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Teaching the sterile start: a rapid scoping review and proposed START-OR competency model

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Abstract

Background

Surgical hand preparation, patient skin antisepsis, draping readiness and sterile-table set-up are often taught as separate rituals, although delays and failures arise at their interfaces. Evidence also spans microbiology, infection prevention, human factors and education, making it difficult to define what learners should time, observe, communicate and re-check.

Methods

A rapid scoping review mapped global indexed evidence on three sterile-start processes: surgical hand preparation; the transition from skin antisepsis to draping or incision; and sterile-field or instrument-table set-up. Web of Science and Scopus were searched from inception to 2 August 2026. Records were deduplicated and subjected to a high-recall rule-assisted primary screen. All candidate records underwent eligibility verification, and the full text of every included source was confirmed, verified and analysed by the author team. Data were charted by domain, design, specialty, educational outcome and first indexed affiliation region. Findings were integrated into the proposed Surgical Timing and Aseptic Readiness Tool for the Operating Room (START-OR).

Results

Of 5747 imported records, 298 duplicates were removed, 747 candidates underwent structured eligibility verification and 143 full-text evidence sources were included after author-team confirmation and analysis. The map comprised 30 education, assessment or implementation sources; 44 surgical hand-preparation sources; 61 skin-preparation sources; and eight sterile-field or table sources. Evidence did not support one universal minute value across products and contexts. Instead, hand preparation required product-specific technique, complete coverage, specified duration and drying; skin preparation required complete visible drying, absence of pooling and fire-risk control before draping; and sterile-field management required minimizing unnecessary open exposure and re-validating integrity after delay. Educational studies identified recurrent gaps in timing accuracy, coverage, feedback, monitoring and shared responsibility. START-OR therefore separates team, patient and field clocks, then reunites them at a voiced sterile-start pause and seven readiness gates.

Conclusions

Perioperative education should replace memorized universal times with observable readiness criteria, interprofessional verification, simulation of delays and feedback linked to patient-safety outcomes.

START-OR is a proposed, unvalidated curriculum and quality-improvement model that requires prospective multicentre testing before clinical adoption.

Background

Surgical-site infection prevention depends on a bundle of coordinated actions rather than on a single antiseptic product. International guidance places surgical hand preparation, pre-incision skin antisepsis, sterile technique and team verification within broader patient-safety systems, while the surgical safety checklist illustrates how a brief, voiced pause can convert individual tasks into shared situational awareness [1–7].

The educational problem is therefore not only whether a learner can recite a recommended duration. Competent performance requires knowing the product and its instructions for use, covering the correct anatomical area, recognizing complete drying and pooling, protecting the sterile field during delays, communicating uncertainty and stopping progression when readiness has not been achieved. These abilities span knowledge, psychomotor skill, performance in practice, deliberate practice, simulation and interprofessional teamwork [8–15].

Scoping review methodology is appropriate when evidence is heterogeneous in design, terminology and outcome and when the purpose is to map concepts, identify gaps and clarify whether narrower systematic review questions are feasible. This topic combines laboratory efficacy studies, randomized comparisons, audits, qualitative studies, educational interventions and professional guidance, making an integrative evidence map more defensible than a pooled global effect estimate [16–18].

A further conceptual problem is that the three relevant timelines are usually documented separately: the team clock for surgical hand preparation, the patient clock for antiseptic application and drying, and the field clock for opening and exposing sterile instruments. Treating these as independent rituals may conceal interface failures, such as a fully prepared table waiting for an unready patient, draping before an alcohol-based preparation has dried, or rushing gowning before the hands and forearms are dry [1, 3, 5, 8, 15].

This rapid scoping review therefore aimed to map the worldwide indexed evidence on timing, readiness, education and assessment for the sterile start; compare patterns across surgical specialties; identify educational interventions and outcome levels; and develop a transparent, testable process model for proactive aseptic management. The review questions were: what is timed or verified, how is competence taught and assessed, what specialty modifiers matter, and which observable gates should precede incision [16–18].

Methods

Review design and reporting

A rapid scoping review was conducted using the methodological foundations of Arksey and O'Malley, subsequent refinements, JBI guidance and PRISMA-ScR. PRISMA 2020 was used to strengthen flow reporting, while the model-development component was treated as a transparent evidence-informed synthesis rather than as a validated clinical guideline [16–22].

The review was initiated from an author-defined protocol and search plan, but it was not prospectively registered. This deviation is reported explicitly because protocol timing and public availability affect reproducibility; the complete search strategies and dated search record are supplied in Additional file 1 [19–21].

Eligibility criteria

Eligibility was structured using Population–Concept–Context. Populations included learners and practising members of the perioperative team; the concept covered timing, readiness, technique, education, assessment, implementation or contamination related to the three sterile-start processes; and contexts included operating rooms, simulation centres, skills laboratories and perioperative training across specialties. Table 1 presents the operational criteria [16, 18–19, 21].

Table 1
Eligibility criteria

PCC element	Included	Excluded	Rationale
Population	Medical, nursing and surgical-technology students; residents; surgeons; perioperative nurses; instrument/scrub personnel; anaesthesia and support staff when participating in the sterile start.	Veterinary-only populations; dental-only settings; patients without a perioperative-team or sterile-start component.	The journal focus requires relevance to healthcare-professional learning or performance.
Concept	Timing, duration, coverage, drying, readiness, compliance, teaching, simulation, feedback, assessment, implementation, contamination or infection outcomes for hand preparation, skin preparation-to-draping/incision, or sterile-field/table set-up.	Instrument reprocessing without a sterile-start link; unrelated transplantation bench time; general hand hygiene without surgical preparation; antisepsis outside operative/procedural care.	The concept joins clinical evidence with teachable and observable competencies.
Context	Operating rooms, procedure rooms, simulation, skills laboratories, perioperative education and quality-improvement programmes in any country or surgical specialty.	Non-healthcare environments and purely industrial or veterinary contexts.	Broad context supports global mapping and specialty comparison.
Evidence type	Primary studies, systematic or integrative reviews, protocols with relevant methods, educational interventions, audits, qualitative studies and implementation/guidance papers.	Editorials without substantive methods or data; duplicate publications; records lacking sufficient topical information.	Scoping reviews map breadth rather than restrict by a single design.
Language/date	All indexed languages and all publication years available in the source exports.	No exclusion solely by date; language limitations were imposed only by indexed metadata availability.	Reduces avoidable temporal and language restriction.

PCC, Population–Concept–Context. Records were retained only when full-text assessment confirmed a defensible link to the sterile start [16, 18–19, 21].

Information sources and search strategy

Web of Science Core Collection and Scopus were searched from inception through 2 August 2026. Search blocks combined terms for surgical hand preparation, surgical skin antisepsis, draping and drying, sterile fields, instrument tables, set-up, exposure, duration, interval, contamination, education, assessment and implementation. Searches were designed for sensitivity, documented according to

PRISMA-S and internally checked against PRESS principles; exact database syntax is available in Additional file 1 [23–24].

The two-database strategy was prespecified for the rapid mapping objective because Web of Science and Scopus provided broad interdisciplinary coverage, complete indexed records and cited-reference fields. Together they yielded 5747 records, 5449 unique records after deduplication and representation across every prespecified evidence domain and specialty group. This deliberate scope is sufficient for the stated rapid-review mapping objective, but it is not presented as exhaustive of MEDLINE, Embase, CINAHL, ERIC, Cochrane or grey literature and remains a limitation for future replication [18–19, 23–24].

An a priori charting framework linked source characteristics to educational quality, intervention replicability, learning level, experiential learning and teamwork. MERSQI and TIDieR informed description, while Kirkpatrick, Kolb, healthcare team-training evidence and TeamSTEPPS informed the transition from learning outcomes to workplace behaviour and system improvement [25–30].

Record management and selection

The source workbook contained 5747 imported records: 5095 from Web of Science and 652 from Scopus. Deduplication used normalized DOI and a title–year key, producing 5449 unique records. A high-recall rule-assisted title/abstract screen identified 747 candidates, after which candidate records were evaluated against the eligibility criteria. The full text of every retained source was then confirmed, verified and analysed before charting. Duplicates, veterinary records and records whose apparent timing terminology referred to unrelated processes were removed [21–23].

Primary title/abstract screening was conducted by ADP using a high-recall rule-assisted workflow. WAP and ARP participated in the full-text verification and analytic confirmation of the included evidence set, and uncertain eligibility or classification decisions were resolved by author-team consensus. Automated rules supported recall and consistency but did not make final inclusion decisions, and no record was excluded solely by automation. The primary-screening design is reported transparently as a rapid-review limitation [31–32].

Data charting and synthesis

Charted fields included bibliographic identifiers, year, journal, title, abstract, design group, primary domain, surgical specialty, educational outcome level, database source and first explicitly stated country in the indexed affiliation field. Full text was retrieved, confirmed and analysed for all 143 included sources. The affiliation variable describes authorship geography and was not interpreted as the study site [19, 21, 23].

Study design and reporting quality were described rather than used as exclusion criteria, consistent with scoping review practice. The Medical Education Research Study Quality Instrument informed the

education-quality lens, and TIDieR informed the assessment of whether training interventions were described with enough detail to reproduce [25–26].

Educational outcomes were organized using a four-level progression from reaction to learning, behaviour and patient, organizational or environmental outcomes. Kolb's experiential cycle, simulation evidence, interprofessional competencies and TeamSTEPPS informed the translation from mapped evidence to curriculum design, assessment and team communication [9–15, 27–30].

Development of the proposed START-OR model

START-OR—Surgical Timing and Aseptic Readiness Tool for the Operating Room—was developed through deductive integration of three evidence domains and patient-safety education frameworks. Candidate elements were retained only when they were observable, teachable, auditable and compatible with product instructions and local policy. The resulting model separates three clocks, defines seven readiness gates and adds an education-to-practice cycle. It is explicitly a proposed and unvalidated model, not a replacement for manufacturers' instructions, institutional policy or regulatory guidance [1, 3, 5, 8–9, 15, 27–30].

Patient and public involvement and ethics

Patients and members of the public were not involved because the study used published and indexed literature. Ethics committee approval and participant consent were not required; nevertheless, patient safety, dignity and avoidance of preventable harm were used as normative constraints during model development [1, 5, 8, 15].

Results

Selection of evidence

The review imported 5747 records, removed 298 duplicates, screened 5449 unique records, retained 747 high-recall candidates and included 143 full-text evidence sources after author-team confirmation, verification and analysis. The flow and exclusion stages are shown in Fig. 1, and the numerical audit trail is summarized in Table 2 [21–22].

Table 2
Search and selection summary

Stage	n	Audit note
Imported records	5747	Web of Science 5095; Scopus 652
Duplicate records removed	298	Normalized DOI or title–year
Unique records	5449	Entered broad title/abstract screening
Excluded at broad screening	4702	No defensible sterile-start relevance
High-recall candidates	747	Rule-assisted retrieval followed by author-team eligibility verification
Excluded after structured verification	604	Unrelated process, duplicate version, veterinary or insufficient topical information
Included evidence sources	143	All 143 full texts confirmed and analysed; 30 education/implementation; 44 hand; 61 skin; 8 field/table

Counts were generated from the consolidated author-provided Web of Science and Scopus corpus dated 2 August 2026 [21–23].

Characteristics and global distribution

The 143 sources were published from 1979 to 2026, with a median publication year of 2017. Fifty-five sources were published from 2020 onward, 52 during 2010–2019, 26 during 2000–2009 and 10 before 2000. The evidence base diversified over time from product-efficacy and microbiological studies toward educational interventions, implementation research and sterile-field technologies, as illustrated in Fig. 2 [33–175].

Randomized or controlled comparative studies were the largest design group (44/143), followed by laboratory or experimental efficacy studies (34/143), audit, observational or qualitative studies (22/143), systematic reviews or meta-analyses (15/143), other primary studies (13/143), educational interventions or simulations (6/143), protocols (5/143) and narrative guidance (4/143). Most evidence came from mixed perioperative settings, orthopaedics, trauma or spine, general or abdominal surgery, and obstetrics or gynaecology [33–175].

First indexed affiliations suggested broad international authorship but uneven representation: North America accounted for 44 records, Europe 42, Asia 36, Oceania 5, Africa 4 and Latin America and the Caribbean 4; 8 records were other or unclear. Because this field was derived from affiliation metadata, it should not be read as a study-site distribution. The imbalance nevertheless warns against treating practices from well-indexed settings as universally transferable. Table 3 summarizes the domain, design, specialty and affiliation characteristics [33–175].

