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Bridging Theory and Practice in Sterilization of Healthcare Facilities

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ABSTRACT: Background The sterilization of medical instruments is essential for infection prevention and maintaining healthcare quality. Despite comprehensive international guidelines, there are gaps between recommended standards and real-world practices. **Aim** This narrative review evaluates discrepancies between sterilization guidelines and actual implementation, identifies contributing factors, and presents evidence-based strategies to bridge these gaps. **Methods** A narrative review with analytical synthesis was conducted using PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. Literature published from January 2000 through December 2025 was retrieved. Search concepts covered sterilization, sterile processing/CSSD, infection prevention and control, guideline adherence, implementation gaps, monitoring, quality improvement, and healthcare-associated infections. Peer-reviewed studies, review articles, international standards, and guideline documents relevant to sterilization practice were included. The search strategy and database-specific search strings are provided in Appendix A. Evidence was synthesized narratively across knowledge, implementation, and systemic domains. **Results** The updated evidence continued to demonstrate gaps between recommended sterilization standards and routine practice, particularly in cleaning, preparation, packaging, monitoring, traceability, and quality assurance. Recent evidence in 2025 further identified implementation gaps and demonstrated the potential value of structured quality-improvement approaches, competency-focused interventions, and updated professional guidance. **Conclusions** Bridging the gap between theory and practice requires integrated technical, educational, organizational, and quality-assurance interventions. Updated 2025 guidance and studies reinforce the importance of standardized workflows, competency-based training, monitoring and traceability, adherence to manufacturers' instructions for use, and leadership-supported quality improvement.

KEY WORDS: Sterilization; Infection Control; Patient Safety; Healthcare Quality; Implementation Gap; Healthcare-Associated Infections

1 Introduction

The sterilization of reusable medical instruments is a critical component of infection prevention, patient safety, and healthcare quality across all clinical settings. Inadequate sterilization of critical and semi-critical devices can directly lead to healthcare-associated infections (HAIs), increased morbidity and mortality, prolonged hospital stays, and economic strain on healthcare systems[1-6]. Despite international guidelines from the CDC, WHO, WFHSS, and ISO, HAIs remain a global challenge, which shows that standards alone are insufficient to ensure compliance[1-4,7-9].

Multiple studies indicate that theoretical recommendations are often not applied consistently in clinical workflows. Observational studies have documented deviations in cleaning, packaging, sterilization cycle parameters, and monitoring outcomes[5,10-15]. These deviations typically result from complex interactions of human, organizational, and systemic factors, including workload, knowledge gaps, and weak

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monitoring[9-11,16-17].

This review emphasizes behavioral, managerial, and contextual determinants of implementation gaps and proposes practical, evidence-based strategies to improve sterilization compliance (see Table 1, Table 2, and Figure 1).

2 Methods

2.1 Review design and reporting approach

This study was conducted as a narrative review with analytical synthesis to integrate heterogeneous evidence on sterilization practice and implementation. The Scale for the Assessment of Narrative Review Articles (SANRA) was adopted as the reporting framework to ensure methodological quality and transparency. PRISMA 2020 was not used as this work does not claim to be a systematic review or meta-analysis.

2.2 Information sources and search period

Literature searches were conducted in PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. Literature published from January 2000 through December 31, 2025, was retrieved.

2.3 Search strategy

The search strategy combined free-text terms and relevant database indexing terms. Core concepts were combined using Boolean operators (AND/OR). The principal concepts were: (sterilization OR sterilisation OR "sterile processing" OR CSSD OR "central sterile supply") AND (hospital* OR healthcare OR "healthcare facilit*") AND ("infection control" OR "infection prevention" OR "healthcare-associated infection*" OR adherence OR compliance OR implementation OR monitoring OR "quality improvement"). Database-specific versions of the strategy are provided in Appendix A. The strategy was designed to capture both technical sterilization literature and literature concerning implementation of recommended practices.

