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HEALTH POLICY AND TECHNOLOGY IMPLICATIONS OF CLINICAL INTEROPERABILITY IN NURSING WORKFLOWS: A SCOPING REVIEW

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ABSTRACT

Clinical interoperability is widely promoted as a way to improve care quality, continuity, and safety, but direct evaluative evidence on how it affects nursing-facing medication workflows and structured documentation remains unclear. This scoping review aimed to synthesize recent peer-reviewed nursing-facing evaluative evidence on clinical interoperability in medication workflows and structured documentation. We conducted a scoping review of English-language, peer-reviewed studies published from 2021 onward. Searches were run in Scopus, MEDLINE via EBSCOhost, CINAHL Ultimate via EBSCOhost, and IEEE Xplore. Eligible studies evaluated interoperability, health information exchange, or standards-based exchange and reported at least 1 extractable nursing-facing outcome related to medication workflows, structured documentation, documentation quality, semantic completeness, or closely related operational performance. Two reviewers independently screened records, assessed full texts, extracted data, and appraised methodological quality using Joanna Briggs Institute tools to support cautious interpretation of heterogeneous evidence. Findings were synthesized narratively using SWiM-informed principles. Of 87 full-text reports assessed for eligibility, 5 studies were included. Three studies examined device-to-electronic health record interoperability in medication-administration settings, and 2 examined standards-based or semantic aspects of structured nursing documentation. One included report was a peer-reviewed conference abstract. None directly measured documentation burden. The clearest direct evaluative signal came from a multihospital before-after study showing that smart pump autoprogramming was associated with lower total infusion errors, high-risk

medication errors, and continuous-medication errors. The documentation-focused studies identified inconsistent structured entries, duplication, semantically incomplete documentation, and limited representation of workforce-related nursing indicators. Recent peer-reviewed nursing-facing evaluative evidence on clinical interoperability is limited and concentrated mainly in medication workflows and structured documentation. Within this small and heterogeneous evidence base, device-to-EHR integration provides the clearest direct evaluative signal in medication-administration processes, whereas standards-focused studies mainly identify unresolved documentation and semantic gaps. More multicenter evaluations are needed to assess documentation burden, workflow efficiency, and safety outcomes directly. These findings offer direct evidence bridging technical interoperability and frontline care, which can inform health system policies, technology procurement, and nursing workforce management.

KEYWORDS: Clinical Interoperability; Health Information Exchange; Electronic Health Record; Semantic Interoperability; Structured Documentation; Nursing Informatics; Medication Administration; Medication Safety; Workflow; Scoping Review.

1. INTRODUCTION

Interoperability is a major focus in medical informatics because information exchange only matters when it actually improves clinical work. At the policy and infrastructure levels, interoperability, health information exchange (HIE), and standards-based exchange are linked to safer care, continuity, and better data availability. Recent broader reviews also show that interoperability research remains active across HIE implementation outcomes, general EHR interoperability approaches, FHIR-enabled service design, and FHIR-based data models and structures [12,15,18,19]. On the front lines, however, the practical value of these capabilities depends on how well exchange functions are embedded in medication systems, electronic health record (EHR) workflows, and structured documentation routines.

Nursing work sits directly at the center of this problem. Nurses interact continuously with documentation systems, medication-administration workflows, device-linked data streams, and handover information across care settings. As a result, poor interoperability is more than a technical defect; it can contribute to duplicate charting, fragmented records, workarounds, missing structured data, and weak semantic reuse of nursing information. At the same time, broader work on semantic interoperability and FHIR-based terminology issues shows that documentation quality depends not only on data exchange standards but also on information models, terminologies, and implementation choices [13,14]. Recent scoping work on standardized nursing terminology likewise highlights the importance of structured nursing data for documentation, comparability, and continuity of care [17].

Direct evidence for nursing is difficult to isolate. While there is an extensive body of literature on interoperability architectures, policy frameworks, terminology standards, and enterprise integration, much of it does not report outcomes that can be interpreted at the level of nursing workflow or documentation. Broader reviews of health information technology and EHR usability have shown that digital systems can alter nursing time, performance, and safety [1,2], and recent scoping work on EHR usability challenges has further highlighted documentation burden and workflow disruption as persistent concerns [16]. However, those reviews typically aggregate multiple technologies and exposures and do not isolate interoperability-specific effects in a way that allows nursing-facing operational interpretation.