Table 3
Characteristics of included evidence

Dimension	Category	n (%)
Primary domain	Patient skin preparation	61 (42.7%)
Primary domain	Surgical hand preparation	44 (30.8%)
Primary domain	Education, assessment and implementation	30 (21.0%)
Primary domain	Sterile field/table and environment	8 (5.6%)
Design group	Randomized/controlled comparative study	44 (30.8%)
Design group	Laboratory/experimental efficacy study	34 (23.8%)
Design group	Audit/observational/qualitative study	22 (15.4%)
Design group	Systematic review/meta-analysis	15 (10.5%)
Design group	Other primary study	13 (9.1%)
Design group	Educational intervention/simulation	6 (4.2%)
Design group	Protocol	5 (3.5%)
Design group	Narrative review/guidance	4 (2.8%)
Specialty	Mixed/unspecified perioperative setting	77 (53.8%)
Specialty	Orthopedics, trauma and spine	27 (18.9%)
Specialty	General and abdominal surgery	20 (14.0%)
Specialty	Obstetrics and gynecology	11 (7.7%)
Specialty	Cardiac and vascular surgery	6 (4.2%)
Specialty	Pediatric surgery	1 (0.7%)
Specialty	Ophthalmic surgery	1 (0.7%)
First indexed affiliation	Europe	42 (29.4%)
First indexed affiliation	North America	44 (30.8%)
First indexed affiliation	Asia	36 (25.2%)
First indexed affiliation	Oceania	5 (3.5%)
First indexed affiliation	Africa	4 (2.8%)
First indexed affiliation	Latin America and the Caribbean	4 (2.8%)
First indexed affiliation	Other/unclear	7 (4.9%)
First indexed affiliation	Unreported/unclear	1 (0.7%)

Percentages use 143 as the denominator. Affiliation region is an authorship-geography descriptor and is not equivalent to the study setting [33–175].

Education, assessment and implementation evidence

The newest education-focused sources expanded beyond conventional demonstration. They included video-based instrument-table management, a back-table simulation programme for nursing students, hands-on skin-preparation training, reviews and audits of hand-antisepsis technique, assessment of online videos, time reminders, adaptive preparation for a learner using crutches and head-mounted virtual-reality training. These studies support multimodal teaching but also show that technology is educationally useful only when linked to observable performance and feedback [33–42].

Observational, audit and qualitative studies documented a recurring theory–practice gap. Direct observation found missed technique steps; closed-loop audit and personal instruction improved performance; game-based learning supported instrument recognition and set-up; focus groups showed that skin preparation was shaped by tradition, role ambiguity and team culture; and studies of medical students and obstetric teams found variable knowledge and compliance. These findings locate the problem in curriculum, supervision and shared responsibility rather than in individual memory alone [43–52].

Remote video surveillance, feedback sessions, ultraviolet visualization, guideline implementation, skin-care education, floor marking and explicit monitoring were used to make invisible risk visible. Knowledge and attitudes were associated with sterile-table covering practice, and several studies emphasized organizational oversight, role modelling, product acceptability and local workflow. The educational evidence therefore favoured repeated observation, timely feedback and system redesign over a single induction lecture. Table 4 translates these findings into curriculum, assessment and outcome domains [53–62].

Table 4
Educational findings and outcome gaps

Competency area	Teaching approaches	Assessment options	Synthesis	Evidence
Knowledge and cognitive framing	Guidelines, product instructions, online resources, case-based comparison	Knowledge tests; explanation of why duration, coverage and drying vary	Knowledge was often incomplete or disconnected from observed technique	[33–42] [43–52]
Psychomotor technique	Expert demonstration, deliberate practice, UV/fluorescent visualization, VR and simulation	Direct observation; coverage maps; critical-step checklist; timed sequence	Visual feedback exposed missed areas that duration alone could not detect	[33–42] [53–62]
Behaviour and transfer	Clinical audit, remote video, reminders, coaching and repeated feedback	Compliance in real practice; response to delays; escalation behaviour	Improvement required ongoing monitoring and organizational support	[43–52] [53–62]
Team and system	Role clarification, floor marking, table-covering policy, debrief and safety culture	Shared pause; closed-loop communication; environmental placement	Responsibility was distributed across professions and the environment	[43–52] [53–62]
Outcome gap	Most programmes measured technique or compliance	Link education to contamination, delay, waste and patient outcomes	Few studies followed learners from simulation to durable clinical outcomes	[33–62]

The table translates heterogeneous education and implementation evidence into curriculum-relevant domains; it does not rank interventions by pooled effectiveness [33–62].

Mapped outcome levels reinforced this gap: 78 sources reported patient, organizational or environmental endpoints; 30 reported behaviour or performance; 23 reported learning or technical outcomes; one focused primarily on reaction or perception; and 11 were not classifiable from indexed records. Much of the clinically rich literature was never designed as educational research, while many educational interventions stopped before demonstrating durable workplace or patient benefit [33–175].

Surgical hand-preparation evidence

Recent hand-preparation studies compared waterless and traditional methods, user tolerance, bacterial counts, cost and clinical outcomes. Reviews generally supported alcohol-based rubbing as an effective alternative when an appropriate formulation, amount, coverage and application method were used, but efficacy varied by formulation and test standard. Educationally, this means that 'rub' and 'scrub' are not

interchangeable labels and that a duration cannot be taught independently from the product and technique [63–73].

Systematic reviews, comparative studies and formulation experiments examined residual activity, skin integrity, glycerol concentration, forearm coverage and World Health Organization formulations. Findings were heterogeneous across laboratory standards and clinical endpoints. The consistent teaching principle was to follow the validated product instructions, maintain systematic coverage, avoid shortening the application below the required contact period and allow the hands and forearms to dry before gowning and gloving [74–84].

Evidence from rural hospitals, state-of-the-art reviews and randomized efficacy trials also raised resource and sustainability considerations. Waterless preparation could reduce water use and infrastructure dependence, while shorter validated rub protocols could improve feasibility and skin tolerance. These benefits did not justify an arbitrary short cut: the permitted duration remained formulation-specific, and repeated procedures required attention to clean hands, skin condition and the local protocol [85–95].

Historical studies comparing one-, two-, three-, five- and ten-minute regimens showed why inherited ritual is an unreliable curriculum. A two-minute scrub could be clinically similar to three minutes in one setting, five minutes was not inferior to ten minutes before hip arthroplasty, and some short alcohol-rub regimens met microbiological criteria; however, methods, products, outcome thresholds and procedure duration differed. The defensible educational conclusion is not one global number but the ability to execute and justify a product-specific sequence [96–106].

Patient skin-preparation and readiness evidence

The skin-preparation literature was the largest domain and included recent randomized trials and meta-analyses comparing alcohol-containing and aqueous preparations, chlorhexidine, povidone-iodine and olanexidine across clean-contaminated, abdominal and orthopaedic surgery. Several studies favoured alcohol-containing regimens or particular formulations, but effect estimates varied by procedure, comparator, concentration and outcome. Product choice therefore requires local guideline alignment rather than a single universal hierarchy [107–117].

Studies from 2021–2022 extended this heterogeneity to open fractures, arthroplasty, upper-limb surgery, caesarean delivery and antimicrobial persistence. Colour, visibility and application quality affected coverage, and cost-effectiveness did not always track microbiological efficacy. Teaching should therefore include anatomical boundaries, visual confirmation, concentration, contraindications, drying and documentation rather than only naming an agent [118–128].

Trials and protocols published in 2019–2020 examined novel preparations, gynaecological and obstetric surgery, trauma and cardiac surgery. The evidence supported treating skin preparation as a process with an endpoint, not as a stroke count. The relevant transition to draping is achieved when the prepared area

is visibly dry, pooling is absent and alcohol-fire hazards are controlled; a fixed waiting time detached from product, volume, site and environmental conditions can create false reassurance [129–140].

Earlier comparative studies and meta-analyses in spine, abdominal, arthroplasty and caesarean surgery showed both clinically important differences and unresolved variation. One randomized spine study reported fewer positive wound-edge cultures when povidone-iodine was applied several minutes before surgery and allowed to dry, while other studies focused on agent comparisons rather than timing. The education message is to teach the observable state of complete drying and the rationale for waiting, not to generalize a single minute from one product or specialty [141–149].

The older evidence base included observational studies, paediatric scoliosis, cardiac and vascular surgery, emergency and elective orthopaedics, nurse-performed preparation and developing-world settings. These studies reinforce that the effectiveness of skin preparation depends on protocol fidelity, site, technique, repeat application, workflow and context. They also show that nurses and instrument/scrub professionals are active safety agents whose assessment and escalation skills should be taught explicitly [150–167].

Sterile-field and instrument-table evidence

The sterile-field domain was small but directly relevant to the proposed third clock. Recent experimental and narrative evidence examined table covering, single- versus two-drape methods, ultraviolet decontamination, local unidirectional airflow and glove-package opening. Across these studies, contamination accumulated with exposure and activity, covering generally reduced airborne deposition, and the method used to introduce items could transfer contaminants. The appropriate educational response is to minimize unnecessary open time, control traffic and item introduction, and re-check the field after delay [168–173].

Older cardiothoracic transmission research and an emergency-caesarean table-preparation study illustrated the tension between contamination risk and time-critical readiness. Advance preparation may be defensible in tightly controlled circumstances, but evidence was limited and context-specific. A universal maximum open-table time cannot be inferred from this map; local policy should specify how tables are covered, observed, revalidated and discarded after breaches [174–175].

Cross-domain timing synthesis and specialty comparison

Across all three domains, time functioned as a process-control variable rather than an independent protective dose. The strongest common rule was readiness-based synchronization: the team clock ends only after the validated hand-preparation sequence and drying; the patient clock advances only after complete skin drying, absence of pooling and fire-risk control; and the field clock should start as close as operationally feasible to use, with revalidation after delays. Table 5 summarizes what can and cannot be taught from the evidence [1–3, 5, 63–175].

Table 5
Timing evidence and readiness rules

Process	Evidence synthesis	Proposed operational rule	What should not be taught	Evidence
Surgical hand preparation	Products, methods and efficacy tests differed; shorter validated regimens sometimes performed similarly to longer traditional scrubs.	Complete prerequisites, product-specified amount and duration, systematic hand/forearm coverage, then complete drying before gowning/gloving.	Do not teach one universal scrub time or equate elapsed time with complete technique.	[63–106]
Skin antisepsis to draping	Agent, concentration, site, volume and specialty modified outcomes; drying was a recurrent safety endpoint.	Record the last application stroke; proceed only after visible dryness, no pooling and controlled alcohol-fire risk.	Do not use an arbitrary universal waiting minute detached from the product and clinical context.	[107–167]
Sterile table and field	Contamination was influenced by exposure, activity, covering, airflow and item-introduction method.	Open as near as feasible to use; protect during non-use; monitor continuously; revalidate after delay or traffic disruption.	Do not infer an evidence-based universal open-table time from the limited heterogeneous studies.	[168–175]
Interfaces	Delays can leave one clock complete while another remains unready.	Use a voiced sterile-start pause and a stop rule when any clock is incomplete or uncertain.	Do not allow schedule pressure or hierarchy to substitute for readiness verification.	[1, 5, 8, 15, 29–30, 33–175]

Rules are evidence-informed educational recommendations and must be reconciled with the product instructions for use, fire-safety policy and institutional standards [1–3, 5, 63–175].

Specialty comparison showed that orthopaedics, trauma and spine had the largest specialty-specific body of evidence, followed by general or abdominal surgery and obstetrics or gynaecology. Implant surgery heightened attention to instrument exposure and low bioburden; emergency obstetrics emphasized readiness without uncontrolled pre-exposure; long or complex procedures raised the importance of hand-product persistence and field revalidation; and sites with folds, hair, groin flora or difficult positioning increased coverage risk. Table 6 converts these modifiers into curriculum adaptations [63–175].

Table 6
Specialty-specific teaching modifiers

Setting	Risk modifiers	Curriculum adaptation	Assessment emphasis	Evidence
Orthopaedics, trauma and spine	Implants, prolonged procedures, large or difficult-to-visualize preparation areas, high consequence of contamination.	Use full-limb or spine simulation, UV coverage checks, implant-item opening near use and delay revalidation.	Coverage completeness, instrument exposure and response to prolonged cases.	[59, 62, 102, 115–127, 134–137, 141–147, 152–161, 170–173]
General and abdominal surgery	Clean-contaminated procedures, broad preparation fields, variable agents and workflow.	Teach site boundaries, product selection rationale, drying and bundle integration.	Protocol fidelity and handoff from preparation to draping.	[98, 107–114, 129–130, 143–148, 155–160]
Obstetrics and gynaecology	Emergency time pressure, caesarean readiness, variable skin and incision contexts.	Simulate urgent starts with covered tables, explicit drying confirmation and no-bypass stop rules.	Maintaining readiness under urgency without premature draping or uncontrolled table exposure.	[51, 125–136, 149, 175]
Cardiac and vascular surgery	Long procedures, groin fields, multiple teams and high consequence of infection.	Add shared role assignment, groin-coverage checks, field traffic control and revalidation during prolonged cases.	Team clock synchronization and environmental discipline.	[49, 140–141, 162, 165, 174]
Paediatric or ophthalmic surgery	Smaller fields, age-specific skin considerations, high-throughput workflow in some settings.	Adapt product, volume and exposure while retaining the same readiness gates.	Avoiding reduced standards because the field or procedure appears smaller.	[66, 153]
Mixed or resource-constrained settings	Water, infrastructure, staffing, product availability and local policy vary.	Teach principles that travel—validated IFU, coverage, drying, protected field and escalation—then localize the workflow.	Equity, feasibility and responsible adaptation without inventing unsupported shortcuts.	[33–167]

Specialty modifies scenarios and emphasis, but it does not remove the core readiness criteria. IFU, instructions for use [33–175].