2.4 Eligibility criteria

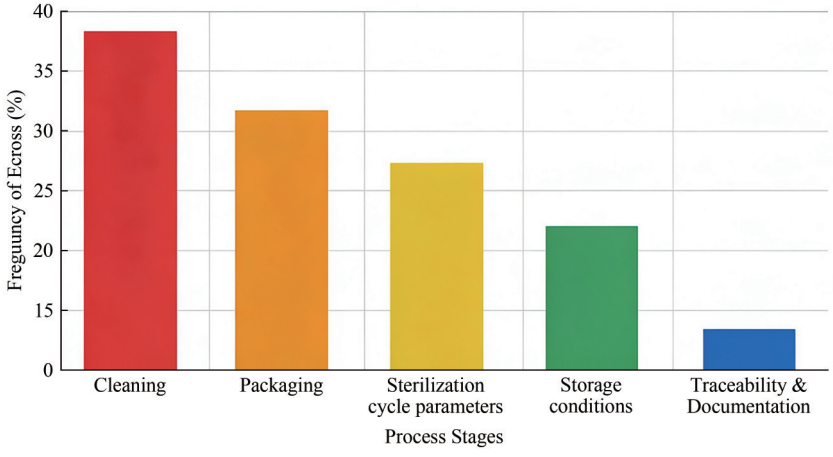
Eligible evidence included peer-reviewed orig-

Table 1 Identified Gaps Between Theoretical Knowledge and Practical Implementation

Gap Type	Description	Contributing Factors	References
Knowledge Gap	Incomplete understanding of sterilization principles	Limited training, outdated curricula	15,17
Implementation Gap	Deviations from SOPs	Human error, workload, lack of supervision	11−13,16
Systemic Gap	Organizational deficiencies	Poor monitoring, inadequate resources, policies	3,5−6,11,13

Table 2 Consequences of Non-Adherence to Sterilization Standards

Consequence	Description	Example/Impact	References
HAIs	Increased infections due to contaminated instruments	Surgical site infections, bloodstream infections	1,11−13,16
Legal/Ethical Risks	Breach of standards	Liability claims, sanctions	1,6−7,11
Economic Burden	Cost of treating HAIs and extended stays	Resource strain on hospitals	11,13,15



Legend: This figure summarizes the relative frequency of common errors at each stage, as shown by observational studies. Errors in cleaning and packaging are the most frequent and contribute most significantly to healthcare-associated infections.

Figure 1 Common Errors Across Sterilization Process Stages

inal studies, review articles, international standards, and guideline documents addressing sterilization or sterile processing in healthcare facilities, implementation of sterilization standards, quality assurance, monitoring, staff competency, workflow, or barriers to adherence. Records were excluded when they were not relevant to healthcare sterilization practice, were non-clinical technical reports without direct applicability to healthcare processing or were opinion pieces without supporting evidence.

2.5 Data extraction and narrative synthesis

Evidence was organized into five domains: (1) knowledge and competency gaps; (2) implementation and workflow gaps; (3) systemic and organizational barriers; (4) consequences for patient safety and healthcare-associated infection prevention; and (5) strategies for improvement. Findings were synthesized narratively, with attention to recurring patterns across different healthcare settings and resource levels. Quantitative effect sizes were not pooled because the evidence was heterogeneous in design, setting, and outcome definition.

2.6 Language restriction

This review was restricted to English-language literature. This restriction was applied for feasibility and consistency across the analysis, while acknowledged as a potential source of language bias. Consequently, relevant evidence published in other languages may not have been identified or incorporated.

2.7 Ethics statement

This study was conducted as a narrative review based on publicly available published literature. Institutional Review Board approval was obtained with a waiver of informed consent, as no human subjects were directly involved in the study.

3 Results

Analysis identified three interrelated categories of gaps: knowledge/competency gaps, implementation/workflow gaps, and systemic/organizational gaps (Table 1).

3.1 Knowledge and competency gaps

3.1.1 Variations in sterilization knowledge across professional groups

Evidence indicates that staff knowledge, training, and competency influence the consistent implementation of sterilization procedures. A 2025 cross-sectional study among healthcare workers found measurable differences in sterilization knowledge across professional groups.

3.1.2 Training as a driver of implementation improvement

The study identified prior training as an important factor associated with better knowledge. These findings support competency-based education and periodic assessment as components of implementation improvement[17].

3.2 Implementation and workflow gaps

Recent guidance emphasizes point-of-use treatment, preparation of reusable devices, sterilization, monitoring, tracking, and adherence to manufacturers' instructions for use[11-12]. A 2025 observational study from Cambodia identified gaps in sterilization-processing practices in hospitals in a lower-middle-income setting[16]. A 2025 pre-post study also demonstrated that structured failure-mode analysis and targeted process interventions can reduce quality defects in CSSD sterilization workflows[13].