To address that gap in a more focused way, we designed this scoping review to synthesize recent peer-reviewed nursing-facing evaluative evidence on clinical interoperability in medication workflows and structured documentation.

2. METHODS

2.1 Study design and reporting guideline

We conducted a scoping review to map recent peer-reviewed nursing-facing evaluative evidence on clinical interoperability in medication workflows and structured documentation. The review was conducted and reported in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR). The completed PRISMA-ScR checklist is provided in Supplementary File 1. An internal review protocol was developed before the searches were run on February 19, 2026. Because the anticipated evidence was heterogeneous in intervention type, implementation context, study design, and outcome definition, a scoping review with narrative synthesis was considered the most appropriate approach.

2.2 Eligibility criteria

Eligible studies evaluated clinical interoperability, health information exchange, or standards-based exchange relevant to nursing practice, medication workflows, or structured documentation. To be included, studies had to report at least 1 extractable nursing-facing evaluative outcome related to medication workflows, structured documentation, documentation quality, semantic completeness, accuracy, timeliness, or closely related operational performance. Closely related operational processes were defined a priori as tasks directly involving nursing execution, such as barcode scanning compliance, workaround frequency, or guardrail adherence during medication administration.

We included peer-reviewed journal articles and conference proceedings published in English from 2021 onward. We excluded editorials, commentaries, reviews, protocols, theses, book chapters, and purely technical or conceptual papers without extractable nursing-facing evaluative outcomes. We also excluded studies focused only on adoption attitudes, awareness, or organizational associations without measurable workflow, documentation, or related operational findings.

2.3 Information sources and search strategy

Searches were conducted in Scopus, MEDLINE via EBSCOhost, CINAHL Ultimate via EBSCOhost, and IEEE Xplore. Initial searches were run in Scopus and MEDLINE on February 20, 2026. Additional searches were run in CINAHL Ultimate on March 4

and March 10, 2026, and in IEEE Xplore on March 9, 2026. The locked review window was 2021-2026. Global search limits were English language and peer-reviewed scholarly records; book chapters were excluded from IEEE Xplore.

The search strategy combined 3 concept blocks: (1) interoperability and standards-based exchange, including terms such as "health information exchange," HIE, interoperability, FHIR, and HL7; (2) nursing, including terms such as nurs*, "registered nurse*," "nursing staff," and "nursing documentation"; and (3) nursing-facing evaluative outcomes, including terms such as documentation, workflow, efficiency, workload, completeness, accuracy, timeliness, duplication, and error. For example, the MEDLINE strategy combined an interoperability/HIE block, a nursing block, and an outcomes block using AND logic. In selected databases, broader sensitivity searches were also run without the outcome block to reduce the risk of missing potentially relevant studies. Full database-specific strategies, execution dates, limits, and count reconciliations are reported in Supplementary File 2.

Because of institutional access constraints, Embase and Web of Science were not searched. This should be considered a review limitation. In addition, the archived package retained the original Scopus and MEDLINE strategies, whereas the CINAHL Ultimate and IEEE Xplore updated-search strategies were reconstructed from the saved protocol, exported result sets, and final screening counts because direct platform search-history exports were not retained. This is also acknowledged as a transparency limitation.

2.4 Selection, data extraction, and methodological appraisal

Two reviewers (Fuad Alhosban and Alaa S. Mushtaha) independently screened titles and abstracts and then assessed full-text reports for final inclusion. Disagreements were resolved through discussion and consensus. Data were extracted using a structured form that captured country, setting, study design, user group, interoperability mechanism, outcome domains, principal findings, and key limitations. Supplementary File 3 and 4 contain the extraction, appraisal, and decision records described in the submission package.

Methodological quality was appraised using the appropriate Joanna Briggs Institute (JBI) critical appraisal tools. JBI quasi-experimental checklists were applied to implementation and before-after studies. For standards-focused and documentation-focused studies, the JBI analytical cross-sectional checklist was used when the study evaluated existing documentation structures without prospectively testing an intervention. Critical appraisal was included to support cautious interpretation of heterogeneous evidence and to distinguish stronger direct evaluative studies from more indirect gap-identifying reports. Because the included studies varied substantially in design, setting, and outcome definition, meta-analysis was not appropriate. Findings were therefore synthesized narratively using SWiM-informed principles, and the synthesis was organized into 3 domains: (1) medication workflows and related operational performance, (2) structured documentation quality and semantic completeness, and (3) documentation- or medication-related safety findings.