The proposed START-OR model

START-OR converts the sterile start into three parallel, observable clocks that converge at a voiced readiness pause (Fig. 3). The team clock advances from initiation of hand preparation (H0), through completion of the product-specific technique and duration (H1), to dry hands and forearms with safe gowning and gloving (H2). The patient clock advances from the final antiseptic stroke (P0), through complete drying, absence of pooling and controlled fire risk (P1), to permission for sterile draping (P2). The field clock begins when the first sterile item is opened (F0), advances when the back table and Mayo stand are prepared and verified (F1), and reserves high-risk or implant-related items for opening as close as operationally possible to first use (F2) [1, 3, 5, 15, 63–175].

The central rule is deliberately stricter than “wait a fixed number of minutes”: elapsed time is documented within each clock, but progression occurs only when the responsible team member can demonstrate and communicate the corresponding readiness state. Figure 3 therefore links the three clocks to seven sequential gates: Gate 1 briefs and classifies the case; Gates 2–4 verify team, patient and field readiness; Gate 5 is the closed-loop sterile-start pause; Gate 6 governs delays, breaches, uncertainty and revalidation; and Gate 7 converts deviations and near misses into debriefing and improvement. Table 7 operationalizes each gate through triggers, required actions, observable evidence and explicit stop rules [5, 8, 15, 29–30, 33–175].

Table 7
START-OR readiness gates

Gate	Trigger	Required team action	Observable evidence	Stop rule
1. Brief and classify	Before preparation starts	Identify specialty risks, urgency, implant use, alcohol/fire considerations, expected delays, product IFU and role ownership.	Brief completed; roles named; required products and equipment present.	Do not start opening or applying products when critical resources or roles are unresolved.
2. Team readiness	Before gowning/gloving	Verify prerequisites, complete hand/forearm coverage for the specified duration, then dry completely.	H1 and H2 visibly confirmed; deviation voiced.	Repeat or correct when coverage, duration, contamination or drying is uncertain.
3. Patient readiness	Before draping	Verify anatomical coverage, final application point, visible dryness, no pooling and controlled fire risk.	P1 confirmed by the responsible preparer and acknowledged by the team.	Do not drape or activate ignition sources while wetness or pooling remains.
4. Field readiness	Before sterile use	Confirm table integrity, monitoring responsibility, traffic control, item introduction and high-risk item timing.	F1 confirmed; breaches absent; delayed items planned.	Replace or re-establish the field after a breach or unresolved contamination.
5. Sterile-start pause	Immediately before draping/incision according to workflow	Voice H2, P1/P2 and F1 status; confirm concerns and permission to proceed.	Closed-loop confirmation from designated team members.	Any team member may stop progression when a clock is incomplete.
6. Delay and event response	Whenever workflow stops or conditions change	Protect the field, reassess drying/coverage, monitor traffic, document the delay and decide whether re-preparation is needed.	Revalidation documented and voiced before restart.	No automatic continuation after an unobserved or uncontrolled delay.
7. Debrief and improve	After the case or audit cycle	Record deviations, waste, contamination signals, near misses and learning needs; provide non-punitive feedback.	Dashboard entry and assigned improvement action.	Do not normalize repeated workarounds without review.

START-OR is proposed for education and quality improvement. Local implementation requires governance, product-specific validation and prospective evaluation [1, 3, 5, 8, 15, 29–30, 33–175].

Education-to-practice cycle and assessment

The proposed curriculum follows six linked stages: orient learners to evidence and local risks; demonstrate with visible timing cues; practise deliberately in simulation; verify performance with direct observation and objective coverage methods; transfer under supervision; and improve through audit, feedback and debrief. Figure 4 depicts this cycle, which makes the clinical process a longitudinal competency rather than a one-time demonstration [8–14, 27–30, 33–62].

Assessment should combine critical-step checklists with coverage visualization, timestamp review, team communication and delayed-start scenarios. Passing should require completion of all locally designated critical safety items; elapsed time alone should never compensate for missed coverage, wet hands or skin, pooling, an unmonitored field or failure to escalate. Table 8 proposes an assessment bundle that can be evaluated at learner, team and system levels [9–15, 25–27, 29–30, 33–62].

Table 8
Proposed START-OR assessment bundle

Competency	Learning method	Assessment	Proposed pass principle
Knowledge and justification	Interactive seminar; product and case comparison	Short-answer or script-concordance questions explaining product, duration, drying, covering and stop rules.	Correct rationale for all critical transitions; misconceptions remediated before practice.
Coverage and psychomotor skill	Demonstration plus deliberate practice	Direct-observation checklist; UV/fluorescent coverage for hands or simulated skin; contamination tracers for item introduction.	All critical anatomical areas covered and no critical breach.
Timing and readiness judgement	Timed simulation with variable products and environmental conditions	Timestamp log plus explanation of why the learner proceeded or waited.	Product-specific timing respected and progression based on observable readiness.
Team communication	Interprofessional simulation and TeamSTEPPS tools	Closed-loop call-out of H2, P1/P2 and F1; escalation of wetness, pooling, breach or delay.	Concern voiced and acknowledged without prompting.
Delay management	Unexpected delay, staff change, traffic or contamination scenario	Decision record: protect, observe, revalidate, re-prepare or discard.	Action matches local policy and uncertainty triggers a stop.
Workplace transfer	Supervised cases and mini-CEX style observation	Repeated observations across specialties and shifts.	Stable performance across more than one context; feedback acted upon.
System improvement	Audit and debrief dashboard	Compliance, delay, waste, near miss, contamination signal and corrective-action review.	Trends reviewed by the perioperative education and safety team.

Thresholds are intentionally expressed as safety principles rather than universal numerical cut-offs. Institutions should validate local checklists and reliability [8–15, 25–30, 33–62].

Discussion

Principal findings

This review mapped a large clinical evidence base but a comparatively small educational evidence base. The central finding is that the sterile start should not be taught as three isolated countdowns. Across hand preparation, skin preparation and sterile-field management, the defensible unit of competence is

the ability to reach, recognize, communicate and maintain readiness under changing conditions [1, 3, 5, 8, 15, 33–175].

A universal minute value was not supported because timing interacted with formulation, application method, anatomical site, volume, environmental conditions, procedure type, test standard and outcome. In education, universal numbers are attractive because they are easy to remember and audit, but they can create a false proxy for safety. START-OR retains timestamps for traceability while subordinating progression to observable completion criteria [1–3, 63–175].

Implications for surgical hand-preparation education

Hand-preparation curricula should distinguish detergent scrubbing from alcohol-based rubbing, include skin-health prerequisites, teach the exact product instructions and require complete drying before gowning and gloving. Historical comparisons justify abandoning unnecessarily prolonged ritual, but they do not authorize unvalidated shortening. Learners should be able to explain why a locally approved two- or three-minute process applies to a specific product rather than repeating the number as a universal truth [3–4, 63–106].

Objective observation is essential because elapsed time can conceal missed thumbs, interdigital spaces, wrists or forearms. UV visualization, direct observation, video feedback and repeated audit can convert technique from a hidden individual act into assessable performance. These methods should be used formatively and non-punitively, with escalation when the environment or product supply prevents correct performance [8–14, 33–62].

Implications for skin-preparation education

Skin-preparation teaching must integrate agent selection, anatomical coverage, application sequence, concentration, contraindications, drying and fire safety. The transition to draping should be verbalized as a readiness decision: the solution is visibly dry, pooling is absent and relevant ignition risk has been controlled. This framing is more transferable than teaching a single waiting period because it remains valid across products and specialties [1–2, 5, 107–167].

Coverage is also an educational outcome. Studies using coloured preparations or fluorescence showed that even experienced personnel can miss clinically relevant areas and that novices may perform worse. Simulation should therefore reproduce difficult positions and large preparation fields, include visual coverage feedback and assess whether the learner can identify when assistance or re-application is required [35, 47, 116, 147].

Implications for sterile-field and table education

The field-clock evidence was sparse, which makes overprecision particularly unsafe. Available studies supported reducing unnecessary exposure, covering prepared tables during non-use when compatible with local policy, controlling item-introduction techniques and considering airflow and traffic. The

educational objective is continuous stewardship of the field, including the ability to recognize when a delay changes risk and to initiate revalidation [50, 59, 168–175].

Emergency readiness illustrates the trade-off. A pre-prepared table may shorten response time but can increase monitoring and contamination concerns. START-OR does not resolve that balance with a universal time; it requires explicit local policy, assigned observation, protection, a documented delay response and a stop rule. This makes the rationale auditable and suitable for simulation [5, 15, 29–30, 175].

Interprofessional and competency-based implications

The sterile start is distributed work. Surgeons, nurses, surgical technologists or instrument personnel, anaesthesia professionals and support staff hold different information and control different risks. A shared pause can reduce hierarchy-dependent assumptions by requiring the responsible person for each clock to voice readiness and by granting any team member authority to stop progression. This aligns technical skill with interprofessional values, role clarity, communication and teamwork [5–6, 8, 15, 29–30].

Competency should be demonstrated at multiple levels: knowledge of standards, skill in coverage, performance under time pressure, communication during uncertainty and contribution to patient and organizational outcomes. A curriculum that measures satisfaction only is inadequate; a programme that measures bacterial counts but not learning transfer is also educationally incomplete. START-OR links Miller's progression, deliberate practice, simulation and workplace audit in one assessment architecture [9–14, 25, 27–28, 33–62].

Global transfer and specialty adaptation

The affiliation distribution suggests that the indexed literature is concentrated in Europe, North America and Asia, with limited representation from Africa and Latin America and the Caribbean. Resource constraints, climate, water availability, product supply, operating-room design and professional role definitions can alter implementation. The proposed model therefore standardizes principles—validated instructions, coverage, drying, protected fields, communication and revalidation—while requiring local adaptation of workflow and measurement [1, 3, 8, 15, 33–175].

Specialty adaptation should modify the scenario, not dilute the competency. Orthopaedic and implant surgery can emphasize exposure and contamination consequences; obstetric emergencies can test safe acceleration; cardiac and vascular cases can test prolonged synchronization; and high-throughput settings can test whether efficiency pressures provoke premature transitions. Assessment across more than one context is needed before declaring transfer [9–10, 13, 15, 29–30, 63–175].

Implementation and research agenda

Implementation should begin with local governance rather than immediate clinical enforcement. A multidisciplinary group should reconcile START-OR with manufacturer instructions, fire-safety standards, infection-prevention policy and role descriptions; pilot the checklist in simulation; establish inter-rater reliability; conduct a limited clinical feasibility phase; and review unintended consequences such as delay, waste, workarounds or punitive use [1–3, 5, 8, 15, 25–26, 29–30].

The research agenda should move beyond isolated microbiological efficacy toward comparative educational and implementation studies. Priority designs include multicentre simulation trials, stepped-wedge implementation, prospective validation of readiness gates, human-factors studies of delays, equity-focused adaptation and linkage of educational performance to contamination signals, waste, near misses and surgical-site infection. Table 9 specifies core questions and reporting requirements [16–21, 23–26, 33–175].

Table 9
Research priorities for sterile-start education

Priority	Question	Preferred design	Core outcomes
Model validation	Do START-OR gates demonstrate content validity, feasibility, inter-rater reliability and predictive validity?	Delphi plus multicentre simulation and prospective cohort.	Gate completion, reliability, delays, near misses, contamination signals and unintended consequences.
Educational effectiveness	Does the six-stage curriculum improve knowledge, coverage, judgement, communication and workplace transfer?	Cluster-randomized or stepped-wedge education trial.	Immediate learning, retained skill, workplace behaviour and patient/organizational outcomes.
Delay management	Which delay duration and environmental conditions require protection, revalidation or replacement in different field configurations?	Controlled environmental experiments plus observational clinical study.	Air and surface bioburden, field integrity, traffic, cover method and decision accuracy.
Product-specific timing	Which validated timings remain effective under real-world volume, technique and repeated-case conditions?	Pragmatic comparative study stratified by product and specialty.	Coverage, bacterial reduction, skin tolerance, water use, cost and SSI where feasible.
Equity and global adaptation	How do resources, roles, infrastructure and culture alter implementation?	Mixed-methods studies in underrepresented regions and resource settings.	Feasibility, acceptability, fidelity, adaptation, cost and safety equity.
Reporting quality	Can interventions and searches be replicated?	Use PRISMA-ScR/PRISMA-S, TIDieR and a medical-education quality instrument.	Complete search syntax, intervention dose, assessor training, missing data and protocol deviations.

SSI, surgical-site infection. Research should pre-specify which outcomes are educational, behavioural, environmental and clinical [16–21, 23–26, 33–175].

Strengths and limitations

Strengths include a large deduplicated corpus, transparent separation of clinical and educational evidence, explicit specialty comparison, inclusion of sterile-field evidence often omitted from hand- or skin-focused reviews, traceable counts and a model whose elements are observable and testable. Every included source is represented in the reference list and the evidence map is supplied as an additional file [16, 19, 21, 23, 26, 33–175].

