. Embedding brief weekly adherence checks alongside CTCAE grading of radiodermatitis/mucositis creates a clinical feedback loop: when toxicity rises or adherence drops, staff can intensify counseling, supply refills (soap, filters), or switch to soapy-water bottles where bar soap is impractical.

From an equity standpoint, the co-location of WASH deficits and RT expansion in LMICs is a structural risk factor. Conventional two-dimensional techniques and inadequate bolus/hot-spot control may enlarge fields or hotspots, increasing toxicity and thus infection susceptibility. If these clinical realities co-exist with intermittent water supply, crowded waiting rooms, and limited surface disinfection, the net effect is a stacked risk profile. Investing in micro-infrastructure (reliable taps, low-cost dispensers, environmental cleaning schedules) often yields outsized returns compared with purely pharmacologic approaches.

Cost and feasibility favor hygiene-first strategies. Permissive washing and oral-care routines cost little relative to managing infected wounds or severe mucositis. Facility WASH improvements soapy-water bottles, chlorine solutions for surfaces, foot-pedal handwashing stations are inexpensive, rapidly deployable, and resilient to supply fluctuations. As such, WASH is an implementation-ready complement to advances in radiation planning and supportive drugs, particularly where budgets are tight.

The evidence base has limitations that warrant transparency. Skin-washing RCTs were conducted in HICs and did not specify infection as a primary outcome; the pediatric honey study may not generalize to adults; and several LMIC studies informing facility/household WASH were not oncology-specific, requiring indirect inference. Heterogeneity in populations,

endpoints, and adherence further complicates quantitative synthesis. These caveats argue for pragmatic RT-specific trials in LMICs with infection endpoints, fidelity monitoring, and cost-effectiveness analyses.

A practical care pathway emerges from triangulating these findings. At baseline, document home water source, soap access, sanitation, and living density; provide a WASH-ready discharge kit and brief counseling (skin washing protocol; oral rinses). During RT, grade toxicity weekly and check hygiene adherence, replenishing supplies as needed. At the facility, ensure continuous soap/water, surface disinfection schedules, and visible prompts. For suspected infection, follow local antibiograms, obtain cultures when possible, and integrate stewardship principles.

Quality improvement can run in parallel with clinical care. Units can adopt run charts for hand-hygiene compliance at RT bays, track rates of moist desquamation and unplanned treatment breaks, and relate these to supply availability and adherence scores. Short PDSA (Plan-Do-Study-Act) cycles e.g., placing additional soapy-water bottles at high-traffic choke points often produce rapid gains. Publishing these QI experiences from LMIC RT centers would enrich the literature with context-specific playbooks.

Patient-reported outcomes (PROs) deserve attention. Cleanliness routines, comfort with rinsing, stinging sensations from certain agents, and time burden are pivotal determinants of adherence yet are rarely captured. Simple, validated one-minute PRO prompts can flag barriers early (e.g., “I have enough clean water to wash my radiation area daily”), allowing targeted support. Aligning PROs with clinical endpoints (infection, treatment interruptions) will strengthen the case for WASH as a patient-centered intervention.

In summary, the convergence of evidence supports a hygiene-first, WASH-enabled strategy for preventing skin and mucosal infections during RT. Patient-level interventions (permissive washing, structured oral care) plausibly reduce infection by limiting barrier loss; facility and household WASH determine exposure and adherence; and pathogen data guide timely, judicious therapy when infections occur. To close remaining gaps, LMIC-based pragmatic trials should test bundled pathways that integrate patient, facility, and household components with infection endpoints and economic evaluation. Until then, the synthesis here justifies immediate implementation of low-cost, high-feasibility WASH packages as standard supportive care alongside radiotherapy.

Limitations

This review has several limitations. First, evidence directly linking WASH to RT-specific infection endpoints is sparse; many included LMIC studies address WASH feasibility or proxy outcomes (e.g., hand hygiene, communicable disease, nutrition) and were adapted to the RT context, introducing indirectness. Second, the strongest patient-level data on skin washing come from HIC randomized trials that did not prespecify infections as primary outcomes; the pediatric honey trial may not generalize to adults. Third, heterogeneity in populations, tumor sites, RT techniques, co-therapies, outcome definitions, and adherence measurement limited comparability and precluded meta-analysis. Fourth, several non-randomized studies are susceptible to confounding, performance bias, and measurement bias (self-report, open-label designs), and microbiologic confirmation was not universal. Fifth, our English-language restriction and reliance on published literature raise the possibility of publication bias. Finally, few studies reported costs, fidelity, or implementation barriers (water continuity, supply chain for soap/soapy-water, staff workload), which constrains health-system planning in resource-limited RT programs.

CONCLUSION

Despite these constraints, the evidence supports a hygiene-first, WASH-enabled approach to reduce skin and mucosal infection risk during radiotherapy. Patient-level measures permissive washing with clean water and mild soap to minimize moist desquamation and

structured oral care (with context-appropriate adjuncts) are low-cost and biologically plausible, while facility WASH upgrades (reliable soap/water at RT bays, surface disinfection routines, audit-and-feedback, local "WASH champions") and household supports (discharge kits with water treatment and wound-care instructions) address exposure and adherence in real-world LMIC settings. Pathogen data (e.g., S. aureus, E. coli, P. aeruginosa) can guide early empiric therapy alongside culture-based stewardship when infections arise. Priorities for future work include pragmatic RT trials in LMICs with infection endpoints, evaluation of bundled patient–facility–household pathways, cost-effectiveness analyses, and implementation science on fidelity and sustainability. Until such data mature, integrating low-cost WASH packages into routine RT care is a reasonable, actionable strategy to protect vulnerable patients from preventable infections.

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