3. RESULTS

3.1 Study selection

Initial searches in Scopus and MEDLINE identified 531 records. After removal of 109 duplicates, 422 unique records were screened by title and abstract. Updated searches in CINAHL Ultimate and IEEE Xplore contributed 364 additional unique records after internal and cross-set deduplication against the previously screened set. Across both search phases, 87 full-text reports were assessed for eligibility (6 from the initial search phase and 81 from the updated search phase). Of these, 82 were excluded, leaving 5 studies in the final synthesis. The most common reason for exclusion at the full-text stage was the absence of extractable nursing-facing evaluative outcomes related to medication workflows, structured documentation, or closely related operational performance. No additional studies were added through citation chasing. Full screening counts and exclusion reasons are provided in Supplementary File 2 and 4.

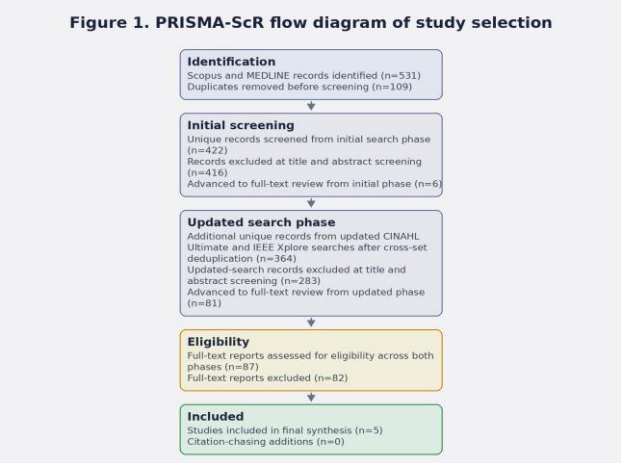

Figure 1. PRISMA-ScR flow diagram of study selection.

3.2 Study characteristics

The 5 included studies formed 2 clear evidence groups that aligned with the review focus. Three studies, all conducted in the United States, evaluated device-to-EHR interoperability in medication-administration workflows. Two studies, conducted in Germany and Finland, evaluated structured documentation or semantic interoperability in nursing data and documentation systems. Overall, the evidence base was small, heterogeneous, and concentrated in a limited number of operational contexts.

The medication-workflow studies were conducted in inpatient or outpatient infusion settings and examined closed-loop or smart pump interoperability linked to the electronic health record. Their designs included a quality-improvement project, an implementation abstract, and a multihospital before-after observational study. Among these, the multihospital before-after study provided the strongest direct evaluative evidence because it reported explicit denominators, comparative preimplementation and postimplementation error rates, and statistical testing. By contrast, the other 2 medication-workflow studies mainly provided implementation or adherence findings and were limited by the absence of full analytic reporting, formal variance estimates, or inferential testing.

The 2 structured-documentation studies did not evaluate direct workflow time or documentation burden. Instead, they examined standards-based representation of nursing quality indicators and the semantic consistency of real-world nursing documentation. One study assessed the availability of nursing quality indicators in German FHIR implementations, and the other reviewed Finnish nursing documentation to evaluate semantic interoperability and documentation structure. These studies were relevant to the review because they addressed nursing-facing documentation quality and semantic completeness, but they provided indirect rather than direct evaluative evidence on operational workflow effects.

Across the full set, reporting quality varied substantially. The evidence was strongest where interoperability changed task execution directly within medication-administration workflows and where outcomes were measured quantitatively. Evidence related to structured documentation was more gap-identifying than effect-estimating, highlighting limitations in data representation, structured-entry consistency, and semantic reuse rather than demonstrating direct reductions in documentation burden or improvements in workflow efficiency.

Table 1. Characteristics of included studies on medication workflows and structured documentation.

Study	Setting / country	Design	Interoperability focus	Main nursing-facing findings
Smith & Savage, 2025 [6]	Inpatient, US	Quality-improvement project	Infusion interoperability workflow for agency nurses	Adherence improved after targeted onboarding, rounding, and local workflow support.
Cappucci, 2022 [7]	Outpatient infusion, US	Implementation abstract	Closed-loop pump interoperability	Reported higher interoperability compliance and fewer workarounds; abstract-level evidence only.
Skog et al, 2022 [8]	3 hospitals, US	Before-after observational study	Smart pump autoprogramming integrated with EHR	Lower total (114.6 to 96.5 per 100 infusions; P=.02), high-risk (12.8 to 6.8; P=.01), and continuous-medication (12.6 to 6.0; P=.005) error rates after implementation.
Netzband et al, 2023 [9]	National standards, Germany	FHIR mapping study	Nursing quality indicators in FHIR	Patient-focused indicators were represented; workforce-related nursing data were limited.
Helenius et al, 2025 [10]	Cardiac services, Finland	Retrospective documentation review	Semantic interoperability of nursing documentation	Structured entries were inconsistent, duplicated, and often semantically incomplete.