Several limitations are material. Only Web of Science and Scopus were searched; primary title/abstract screening was conducted by one experienced reviewer, although the included full-text set and analytic classifications were verified by the author team; geography was derived from affiliations rather than confirmed study sites; design classification was partly rule-assisted; no formal risk-of-bias appraisal was used for exclusion; and the protocol was not prospectively registered. These limitations can produce missed studies, classification error and overrepresentation of well-indexed settings [18–21, 23–24, 31–32].

The evidence map also included reviews, protocols and primary studies, so source counts should not be interpreted as independent patient samples. No meta-analysis was attempted because products, timings, comparators, specialties and outcomes were not sufficiently homogeneous across all three processes. START-OR was developed from mapped evidence and educational theory but has not undergone stakeholder consensus, reliability testing, feasibility evaluation or outcome validation [16–19, 25–26, 33–175].

Conclusions

Teaching the sterile start requires more than teaching minutes. The perioperative team should complete and verify a product-specific hand-preparation sequence, wait for visible patient-skin readiness and fire safety, minimize unnecessary sterile-field exposure, revalidate after delays and voice the status of all three clocks before proceeding. The proposed START-OR model converts these principles into seven readiness gates and a longitudinal education-to-practice cycle. It should be treated as a testable curriculum and quality-improvement proposal—not as a validated clinical standard—until independent multicentre evaluation is completed [1, 3, 5, 8, 15, 29–30, 33–175].

Abbreviations

AHRQ
Agency for Healthcare Research and Quality
HMD
head-mounted display
IFU
instructions for use
IPEC
Interprofessional Education Collaborative
JBI
Joanna Briggs Institute
MERSQI
Medical Education Research Study Quality Instrument
OR
operating room

PCC
Population–Concept–Context
PRISMA
Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRISMA-ScR
PRISMA extension for Scoping Reviews
SSI
surgical-site infection
START-OR
Surgical Timing and Aseptic Readiness Tool for the Operating Room
TIDieR
Template for Intervention Description and Replication
UV
ultraviolet.

Declarations

Ethics approval and consent to participate

Not applicable. This study analysed published and indexed literature and did not involve human participants, identifiable data or animals.

Consent for publication

Not applicable.

Availability of data and materials

The evidence map supporting this manuscript is included as Additional file 2. Database export files may remain subject to the licensing conditions of Web of Science and Scopus; therefore, the additional file contains the charted bibliographic evidence used for synthesis rather than redistributing proprietary platform records.

Competing interests

The authors declare that they have no competing interests.

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Author contributions

ADP conceived the review, designed the methodology and rule-assisted workflow, curated the evidence corpus, conducted the primary screening and charting, interpreted the findings, developed the proposed START-OR model, prepared the visualizations and drafted the manuscript. WAP, AVO and ARP contributed to investigation, full-text verification, validation of the included evidence set, data curation, analytic confirmation and critical revision of the manuscript. All authors reviewed and approved the final version and accept accountability for the work.

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Generative artificial intelligence statement

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References

1. World Health Organization. Global guidelines for the prevention of surgical site infection. 2nd ed. Geneva: World Health Organization; 2018.
2. Berríos-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for Disease Control and Prevention guideline for the prevention of surgical site infection, 2017. JAMA Surg. 2017;152(8):784–91. 10.1001/jamasurg.2017.0904.
3. World Health Organization. WHO guidelines on hand hygiene in health care: first global patient safety challenge clean care is safer care. Geneva: World Health Organization; 2009.
4. Boyce JM, Pittet D. Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. MMWR Recomm Rep. 2002;51(RR–16):1–45.
5. World Health Organization. Implementation manual WHO surgical safety checklist 2009: safe surgery saves lives. Geneva: World Health Organization; 2009.

6. Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AHS, Dellinger EP, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med. 2009;360(5):491–9. 10.1056/NEJMsa0810119.
7. National Institute for Health and Care Excellence. Surgical site infections: prevention and treatment. NICE guideline NG125. London: NICE. 2019. https://www.nice.org.uk/guidance/ng125. Accessed 3 Aug 2026.
8. World Health Organization. WHO patient safety curriculum guide: multi-professional edition. Geneva: World Health Organization; 2011.
9. Miller GE. The assessment of clinical skills/competence/performance. Acad Med. 1990;65(9 Suppl):S63–7. 10.1097/00001888-199009000-00045.
10. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. Psychol Rev. 1993;100(3):363–406. 10.1037/0033-295X.100.3.363.
11. Gaba DM. The future vision of simulation in health care. Qual Saf Health Care. 2004;13(Suppl 1):i2–10. 10.1136/qshc.2004.009878.
12. Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach. 2005;27(1):10–28. 10.1080/01421590500046924.
13. McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003–2009. Med Educ. 2010;44(1):50–63. 10.1111/j.1365-2923.2009.03547.x.
14. Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA. 2011;306(9):978–88. 10.1001/jama.2011.1234.
15. Interprofessional Education Collaborative. IPEC core competencies for interprofessional collaborative practice: version 3. Washington, DC: Interprofessional Education Collaborative; 2023.
16. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005;8(1):19–32. 10.1080/1364557032000119616.
17. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci. 2010;5:69. 10.1186/1748-5908-5-69.
18. 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.
19. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. JBI Evid Synth. 2020;18(10):2119–26. 10.11124/JBIES-20-00167.
20. Peters MDJ, Godfrey C, McInerney P, Khalil H, Larsen P, Marnie C, et al. Best practice guidance and reporting items for the development of scoping review protocols. JBI Evid Synth. 2022;20(4):953–68. 10.11124/JBIES-21-00242.

21. 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(7):467–73. 10.7326/M18-0850.
22. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. 10.1136/bmj.n71.
23. Rethlefsen ML, Kirtley S, Waffenschmidt S, Ayala AP, Moher D, Page MJ, et al. PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews. Syst Rev. 2021;10:39. 10.1186/s13643-020-01542-z.
24. McGowan J, Sampson M, Salzwedel DM, Cogo E, Foerster V, Lefebvre C. PRESS peer review of electronic search strategies: 2015 guideline statement. J Clin Epidemiol. 2016;75:40–6. 10.1016/j.jclinepi.2016.01.021.
25. Reed DA, Cook DA, Beckman TJ, Levine RB, Kern DE, Wright SM. Association between funding and quality of published medical education research. JAMA. 2007;298(9):1002–9. 10.1001/jama.298.9.1002.
26. Hoffmann TC, Glasziou PP, Boutron I, Milne R, Perera R, Moher D, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. BMJ. 2014;348:g1687. 10.1136/bmj.g1687.
27. Kirkpatrick DL, Kirkpatrick JD. Evaluating training programs: the four levels. 3rd ed. San Francisco: Berrett-Koehler; 2006.
28. Kolb DA. Experiential learning: experience as the source of learning and development. Englewood Cliffs: Prentice Hall; 1984.
29. Weaver SJ, Dy SM, Rosen MA. Team-training in healthcare: a narrative synthesis of the literature. BMJ Qual Saf. 2014;23(5):359–72. 10.1136/bmjqs-2013-001848.
30. Agency for Healthcare Research and Quality. TeamSTEPPS 3.0 curriculum materials. Rockville: AHRQ. 2024. https://www.ahrq.gov/teamstepps-program/curriculum/index.html. Accessed 3 Aug 2026.
31. Tricco AC, Antony J, Zarin W, Strifler L, Ghassemi M, Ivory J, et al. A scoping review of rapid review methods. BMC Med. 2015;13:224. 10.1186/s12916-015-0465-6.
32. Waffenschmidt S, Knelangen M, Sieben W, Bühn S, Pieper D. Single screening versus conventional double screening for study selection in systematic reviews: a methodological systematic review. BMC Med Res Methodol. 2019;19:132. 10.1186/s12874-019-0782-0.
33. Ma Y, Tao T, Ma X, Li H, Cheng Z, Kang M, et al. An integrated deep learning framework for effective management of surgical instruments tables based on videos. Health Care Manag Sci. 2026;29(2):19. 10.1007/s10729-026-09761-x.
34. Park J, Suh EE. Development and preliminary evaluation of a procedural performance-oriented back-table setting simulation program for nursing students. J Korean Acad Soc Nurs Educ. 2026;32(2):230–9. 10.5977/jkasne.2026.32.2.230.

35. Schaps D, Schultz M, Woody R, Masoud S, Mantyh C. Hands-on training for preoperative skin preparation improves compliance with manufacturer instructions for use. Am J Surg. 2026;251:116719. 10.1016/j.amjsurg.2025.116719.
36. Pinto FD, Ferreira RA, de Siqueira FMCDS, Silva JDOL, Camerini FG, Fassarella CS. Adherence to surgical hand antisepsis technique steps by surgical teams: an integrative review. Rev Rene. 2025;26:e95533. 10.36517/2175-6783.20252695533.
37. Dagci M, Alptekin HM, Ihtiyar D, Ozturk G, Ozturk H. Evaluation of the Content, Reliability, and Quality of YouTube Videos on Surgical Hand Scrubbing. AORN J. 2025;121(4):e1–10. 10.1002/aorn.14319.
38. Muhammed A, Ahmed Mohmed MH, Mohammed Ahmed AB, Ali Abdelrahman MEO, Elamin R, Ali Fadul MA, et al. Improving Quality and Compliance of Surgical Hand Scrubbing Practices: A Clinical Audit. Cureus. 2025;17(3):e80821. 10.7759/cureus.80821.
39. Ahmed EAO, Mohamed ZHS, Sayed MS, Mohamed Ahmed EA, Bala AMAA, Abdelrahem MA, et al. Surgical Hand Scrubbing: A Clinical Audit at a Referral Hospital. Cureus. 2025;17(11):e96465. 10.7759/cureus.96465.
40. Bakcek Akcelik O, Kolcak B, Öner Karaveli E, Tastan S. The effects of time reminders on surgical hand scrub performance and student satisfaction: A randomized controlled study. Nurse Educ Pract. 2025;88:104561. 10.1016/j.nepr.2025.104561.
41. Lawton C, Schwaitzberg SD. Accommodating Learners: An Adaptive Approach to Surgical Hand Preparation With Crutches. J Surg Educ. 2024;81(12):103299. 10.1016/j.jsurg.2024.103299.
42. Gungor S, Yava A, Koyuncu A. Designing and implementing a training program on surgical hand scrubbing, wearing surgical cap and surgical mask, gowning, and gloving using HMD-based virtual reality technologies for nursing students: an exploration of student perceptions. Front Med. 2024;11:1364465. 10.3389/fmed.2024.1364465.
43. Rutala WA, Boyce JM, Weber DJ. Disinfection, sterilization and antisepsis: An overview. Am J Infect Control. 2023;51(11):A3–12. 10.1016/j.ajic.2023.01.001.
44. Gulsen M, Aydingulu N, Arslan S, Dogan SD, Alptekin D, Nazik E. Surgical handwashing practices of operating room staff: An observational study. Scand J Caring Sci. 2022;36(4):926–34. 10.1111/scs.12988.
45. Mukherjee R, Roy P, Parik M. Achieving Perfect Hand Washing: an Audit Cycle with Surgical Internees. Indian J Surg. 2021;83(5):1166–72. 10.1007/s12262-020-02619-8.
46. Nasiri M, Eslami J, Rashidi N, Paim CPP, Akbari F, Torabizadeh C, et al. Playing with Surgical Instruments (PlaSurIn) game to train operating room novices how to set up basic surgical instruments: A validation study. Nurse Educ Today. 2021;105:105047. 10.1016/j.nedt.2021.105047.
47. Markström I, Bjerså K, Bachrach-Lindström M, Falk-Brynhildsen K, Hollman Frisman G. Operating room nurses' experiences of skin preparation in connection with orthopaedic surgery: A focus group study. Int J Nurs Pract. 2020;26(5):e12858. 10.1111/ijn.12858.
48. Schwartz X, Schmitz M, Safdar N, Pop-Vicas A. Adherence to surgical hand antisepsis: Barriers and facilitators in a tertiary care hospital. Am J Infect Control. 2018;46(6):714–6.

10.1016/j.ajic.2017.12.011.