3.3 Systemic and organizational gaps

Implementation depends not only on technical knowledge but also on quality systems, monitoring, traceability, leadership, staffing, and available resources. WHO guidance on infection prevention and control emphasizes facility-level systems and behavior-modifying interventions, while recent multi-society sterilization guidance explicitly addresses implementation and tracking[5,11].

These domains are interrelated and can compromise sterility assurance when deficiencies in technical processes, staff competency, monitoring, or organizational support occur simultaneously. The available evidence therefore supports integrated interventions rather than isolated educational measures[3,5-6,10-17].

4 Limitations

This narrative review has several limitations.

First, quantitative effect sizes were not pooled because of heterogeneity in study designs, settings, and outcome measures. Second, the English-language restriction in selected literature may have introduced language bias. Third, narrative selection and interpretation of heterogeneous evidence remain subject to reviewer judgment. Fourth, evidence published after December 31, 2025 was not included in the search. These limitations should be taken into consideration when interpreting the generalizability of the synthesis.

5 Discussion

Sterilization is a critical patient-safety and quality-improvement process. Contemporary guidance emphasizes that appropriate processing requires a coordinated sequence extending from point-of-use treatment and device preparation through sterilization, monitoring, tracking, and implementation[11-12]. The updated literature supports the view that implementation gaps arise from interacting technical, behavioral, workflow, and organizational factors.

Education alone is unlikely to address all implementation barriers. Recent evidence supports combining competency development with process monitoring, traceability, workflow redesign, and structured quality-improvement methods[11-13,16]. The 2025 multi-society guidance also emphasizes implementation considerations and monitoring for effectiveness of processing[11].

6 Conclusions

It is essential to bridge theoretical and practical sterilization standards for patient safety and healthcare quality. The updated evidence indicates that sustainable improvement requires integrated technical, educational, organizational, monitoring, and quality-assurance strategies[3,5-6,10-17].

7 Implications for Practice

Healthcare leaders should support context-specific SOPs, competency-based training, monitoring and traceability systems, quality-assurance programs, and alignment with current professional and international guidance. Recent guidance specifically emphasizes point-of-use treatment, adherence to manufacturers' instructions for use, appropriate processing and storage, monitoring, and implementation[11-12]. Structured quality-improvement methods may further strengthen CSSD performance[13].

Appendix A. Database Search Strategies

Date limits: January 1, 2000 through December 31, 2025. English-language literature was included.

Google Scholar: (sterilization OR sterilisation OR "sterile processing" OR CSSD) AND (healthcare OR hospital) AND ("infection control" OR adherence OR compliance OR implementation OR monitoring OR "quality improvement"). Additional combinations used sterilization with cleaning, packaging, monitoring, competency, workflow, leadership, traceability, and healthcare-associated infections.

Web of Science: TS=((sterilization OR sterilisation OR "sterile processing" OR CSSD OR "central sterile supply") AND (hospital* OR healthcare OR "healthcare facilit*") AND ("infection control" OR "infection prevention" OR "healthcare-associated infection*" OR adherence OR compliance OR implementation OR monitoring OR "quality improvement")).

Scopus: TITLE-ABS-KEY((sterilization OR sterilisation OR "sterile processing" OR CSSD OR "central sterile supply") AND (hospital* OR healthcare OR "healthcare facilit*") AND ("infection control" OR "infection prevention" OR "healthcare-associated infection*" OR adherence OR compliance OR implementation OR monitoring OR "quality improvement")).

PubMed/MEDLINE: (sterilization[Title/Abstract] OR sterilisation[Title/Abstract] OR "sterile processing" [Title/Abstract] OR CSSD[Title/Abstract] OR "central sterile supply" [Title/Abstract]) AND (hospital*[Title/Abstract] OR healthcare[Title/Abstract] OR "healthcare facilit*"[Title/Abstract]) AND ("infection control" [Title/Abstract] OR "infection prevention"[Title/Abstract] OR "healthcare-associated infection*"[Title/Abstract] OR adherence[Title/Abstract] OR compliance[Title/Abstract] OR imple-

mentation[Title/Abstract] OR monitoring[Title/Abstract] OR "quality improvement"[Title/Abstract]).

Reporting note: This manuscript remains a narrative review. SANRA was used as a quality-oriented framework for narrative review reporting; PRISMA 2020 is cited only to distinguish systematic-review reporting requirements and to support transparent reporting principles. No claim of systematic-review or meta-analytic methodology is made.

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