Table 2. Synthesis by evidence cluster.

Evidence cluster	Study	Outcome domain	Key finding	Overall direction
Medication-workflow interoperability	Smith & Savage, 2025 [6]	Workflow adherence	Implementation support improved adherence to the local interoperability benchmark.	Favorable but indirect
Medication-workflow interoperability	Cappucci, 2022 [7]	Documentation/process performance	Improved compliance, scanning, and charge-capture processes after closed-loop implementation.	Favorable but abstract-level
Medication-workflow interoperability	Skog et al, 2022 [8]	Medication/process safety	Fewer administration and user-documentation errors after autoprogramming implementation.	Favorable and strongest direct evidence
Structured documentation and semantic interoperability	Netzband et al, 2023 [9]	Data-model coverage	Nursing workforce indicators remained insufficiently represented in current FHIR implementations.	Gap-identifying
Structured documentation and semantic interoperability	Helenius et al, 2025 [10]	Documentation structure	Real-world documentation showed duplication and inconsistent structured coding.	Gap-identifying

3.3 Medication-workflow interoperability

This first group showed the most measurable operational benefits. Smith and Savage [6] investigated agency nurses' use of inpatient infusion interoperability as part of a workflow-improvement initiative. Their baseline review revealed lower adherence among agency staff, driven by poor troubleshooting confidence, short contract lengths, and a lack of alignment with local workflows. Following targeted onboarding, informatics rounding, and enhanced local support, agency nurse adherence met institutional benchmarks. Although exact effect sizes were absent, the study shows that implementation quality and local workflow support drive performance after deployment.

Cappucci [7] reported on outpatient pump interoperability, detailing the integration of the EHR, barcode medication administration, and smart pumps. This abstract noted interoperability compliance rates of 86% at three months and 90% at a later follow-up, alongside fewer reported workarounds and improved scanning compliance. Because it is an abstract without formal denominators, it provides context rather than strong comparative data.

Skog et al. [8] delivered the most rigorous quantitative findings. Observing 350 infusions prior to implementation and 367 afterward across three adult inpatient hospitals, they documented significant safety improvements. Total medication-administration errors dropped from 114.6 to 96.5 per 100 infusions (P=.02). High-risk medication errors fell from 12.8 to 6.8 per 100 infusions (P=.01), and continuous-medication errors decreased from 12.6 to 6.0 per 100 infusions (P=.005). Manual programming accounted for 77.2% of administration and user-documentation errors, compared to just 22.8% using autoprogramming. These results show that directly targeting task execution in closed-loop medication workflows leads to measurable improvements in nursing processes.

3.4 Structured documentation and semantic interoperability

This second group did not report immediate workflow efficiencies, but it remains highly relevant for evaluating nursing data infrastructure. Netzband et al. [9] assessed German FHIR implementations against established nursing quality indicators. They found that while patient-focused metrics were well represented, essential workforce variables—such as workload, experience, turnover, and satisfaction—were either entirely missing or inadequately captured. This indicates that formal interoperability standards still lag in representing the data necessary for nursing workforce analytics.

Helenius et al. [10] reviewed Finnish nursing documentation and observed highly inconsistent use of structured headings. They noted widespread duplication across structured and semistructured fields, frequently lumping multiple distinct interventions under a single heading. These findings show that semantic interoperability depends heavily on daily charting habits and local data-entry behaviors, not just technical design. Across both studies, the primary finding was not time saved, but rather the ongoing maturity gaps in how structured nursing data is modeled and reused.

4. DISCUSSION

4.1 Principal findings

This scoping review identified a small and heterogeneous body of recent nursing-facing evaluative evidence on clinical interoperability in medication workflows and structured documentation. The included studies formed 2 clear evidence groups. The first group, consisting of 3 studies, examined device-to-EHR interoperability in medication-administration settings and provided the most direct operational evidence. The second group, consisting of 2 studies, addressed structured documentation and semantic interoperability and mainly identified limitations in data representation, documentation consistency, and semantic completeness rather than direct workflow effects.