49. Gaspar GG, Menegueti MG, Lopes AER, Santos ROC, de Araújo TR, Nassiff A, et al. Alcohol-based surgical hand preparation: Translating scientific evidence into clinical practice. Antimicrob Resist Infect Control. 2018;7(1):80. 10.1186/s13756-018-0372-7.
50. Van Wicklin SA. Are knowledge and attitudes of perioperative registered nurses associated with the practices of covering and monitoring sterile tables? Perioperative Care Operating Room Manage. 2018;12:16–25. 10.1016/j.pcorm.2018.09.005.
51. Ooi R, Griffiths A. Obstetric competence and compliance with surgical hand antisepsis prior to elective and emergency surgical procedures: a closed-loop audit. J Hosp Infect. 2018;100(2):219–21. 10.1016/j.jhin.2018.02.019.
52. Kasperczak M, Kończyk B, Kaczmarczyk M, Urbanek T, Kuczmik W. The assessment of practices and knowledge on surgical hand preparation among medical students of Medical University of Silesia during their clinical years. Chirurgia Polska. 2018;20(1–2):20–5.
53. Khan A, Nausheen S. Compliance of surgical hand washing before surgery: Role of remote video surveillance. J Pak Med Assoc. 2017;67(1):92–6.
54. Goldberg JL. Guideline Implementation: Hand Hygiene. AORN J. 2017;105(2):203–17. 10.1016/j.aorn.2016.12.010.
55. Laurikainen E, Rintala E, Kaarto AM, Routamaa M. Adherence to surgical hand rubbing directives in a hospital district of Southwest Finland. Infect Dis. 2016;48(2):116–21. 10.3109/23744235.2015.1089591.
56. Vanyolos E, Peto K, Viszlai A, Miko I, Furka I, Nemeth N, et al. Usage of ultraviolet test method for monitoring the efficacy of surgical hand rub technique among medical students. J Surg Educ. 2015;72(3):530–5. 10.1016/j.jsurg.2014.12.002.
57. Harnoss JC, Brune L, Ansorg J, Heidecke C-D, Assadian O, Kramer A. Practice of skin protection and skin care among German surgeons and influence on the efficacy of surgical hand disinfection and surgical glove perforation. BMC Infect Dis. 2014;14(1):315. 10.1186/1471-2334-14-315.
58. Spruce L. Back to Basics: Hand Hygiene and Surgical Hand Antisepsis. AORN J. 2013;98(5):449–60. 10.1016/j.aorn.2013.08.017.
59. De Korne DF, Van Wijngaarden JDH, Van Rooij J, Wauben LSGL, Hiddema UF, Klazinga NS. Safety by design: Effects of operating room floor marking on the position of surgical devices to promote clean air flow compliance and minimise infection risks. BMJ Qual Saf. 2012;21(9):746–52. 10.1136/bmjqs-2011-000138.
60. Kramer A, Assadian O, Hübner N-O, Kampf G. Prevention of postoperative wound infections, part 2: Impact of surgical hand preparation and current aspects for the implementation. Hygiene + Medizin. 2009;34(1–2):41–9.
61. Kramer A, Hübner N, Below H, Heidecke C-D, Assadian O. Improving adherence to surgical hand preparation. Journal of Hospital Infection. 2008;70(SUPPL. 1):35–43. 10.1016/s0195-6701(08)60009-2

62. Khan A, McLaren SG, Nelson CL. Surgical hand scrub practices in orthopaedic surgery. Clin Orthop Relat Res. 2003;414:65–8. 10.1097/01.blo.0000084404.53464.17.
63. Ma Y, Yue X, Li N, Wang J, Wang J, Xia Y, et al. Evaluation of an intervention to improve waterless surgical hand antisepsis accuracy in a tertiary hospital of East China: a prospective pre-post intervention study. Front Public Health. 2025;13:1583510. 10.3389/fpubh.2025.1583510.
64. Lopes AER, Menegueti MG, Gaspar GG, Tartari E, Canini SRMDS, Pittet D, et al. Comparing surgeons' skin tolerance and acceptability to alcohol-based surgical hand preparation vs traditional surgical scrub: A matched quasi-experimental study. Am J Infect Control. 2022;50(10):1091–7. 10.1016/j.ajic.2022.01.028.
65. Parlak EA, Iyigun E, Albay A, Bedir O. Impact of methods and duration of surgical hand scrub on bacterial count: A randomized controlled trial. Am J Infect Control. 2021;49(11):1376–83. 10.1016/j.ajic.2021.05.006.
66. Javitt MJ, Grossman A, Grajewski A, Javitt JC. Association between Eliminating Water from Surgical Hand Antisepsis at a Large Ophthalmic Surgical Hospital and Cost. JAMA Ophthalmol. 2020;138(4):382–6. 10.1001/jamaophthalmol.2020.0048.
67. Myltykbayeva Z, Kovaleva G, Mukhitdinov A, Omarova S, Nadirov R. In Vivo Comparison of Chlorine-Based Antiseptics versus Alcohol Antiseptic for Surgical Hand Antisepsis. Scientifica. 2020;2020:3123084. 10.1155/2020/3123084.
68. Feng W, Lin S, Huang D, Huang J, Chen L, Wu W, et al. Surgical hand rubbing versus surgical hand scrubbing: Systematic review and meta-analysis of efficacy. Injury-International J Care Injured. 2020;51(6):1250–7. 10.1016/j.injury.2020.03.007.
69. Ho Y-H, Wang Y-C, Loh E-W, Tam K-W. Antiseptic efficacies of waterless hand rub, chlorhexidine scrub, and povidone-iodine scrub in surgical settings: a meta-analysis of randomized controlled trials. J Hosp Infect. 2019;101(4):370–9. 10.1016/j.jhin.2018.11.012.
70. De Bengoa Vallejo RB, Fernandez DS, Cervera LA, Aragón LM, Losa Iglesias ME, Collado Yurrita LR, et al. Effectiveness of surgical hand antisepsis using chlorhexidine digluconate and parachlorometaxylenol hand scrub Cross-over trial. Med (United States). 2018;97(42):e12831. 10.1097/md.0000000000012831.
71. Hennig T-J, Werner S, Naujox K, Arndt A. Chlorhexidine is not an essential component in alcohol-based surgical hand preparation: A comparative study of two handrubs based on a modified EN 12791 test protocol. Antimicrob Resist Infect Control. 2017;6(1):96. 10.1186/s13756-017-0258-0.
72. Kampf G, Kramer A, Suchomel M. Lack of sustained efficacy for alcohol-based surgical hand rubs containing ‘residual active ingredients’ according to EN 12791. J Hosp Infect. 2017;95(2):163–8. 10.1016/j.jhin.2016.11.001.
73. Oriel BS, Chen Q, Itani KMF. The impact of surgical hand antisepsis technique on surgical site infection. Am J Surg. 2017;213(1):24–9. 10.1016/j.amjsurg.2016.09.058.
74. Tanner J, Dumville JC, Norman G, Fortnam M. Surgical hand antisepsis to reduce surgical site infection. Cochrane Database Syst Reviews. 2016;2016(1):CD004288.

10.1002/14651858.cd004288.pub3.

75. Liu LQ, Mehigan S. The Effects of Surgical Hand Scrubbing Protocols on Skin Integrity and Surgical Site Infection Rates: A Systematic Review. AORN J. 2016;103(5):468–82. 10.1016/j.aorn.2016.03.003.
76. Suchomel M, Rotter M, Weinlich M, Kundi M. Glycerol significantly decreases the three hour efficacy of alcohol-based surgical hand rubs. J Hosp Infect. 2013;83(4):284–7. 10.1016/j.jhin.2012.11.030.
77. Suchomel M, Kundi M, Pittet D, Rotter ML. Modified World Health Organization hand rub formulations comply with European efficacy requirements for preoperative surgical hand preparations. Infect Control Hosp Epidemiol. 2013;34(3):245–50. 10.1086/669528.
78. Widmer AF. Surgical hand hygiene: Scrub or rub? Journal of Hospital Infection. 2013;83(SUPPL. 1):S35-S39. 10.1016/s0195-6701(13)60008-0
79. Gonçalves KDJ, Graziano KU, Kawagoe JY. A systematic review of surgical hand antisepsis using an alcohol preparation compared to traditional products. Revista da Escola de Enfermagem. 2012;46(6):1483–92. 10.1590/s0080-62342012000600028.
80. Chen CF, Han CL, Kan CP, Chen SG, Hung PW. Effect of surgical site infections with waterless and traditional hand scrubbing protocols on bacterial growth. Am J Infect Control. 2012;40(4):E15–7. 10.1016/j.ajic.2011.09.008.
81. Olson LKM, Morse DJ, Duley C, Savell BK. Prospective, randomized in vivo comparison of a dual-active waterless antiseptic versus two alcohol-only waterless antiseptics for surgical hand antisepsis. Am J Infect Control. 2012;40(2):155–9. 10.1016/j.ajic.2011.10.012.
82. Lai KW, Foo TL, Low W, Naidu G. Surgical hand antisepsis-a pilot study comparing povidone iodine hand scrub and alcohol-based chlorhexidine gluconate hand rub. Annals Acad Med Singap. 2012;41(1):12–6. 10.47102/annals-acadmedsg.v41n1p12.
83. Huebner NO, Kellner NB, Partecke LI, Koburger T, Heidecke CD, Kohlmann T, et al. Determination of antiseptic efficacy of rubs on the forearm and consequences for surgical hand disinfection. J Hosp Infect. 2011;78(1):11–5. 10.1016/j.jhin.2010.01.033.
84. Suchomel M, Kundi M, Allegranzi B, Pittet D, Rotter ML. Testing of the World Health Organization-recommended formulations for surgical hand preparation and proposals for increased efficacy. J Hosp Infect. 2011;79(2):115–8. 10.1016/j.jhin.2011.05.005.
85. Nthumba PM, Stepita-Poenaru E, Poenaru D, Bird P, Allegranzi B, Pittet D, et al. Cluster-randomized, crossover trial of the efficacy of plain soap and water versus alcohol-based rub for surgical hand preparation in a rural hospital in Kenya. Br J Surg. 2010;97(11):1621–8. 10.1002/bjs.7213.
86. Widmer AF, Rotter M, Voss A, Nthumba P, Allegranzi B, Boyce J, et al. Surgical hand preparation: state-of-the-art. J Hosp Infect. 2010;74(2):112–22. 10.1016/j.jhin.2009.06.020.
87. Rotter ML, Kampf G, Suchomel M, Kundi M. Long-term effect of a 1.5 minute surgical hand rub with a propanol-based product on the resident hand flora. J Hosp Infect. 2007;66(1):84–5. 10.1016/j.jhin.2007.02.012.

88. Rotter ML, Kampf G, Suchomel M, Kundi M. Population kinetics of the skin flora on gloved hands following surgical hand disinfection with 3 propanol-based hand rubs: A prospective, randomized, double-blind trial. Infect Control Hosp Epidemiol. 2007;28(3):346–50. 10.1086/510865.
89. Ahmed A. Surgical hand scrub: Lots of water wasted. Ann Afr Med. 2007;6(1):31–3. 10.4103/1596-3519.55733.
90. Huebner NO, Kampf G, Loeffler H, Kramer A. Effect of a 1 min hand wash on the bactericidal efficacy of consecutive surgical hand disinfection with standard alcohols and on skin hydration. Int J Hyg Environ Health. 2006;209(3):285–91. 10.1016/j.ijheh.2006.01.002.
91. Kampf G, Ostermeyer C, Heeg P, Paulson D. Evaluation of two methods of determining the efficacies of two alcohol-based hand rubs for surgical hand antisepsis. Appl Environ Microbiol. 2006;72(6):3856–61. 10.1128/aem.02746-05.
92. Gaonkar TA, Geraldo I, Shintre M, Modak SM. In vivo efficacy of an alcohol-based surgical hand disinfectant containing a synergistic combination of ethylhexylglycerin and preservatives. J Hosp Infect. 2006;63(4):412–7. 10.1016/j.jhin.2006.03.005.
93. Kampf G, Kramer A, Rotter M, Widmer A. Optimizing surgical hand disinfection. Zentralbl Chir. 2006;131(4):322–6. 10.1055/s-2006-947277.
94. Rotter M, Kundi M, Suchomel M, Harke HP, Kramer A, Ostermeyer C, et al. Reproducibility and workability of the European test standard EN 12791 regarding the effectiveness of surgical hand antiseptics: A randomized, Multicenter trial. Infect Control Hosp Epidemiol. 2006;27(9):935–9. 10.1086/507283.
95. Hsieh H-F, Chiu H-H, Lee F-P. Surgical hand scrubs in relation to microbial counts: Systematic literature review. J Adv Nurs. 2006;55(1):68–78. 10.1111/j.1365-2648.2006.03876.x.
96. Kampf G, Voss A, Widmer AF. The surgical hand disinfection between tradition and progress. Hygiene + Medizin. 2006;31(7–8):316–21.
97. Furukawa K, Ogawa R, Norose Y, Tajiri T. A new surgical handwashing and hand antisepsis from scrubbing to rubbing. J Nippon Med School. 2004;71(3):190–7. 10.1272/jnms.71.190.
98. Parienti J, Thibon P, Heller R, Le Roux Y, von Theobald P, Bensadoun H, et al. Hand-rubbing with an aqueous alcoholic solution vs traditional surgical hand-scrubbing and 30-day surgical site infection rates - A randomized equivalence study. JAMA-Journal Am Med Association. 2002;288(6):722–7. 10.1001/jama.288.6.722.
99. Larson EL, Aiello AE, Heilman JM, Lyle CT, Cronquist A, Stahl JB, et al. Comparison of different regimens for surgical hand preparation. AORN J. 2001;73(2):412–20. 10.1016/s0001-2092(06)61981-9.
100. Jones RD, Jampani H, Mulberry G, Rizer RL. Moisturizing alcohol hand gels for surgical hand preparation. AORN J. 2000;71(3):584–92. 10.1016/s0001-2092(06)61580-9.
101. Wheelock SM, Lookinland S. Effect of surgical hand scrub time on subsequent bacterial growth. AORN J. 1997;65(6):1087–92. 10.1016/s0001-2092(06)62949-9.

102. O'Farrell DA, Kenny G, O'Sullivan M, Nicholson P, Stephens M, Hone R. Evaluation of the optimal hand-scrub duration prior to total hip arthroplasty. J Hosp Infect. 1994;26(2):93–8. 10.1016/0195-6701(94)90050-7.
103. Babb JR, Davies JG, Ayliffe GA. A test procedure for evaluating surgical hand disinfection. The Journal of hospital infection. 1991;18 Suppl B:41 – 9. 10.1016/0195-6701(91)90262-7
104. Rehork B, Ruden H. Investigations into the efficacy of different procedures for surgical hand disinfection between consecutive operations. J Hosp Infect. 1991;19(2):115–27. 10.1016/0195-6701(91)90104-g.
105. Pereira LJ, Lee GM, Wade KJ. The effect of surgical handwashing routines on the microbial counts of operating room nurses. Am J Infect Control. 1990;18(6):354–64. 10.1016/0196-6553(90)90249-r.
106. Eitzen HE, Ritter MA, French MLV, Gioe TJ. A microbiological in-use comparison of surgical hand-washing agents. J Bone Joint Surg - Ser A. 1979;61(A3):403–6. 10.2106/00004623-197961030-00016.
107. Onuminya PO, Adamgbe MA, Okpanachi JA, Abambah O, Agbatse IJ, Jibril N, et al. Comparison of Povidone-Iodine against a Combination of Chlorhexidine, Cetrimide, and Methylated Spirit Skin Preparation for Clean-Contaminated Laparotomy Operations at Jos University Teaching Hospital. J West Afr Coll Surg. 2026. 10.4103/jwas.jwas_52_25.
108. Zhu L, Han Z, Wen K, Zhang L, Tang J, Chen X. Efficacy of chlorhexidine in alcohol versus aqueous povidone-iodine for preoperative skin antisepsis in preventing surgical site infections: a systematic review and meta-analysis with trial sequential analysis. BMC Surg. 2026. 10.1186/s12893-026-03958-1.
109. Hsieh HH, Yu Y, Chang CJ, Chang TY. A comparative meta-analysis of povidone-iodine-alcohol vs. chlorhexidine-alcohol for preoperative skin antisepsis in abdominal surgery. Am J Surg. 2025;244:116318. 10.1016/j.amjsurg.2025.116318.
110. Takeuchi M, Obara H, Furube T, Kawakubo H, Kitago M, Okabayashi K, et al. Efficacy of aqueous olanexidine compared with alcohol-based chlorhexidine for surgical skin antisepsis regarding the incidence of surgical-site infections in clean-contaminated surgery: a randomized superiority trial. Bjs-British J Surg. 2025;112(4):znaf065. 10.1093/bjs/znaf065.
111. Widmer AF, Atkinson A, Kuster SP, Wolfensberger A, Klimke S, Sommerstein R, et al. Povidone Iodine vs Chlorhexidine Gluconate in Alcohol for Preoperative Skin Antisepsis. JAMA-Journal Am Med Association. 2024;332(7):541–9. 10.1001/jama.2024.8531.
112. Peristeri V, Nour D, Ahsan HM, Abogabal A, Singh S, Sajid KK. Alcohol-Containing Versus Aqueous-Based Solutions for Skin Preparation in Abdominal Surgery-A Systematic Review and Meta-analysis. J Surg Res. 2023;291:734–41. 10.1016/j.jss.2023.06.011.
113. Boyce JM. Best products for skin antisepsis. Am J Infect Control. 2023;51(11):A58–63. 10.1016/j.ajic.2023.02.002.
114. Takeuchi M, Obara H, Furube T, Kawakubo H, Kitago M, Okabayashi K, et al. Effect of aqueous olanexidine versus alcohol-based chlorhexidine for surgical skin antisepsis on incidence of surgical

site infections in gastrointestinal surgery: multicentre randomised controlled clinical trial (OEDO trial) protocol. BMJ Open. 2023;13(8):e074169. 10.1136/bmjopen-2023-074169.

115. Cho M-R, Choi W-K, Che S-H, Song S-K. Efficacy of skin preparation solutions in patients with total knee replacement: A randomized controlled trial. J Orthop Surg. 2023;31(1):10225536231165358. 10.1177/10225536231165358.
116. Fink K, Örgel M, Baier C, Brauckmann V, Giannoudis V, Liodakis E. Quality of lower limb preoperative skin preparation using colorless versus colored disinfectants–results of an experimental, randomized study in a close to reality setting. PLoS ONE. 2023;18(3 March):e0282662. 10.1371/journal.pone.0282662.
117. Bashir MH, Hollingsworth A, Thompson JD, Shortridge D, Lake SP, Deeken CR, et al. Antimicrobial performance of two preoperative skin preparation solutions containing iodine and isopropyl alcohol. Am J Infect Control. 2022;50(7):792–8. 10.1016/j.ajic.2021.10.031.
118. Beausoleil C, Comstock SL, Werner D, Li L, Eby JM, Zook EC. Antimicrobial persistence of two alcoholic preoperative skin preparation solutions. J Hosp Infect. 2022;129:8–16. 10.1016/j.jhin.2022.08.008.
119. Slobogean GP, Sprague S, Wells JL, Thabane L, Mullins CD, Harris AD, et al. Aqueous skin antisepsis before surgical fixation of open fractures (Aqueous-PREP): a multiple-period, clusterr-andomised, crossover trial. Lancet. 2022;400(10360):1334–44. 10.1016/s0140-6736(22)01652-x.
120. Droll KP, Abouassaly M, Cullinan C, Puskas D, Dubois S. Efficacy of surgical skin preparation solutions in hip arthroplasty: a prospective randomized trial. Can J Surg. 2022;65(6):E756–62. 10.1503/cjs.017221.
121. Hasegawa T, Tashiro S, Mihara T, Kon J, Sakurai K, Tanaka Y, et al. Efficacy of surgical skin preparation with chlorhexidine in alcohol according to the concentration required to prevent surgical site infection: Meta-Analysis. BJS Open. 2022;6(5):zrac111. 10.1093/bjsopen/zrac111.
122. Rougereau G, Chatelain L, Terracher R, Zadegan F, Ollat D. Surgical solutions for preoperative skin preparation in total hip arthroplasty: A cost-effectiveness analysis of Betadine® and Chloraprep™. Orthop Traumatology: Surg Res. 2022;108(6):103355. 10.1016/j.otsr.2022.103355.
123. Hampton J, Park SSW, Palazzi K, Oldmeadow C, Carroll R, Attia J, et al. The effect of preoperative skin preparation on clinical outcomes with incisional surgery: a network meta-analysis. ANZ J Surg. 2022;92(11):2859–67. 10.1111/ans.17831.
124. Wade RG, Bourke G, Wormald JCR, Totty JP, Stanley GHM, Lewandowski A, et al. Chlorhexidine versus povidone-iodine skin antisepsis before upper limb surgery (CIPHUR): an international multicentre prospective cohort study. Bjs Open. 2021;5(6):zrab117. 10.1093/bjsopen/zrab117.
125. Luwang AL, Saha PK, Rohilla M, Sikka P, Saha L, Gautam V. Chlorhexidine-alcohol versus povidone-iodine as preoperative skin antisepsis for prevention of surgical site infection in cesarean delivery-a pilot randomized control trial. Trials. 2021;22(1):540. 10.1186/s13063-021-05490-4.
126. Dörfel D, Maiwald M, Daeschlein G, Müller G, Hudek R, Assadian O, et al. Comparison of the antimicrobial efficacy of povidone-iodine-alcohol versus chlorhexidine-alcohol for surgical skin

preparation on the aerobic and anaerobic skin flora of the shoulder region. Antimicrob Resist Infect Control. 2021;10(1):17. 10.1186/s13756-020-00874-8.

127. Mastrocola M, Matziolis G, Boehle S, Lindemann C, Schlattmann P, Eijer H. Meta-analysis of the efficacy of preoperative skin preparation with alcoholic chlorhexidine compared to povidone iodine in orthopedic surgery. Sci Rep. 2021;11(1):18634. 10.1038/s41598-021-97838-8.
128. Peel TN, Watson E, Lee SJ. Randomised Controlled Trials of Alcohol-Based Surgical Site Skin Preparation for the Prevention of Surgical Site Infections: Systematic Review and Meta-Analysis. J Clin Med. 2021;10(4):663. 10.3390/jcm10040663.
129. Edmiston CE, Lavin P, Spencer M, Borlaug G, Seabrook GR, Leaper D. Antiseptic efficacy of an innovative perioperative surgical skin preparation: A confirmatory FDA phase 3 analysis. Infect Control Hosp Epidemiol. 2020;41(6):653–9. 10.1017/ice.2020.27.
130. Obara H, Takeuchi M, Kawakubo H, Shinoda M, Okabayashi K, Hayashi K, et al. Aqueous olanexidine versus aqueous povidone-iodine for surgical skin antisepsis on the incidence of surgical site infections after clean-contaminated surgery: a multicentre, prospective, blinded-endpoint, randomised controlled trial. Lancet Infect Dis. 2020;20(11):1281–9. 10.1016/s1473-3099(20)30225-5.
131. Elshamy E, Ali YZA, Khalafallah M, Soliman A. Chlorhexidine-alcohol versus povidone-iodine for skin preparation before elective cesarean section: a prospective observational study. J Maternal-Fetal Neonatal Med. 2020;33(2):272–6. 10.1080/14767058.2018.1489533.
132. Dior UP, Kathurusinghe S, Cheng C, Reddington C, Daley AJ, Ang C, et al. Effect of Surgical Skin Antisepsis on Surgical Site Infections in Patients Undergoing Gynecological Laparoscopic Surgery A Double-Blind Randomized Clinical Trial. JAMA Surg. 2020;155(9):807–15. 10.1001/jamasurg.2020.1953.
133. Gezer S, Yalvaç HM, Güngör K, Yücesoy İ. Povidone-iodine vs chlorhexidine alcohol for skin preparation in malignant and premalignant gynaecologic diseases: A randomized controlled study. Eur J Obstet Gynecol Reproductive Biology. 2020;244:45–50. 10.1016/j.ejogrb.2019.10.035.
134. Ritter B, Herlyn PKE, Mittlmeier T, Herlyn A. Preoperative skin antisepsis using chlorhexidine may reduce surgical wound infections in lower limb trauma surgery when compared to povidone-iodine - a prospective randomized trial. Am J Infect Control. 2020;48(2):167–72. 10.1016/j.ajic.2019.08.008.
135. Hadiati DR, Hakimi M, Nurdiati DS, Masuzawa Y, da Silva Lopes K, Ota E. Skin preparation for preventing infection following caesarean section. Cochrane Database Syst Reviews. 2020;2020(6):CD007462. 10.1002/14651858.cd007462.pub5.
136. Tolcher MC, Whitham MD, El-Nashar SA, Clark SL. Chlorhexidine-Alcohol Compared with Povidone-Iodine Preoperative Skin Antisepsis for Cesarean Delivery: A Systematic Review and Meta-Analysis. Am J Perinatol. 2019;36(2):118–23. 10.1055/s-0038-1669907.
137. Peel TN, Dowsey MM, Buising KL, Cheng AC, Choong PFM. Chlorhexidine-alcohol versus iodineealcohol for surgical site skin preparation in an elective arthroplasty (ACAISA) study: a cluster randomized controlled trial. Clin Microbiol Infect. 2019;25(10):1239–45. 10.1016/j.cmi.2019.06.016.

138. Crnich CJ, Pop-Vicas AE, Hedberg TG, Perl TM. Efficacy and safety of a novel antimicrobial preoperative skin preparation. Infect Control Hosp Epidemiol. 2019;40(10):1157–63. 10.1017/ice.2019.200.
139. Dormstetter K, Olson LKM, Bennaars-Eiden A, Bernatchez SF. Evaluation of activity and potential for development of antimicrobial resistance to a new tinted 2% chlorhexidine gluconate/70% isopropyl alcohol film-forming sterile preoperative skin preparation. J Global Antimicrob Resist. 2019;17:160–7. 10.1016/j.jgar.2018.12.008.
140. Boisson M, Corbi P, Kerforne T, Camilleri L, Debauchez M, Demondion P, et al. Multicentre, open-label, randomised, controlled clinical trial comparing 2% chlorhexidine-70% isopropanol and 5% povidone iodine-69% ethanol for skin antisepsis in reducing surgical-site infection after cardiac surgery: the CLEAN 2 study protocol. BMJ Open. 2019;9(6):e026929. 10.1136/bmjopen-2018-026929.
141. Raja SG, Rochon M, Mullins C, Morais C, Kourliouros A, Wishart E, et al. Impact of choice of skin preparation solution in cardiac surgery on rate of surgical site infection: a propensity score matched analysis. J Infect Prev. 2018;19(1):16–21. 10.1177/1757177417722045.
142. Ghobrial GM, Wang MY, Green BA, Levene HB, Manzano G, Vanni S, et al. Preoperative skin antisepsis with chlorhexidine gluconate versus povidone-iodine: a prospective analysis of 6959 consecutive spinal surgery patients. J Neurosurgery-Spine. 2018;28(2):209–14. 10.3171/2017.5.spine17158.
143. Anggrahita T, Wardhana A, Sudjatmiko G. Chlorhexidine-alcohol versus povidone-iodine as preoperative skin preparation to prevent surgical site infection: a meta-analysis. Med J Indonesia. 2017;26(1):54–61. 10.13181/mji.v26i1.1388.
144. Park HM, Han SS, Lee EC, Lee SD, Yoon HM, Eom BW, et al. Randomized clinical trial of preoperative skin antisepsis with chlorhexidine gluconate or povidone-iodine. Br J Surg. 2017;104(2):E145–50. 10.1002/bjs.10395.
145. Morrison TN, Chen AF, Taneja M, Kucukdurmaz F, Rothman RH, Parvizi J. Single vs Repeat Surgical Skin Preparations for Reducing Surgical Site Infection After Total Joint Arthroplasty: A Prospective, Randomized, Double-Blinded Study. J Arthroplasty. 2016;31(6):1289–94. 10.1016/j.arth.2015.12.009.
146. Srinivas A, Kaman L, Raj P, Gautam V, Dahiya D, Singh G, et al. Comparison of the efficacy of chlorhexidine gluconate versus povidone iodine as preoperative skin preparation for the prevention of surgical site infections in clean-contaminated upper abdominal surgeries. Surg Today. 2015;45(11):1378–84. 10.1007/s00595-014-1078-y.
147. Yasuda T, Hasegawa T, Yamato Y, Kobayashi S, Togawa D, Arima H, et al. Optimal Timing of Preoperative Skin Preparation with Povidone-Iodine for Spine Surgery: A Prospective, Randomized Controlled Study. Asian Spine J. 2015;9(3):423–6. 10.4184/asj.2015.9.3.423.
148. Sidhwa F, Itani KMF. Skin Preparation Before Surgery: Options and Evidence. Surg Infect. 2015;16(1):14–23. 10.1089/sur.2015.010.

149. Ngai IM, Van Arsdale A, Govindappagari S, Judge NE, Neto NK, Bernstein J, et al. Skin Preparation for Prevention of Surgical Site Infection After Cesarean Delivery A Randomized Controlled Trial. Obstet Gynecol. 2015;126(6):1251–7. 10.1097/aog.0000000000001118.
150. Young HL, Reese S, Knepper B, Miller A, Mauffrey C, Price CS. The effect of preoperative skin preparation products on surgical site infection. Infect Control Hosp Epidemiol. 2014;35(12):1535–8. 10.1086/678601.
151. Magalini S, Pepe G, Panunzi S, De Gaetano A, Abatini C, Di Giorgio A, et al. Observational study on preoperative surgical field disinfection: Povidone-iodine and Chlorhexidine-alcohol. Eur Rev Med Pharmacol Sci. 2013;17(24):3367–75.
152. Bonnevialle N, Geiss L, Cavalié L, Ibnoulkhatib A, Verdeil X, Bonnevialle P. Skin preparation before hip replacement in emergency setting versus elective scheduled arthroplasty: Bacteriological comparative analysis. Orthop Traumatology: Surg Res. 2013;99(6):659–65. 10.1016/j.otsr.2013.04.004.
153. Dromzee E, Tribot-Laspière Q, Bachy M, Zakine S, Mary P, Vialle R. Efficacy of Integuseal for surgical skin preparation in children and adolescents undergoing scoliosis correction. Spine. 2012;37(21):E1331–5. 10.1097/brs.0b013e3182687d6c.
154. Nishihara Y, Kajiura T, Yokota K, Kobayashi H, Okubo T. Evaluation with a focus on both the antimicrobial efficacy and cumulative skin irritation potential of chlorhexidine gluconate alcohol-containing preoperative skin preparations. Am J Infect Control. 2012;40(10):973–8. 10.1016/j.ajic.2012.04.323.
155. Darouiche RO, Wall MJ Jr, Itani KMF, Otterson MF, Webb AL, Carrick MM, et al. Chlorhexidine-alcohol versus povidone-iodine for surgical-site antisepsis. N Engl J Med. 2010;362(1):18–26. 10.1056/nejmoa0810988.
156. Lee I, Agarwal RK, Lee BY, Fishman NO, Umscheid CA. Systematic Review and Cost Analysis Comparing Use of Chlorhexidine with Use of Iodine for Preoperative Skin Antisepsis to Prevent Surgical Site Infection. Infect Control Hosp Epidemiol. 2010;31(12):1219–29. 10.1086/657134.
157. Paocharoen V, Mingmalairak C, Apisarnthanarak A. Comparison of surgical wound infection after preoperative skin preparation with 4% chlorhexidine [correction of chlohexidine] and povidone iodine: a prospective randomized trial. J Med Association Thail = Chotmaihet thangphaet. 2009;92(7):898–902.
158. Swenson BR, Hedrick TL, Metzger R, Bonatti H, Pruett TL, Sawyer RG. Effects of Preoperative Skin Preparation on Postoperative Wound Infection Rates: A Prospective Study of 3 Skin Preparation Protocols. Infect Control Hosp Epidemiol. 2009;30(10):964–71. 10.1086/605926.
159. Eiselt D. Presurgical Skin Preparation With a Novel 2% Chlorhexidine Gluconate Cloth Reduces Rates of Surgical Site Infection in Orthopaedic Surgical Patients. Orthop Nurs. 2009;28(3):141–5. 10.1097/nor.0b013e3181a469db.
160. Dizer B, Hatipoglu S, Kaymakcioglu N, Tufan T, Yava A, Iyigun E, et al. The effect of nurse-performed preoperative skin preparation on postoperative surgical site infections in abdominal surgery. J Clin

Nurs. 2009;18(23):3325–32. 10.1111/j.1365-2702.2009.02885.x.

161. Keblish D, Zurakowski D, Wilson M, Chiodo C. Preoperative skin preparation of the foot and ankle: Bristles and alcohol are better. J Bone Joint Surgery-American Volume. 2005;87A(5):986–92. 10.2106/jbjs.d.02695.
162. Segal CG, Anderson JJ. Preoperative skin preparation of cardiac patients. AORN J. 2002;76(5):821–8. 10.1016/s0001-2092(06)61035-1.
163. Armstrong EP, Patrick KL, Erstad BL. Comparison of preoperative skin preparation products. Pharmacotherapy. 2001;21(3 I):345–50. 10.1592/phco.21.3.345.34196.
164. Meier DE, Nkor SK, Aasa D, Olaolorun DA, Tarpley JL. Prospective randomized comparison of two preoperative skin preparation techniques in a developing world country. World J Surg. 2001;25(4):441–3. 10.1007/s002680020073.
165. May J, Brooks S, Johnstone D, Macfie J. Does the addition of pre-operative skin preparation with povidone-iodine reduce groin sepsis following arterial surgery? J Hosp Infect. 1993;24(2):153–6. 10.1016/0195-6701(93)90077-d.
166. Brown TR, Ehrlich CE, Stehman FB, Golichowski AM, Madura JA, Eitzen HE. A clinical evaluation of chlorhexidine gluconate spray as compared with iodophor scrub for preoperative skin preparation. Surg Gynecol Obstet. 1984;158(4):363–6.
167. Geelhoed GW, Sharpe K, Simon GL. A comparative study of surgical skin preparation method. Surg Gynecol Obstet. 1983;157(3):265–8.
168. Zarei M, Norouzi N, Teymoori E, Ghafarzadegan R. Covering sterile instrument tables to prevent airborne bacterial contamination and surgical wound infections: A narrative review of operating room nursing practices. Perioperative Care Operating Room Manage. 2025;39:100495. 10.1016/j.pcorm.2025.100495.
169. Zarei M, Teymoori E, Norouzi N, Galougahi MHK, Ghorbani M. Intraoperative airborne bacterial contamination and covered sterile instrument tables: Is the standard two-drape method better than the single-drape method? Experimental study. Perioperative Care Operating Room Manage. 2023;32:100336. 10.1016/j.pcorm.2023.100336.
170. Jennings JM, Miner TM, Johnson RM, Pollet AK, Brady AC, Dennis DA. A back table ultraviolet light decreases environmental contamination during operative cases. Am J Infect Control. 2022;50(6):686–9. 10.1016/j.ajic.2021.09.020.
171. Seth Caous J, Svensson Malchau K, Petzold M, Fridell Y, Malchau H, Ahlstrom L, et al. Instrument tables equipped with local unidirectional airflow units reduce bacterial contamination during orthopedic implant surgery in an operating room with a displacement ventilation system. Infect Prev Pract. 2022;4(3):100222. 10.1016/j.infpip.2022.100222.
172. Zarei M, Babajani-Vafsi S, Kazemi-Galougahi MH, Bakhshi A, Ajorpaz NM, Ghorbani M. The safety of a novel single-drape cover for sterile back tables in the operating room compared to the standard two-drape method: an experimental study. Patient Saf Surg. 2022;16(1):18. 10.1186/s13037-022-00330-z.

173. Holst DC, Angerame MR, Dennis DA, Jennings JM. Does the Method of Sterile Glove-Opening Influence Back Table Contamination? A Fluorescent Particle Study. J Arthroplasty. 2019;34(9):2075–9. 10.1016/j.arth.2019.05.004.
174. Tammelin A, Hambræus A, Ståhle E. Routes and sources of Staphylococcus aureus transmitted to the surgical wound during cardiothoracic surgery: Possibility preventing wound contamination by use of special scrub suits. Infect Control Hosp Epidemiol. 2001;22(6):338–46. 10.1086/501910.
175. Campbell BA, Manos J, Stubbs TM, Flynt NC. Pre-preparation of the sterile instrument table for emergency cesarean section. Surg Gynecol Obstet. 1993;176(1):30–2.

Figures

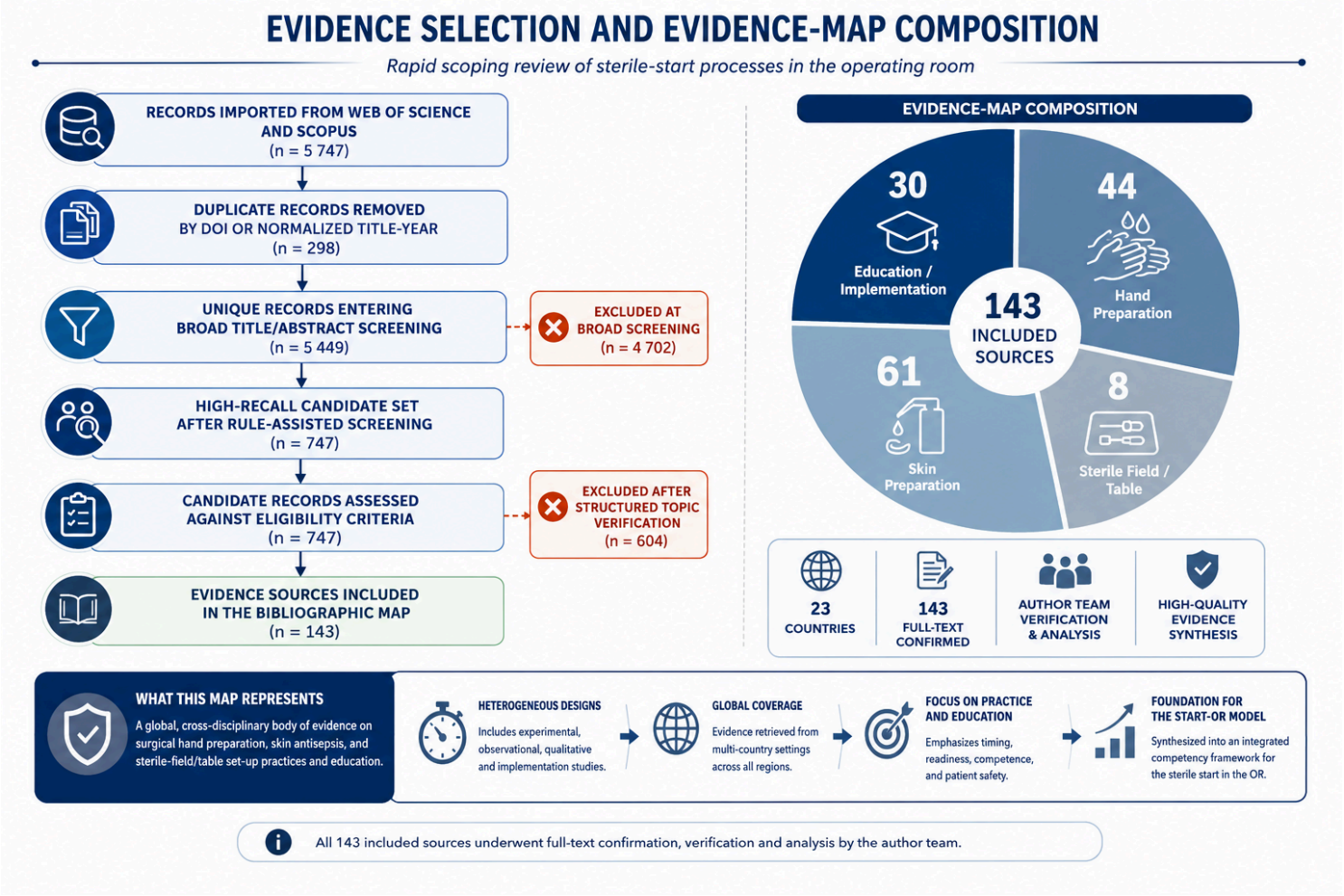


Figure 1

Evidence selection and mapping flow. The flow distinguishes rule-assisted retrieval from author-team eligibility verification. All 143 included sources underwent full-text confirmation, verification and analysis. Counts describe a rapid scoping review with a primary screener and author-team verification of the final evidence set. The lower bar shows the four primary domains [21–22].

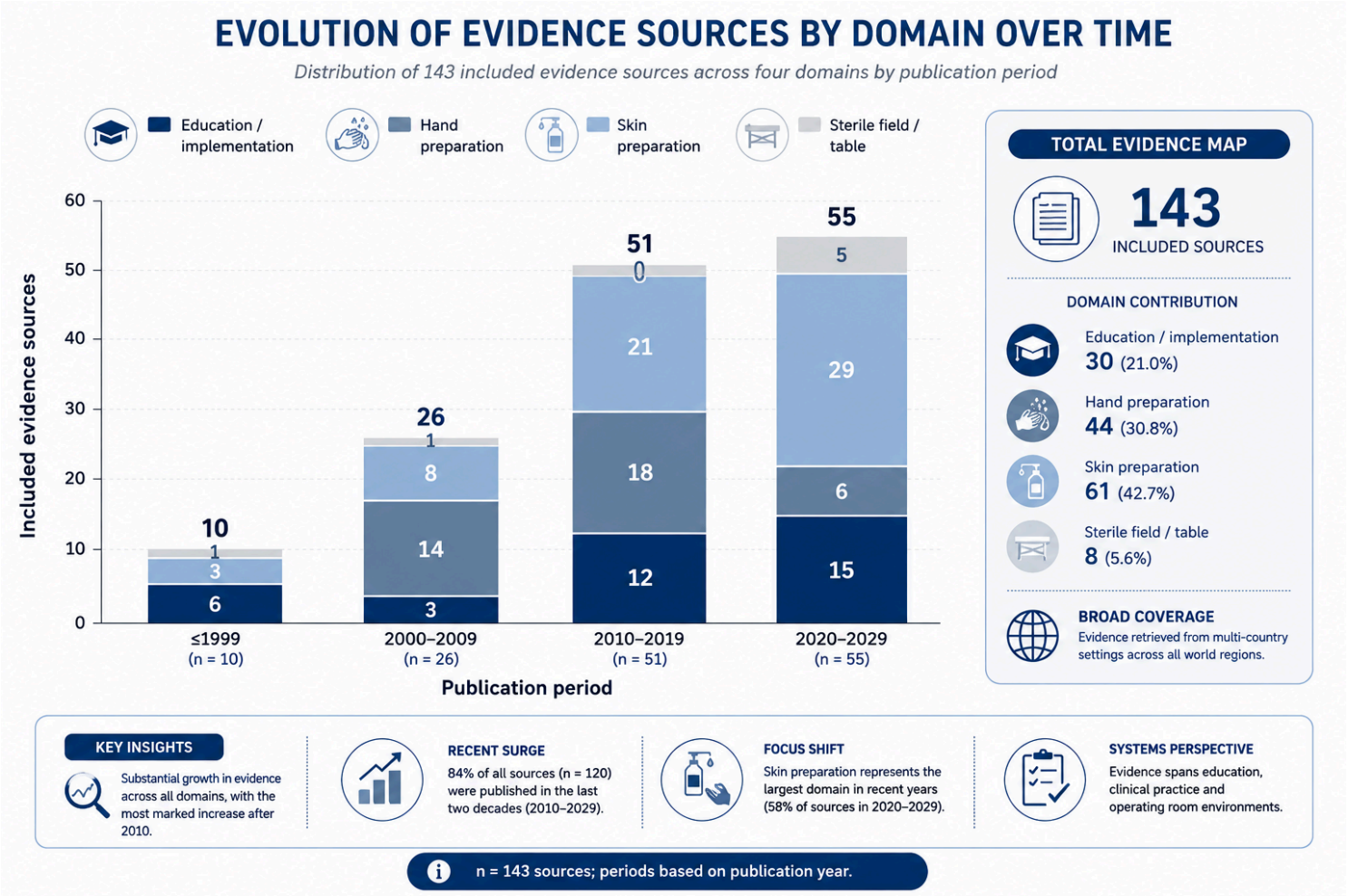


Figure 2

Distribution of included evidence by period and domain. Stacked bars show the number of sources in each domain and publication period. The figure depicts growth of the evidence base but does not imply improved methodological quality over time [33–175].

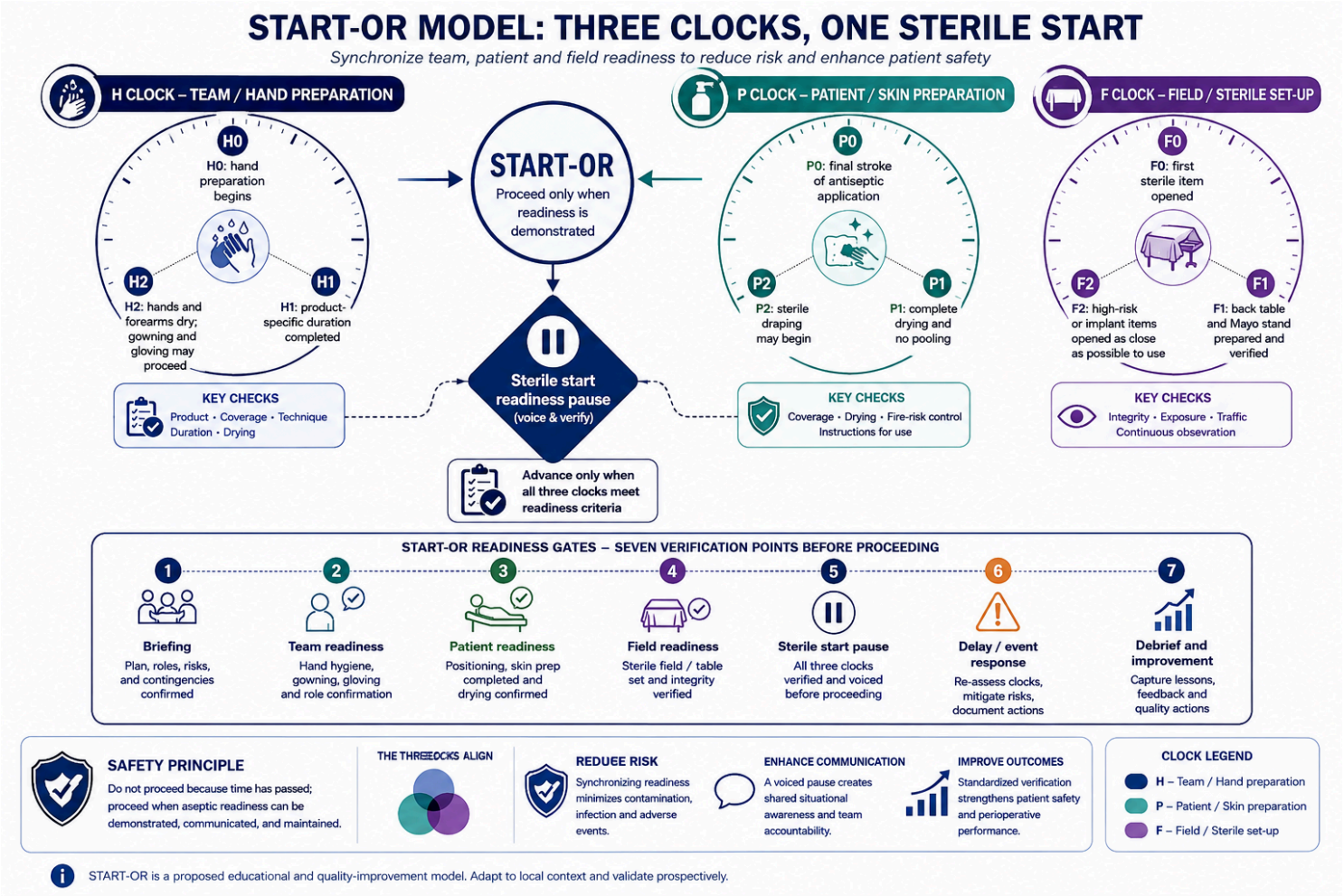


Figure 3

START-OR clock model for the sterile start. The H, P and F clocks represent team/hand preparation, patient/skin preparation and sterile-field set-up. H0–H2, P0–P2 and F0–F2 are observable process states, not universal minute thresholds. The clocks converge at a voiced sterile-start readiness pause; Gates 1–5 govern progression to the sterile start, Gate 6 governs delay/event response and revalidation, and Gate 7 closes the learning loop through debriefing and improvement. F2 is a risk-reduction principle whose application must be reconciled with local workflow, product instructions and specialty needs. START-OR is proposed for education and quality improvement and has not yet been clinically validated [1,3,5,8,15,29–30,63–175].

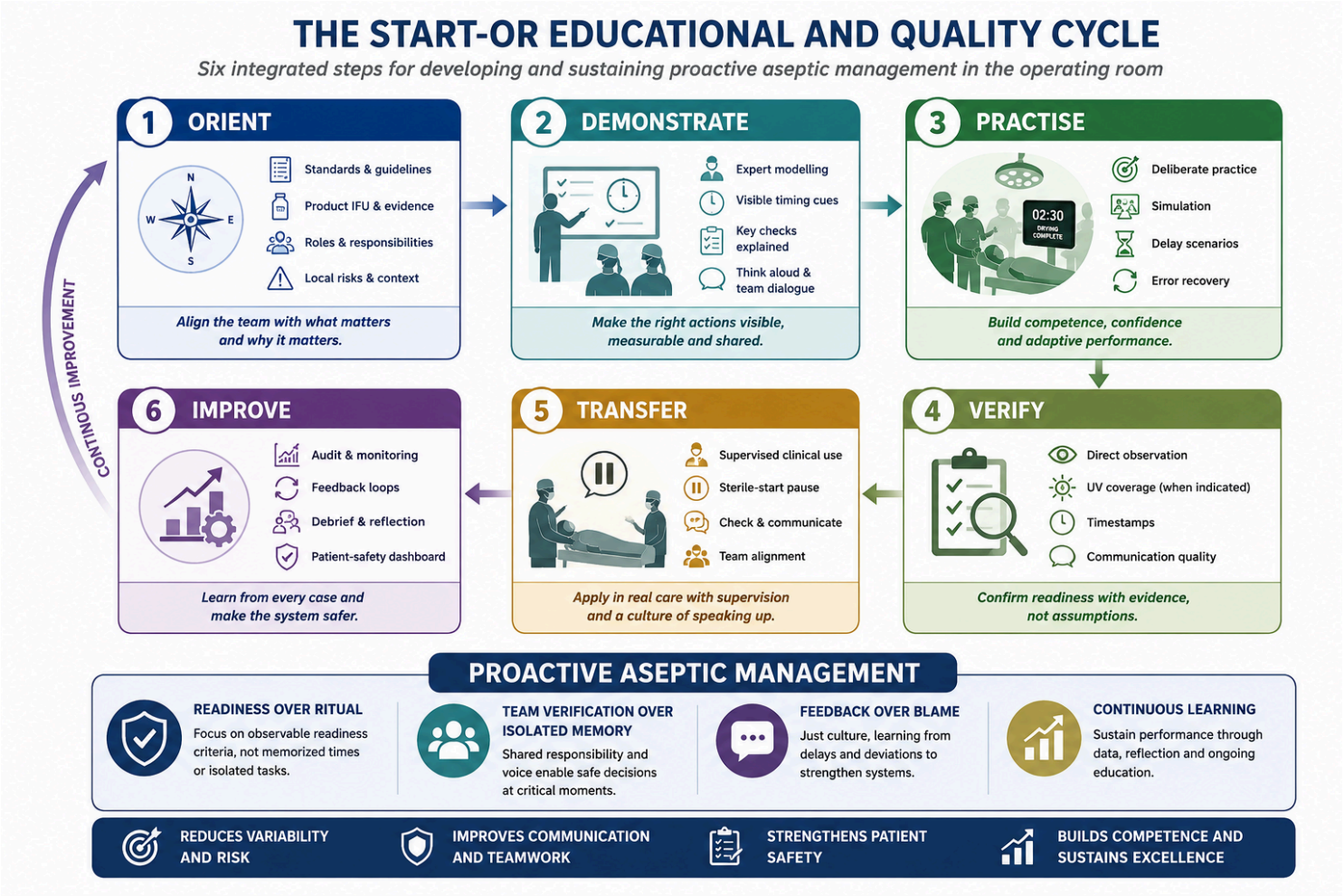


Figure 4

START-OR education-to-practice cycle. The six stages connect curriculum design to workplace improvement. IFU, instructions for use; UV, ultraviolet visualization. The cycle should repeat when products, policies, roles or specialty contexts change [8–15,27–30,33–62].

Supplementary Files

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

- AdditionalFile2EvidenceMapSTARTOR.xlsx
- AdditionalFile1SearchStrategiesSTARTOR.pdf
- AdditionalFile3PRISMAScRchecklistSTARTOR.pdf