Within the medication-workflow group, the clearest direct evaluative signal was seen when interoperability changed task execution directly at the point of care. In this narrow evidence base, device-to-EHR integration was associated with better workflow adherence, fewer reported workarounds, and lower medication-administration and user-documentation error rates after implementation. However, the strength of this conclusion is uneven across studies. The strongest direct evidence came from 1 multihospital before-after study with explicit denominators, comparative error rates, and statistical testing, whereas the other 2 studies provided more limited implementation or abstract-level evidence.

By contrast, the structured-documentation studies did not demonstrate direct reductions in documentation burden or workflow time. Instead, they showed that important nursing data elements remained incompletely represented in standards-based models and that real-world structured documentation could still be duplicated, inconsistently recorded, or semantically incomplete. These findings indicate that technical and semantic

readiness for interoperable documentation does not by itself establish measurable improvement in frontline nursing work.

Taken together, the main finding of this review is not that clinical interoperability has been broadly shown to improve nursing work, but that recent peer-reviewed nursing-facing evaluative evidence remains limited and concentrated in a small number of operational contexts, particularly medication-administration workflows involving device integration. Within that restricted evidence base, the most defensible conclusion is that interoperability shows its clearest evaluated benefit when it is embedded directly in repetitive medication-use tasks, whereas the available documentation-focused literature remains more gap-identifying than effect-estimating.

4.2 Relation to prior literature

These findings should be interpreted within a broader interoperability literature that is substantially larger than the 5-study evidence base included here. Recent scoping and systematic reviews have synthesized HIE implementation outcomes [12], general EHR interoperability approaches and problems [15], FHIR-enabled service design [18], and FHIR-based data models and structures [19]. Taken together, that broader literature confirms that interoperability remains an active and evolving informatics domain, but it also covers much wider solution spaces and outcome domains than the nursing-facing evaluative lens used in the present review.

The review also aligns with the more specific literature on smart infusion pump interoperability. Borrelli et al [11] concluded that integrated smart pump workflows can reduce medication-administration errors and documentation discrepancies. The current synthesis is consistent with that direction of evidence, as the strongest quantitative findings in our review likewise came from device-to-EHR medication workflow studies, especially the multihospital before-after study that reported lower administration and user-documentation error rates after autoprogramming implementation. At the same time, our review shows that this medication-workflow literature represents only 1 part of the nursing-facing interoperability landscape and currently dominates the limited recent evaluative evidence that met our eligibility criteria.

The structured-documentation subgroup should also be interpreted in relation to broader semantic-interoperability literature. Recent reviews of semantic interoperability in EHRs and of FHIR-related semantic issues have highlighted the central roles of data models, terminologies, and mapping approaches in making exchanged data interpretable and reusable across systems [13,14]. Our review complements that literature by focusing on whether those semantic and standards-related efforts have translated into extractable nursing-facing evaluative findings. Within the studies we included, the available evidence was more gap-identifying than effect-estimating, pointing to incomplete representation of nursing data elements, duplication, and semantically incomplete structured documentation rather than direct reductions in documentation burden.

The broader nursing documentation literature provides additional context. Moore et al [1] showed that health information technology can alter nurses' time allocation, and Park et al [2] linked EHR usability to performance and safety considerations. More recently, Xie et al [17] reviewed the use of Clinical Care Classification terminology across nursing practice, education, research, EHR documentation, and terminology mapping, underscoring the ongoing importance of standardized nursing language for comparable and reusable documentation. Accordingly, the present review does not suggest that interoperability lacks relevance to nursing practice. Rather, it indicates that, within the recent peer-reviewed evidence captured by our review design, direct nursing-facing evaluative evidence remains concentrated in a small number of medication-workflow studies, whereas documentation-focused literature more often identifies structural and semantic gaps than measured operational gains.

4.3 Implications for medical informatics and nursing informatics

The practical implications are straightforward. First, interoperability evaluations must explicitly measure frontline outcomes; technical integration does not automatically equal clinical value. Future studies should prioritize tracking documentation time, charting duplication, interruption rates, structured-field completion, semantic consistency, exception handling, and downstream patient safety.

Second, researchers must separate system capabilities from actual workflow effects. While technical interoperability lays the groundwork for better care, realizing those benefits depends on training, workflow alignment, local support, and consistent user adoption.

Third, the geographic clustering of the evidence highlights a major issue with cross-national transferability. The included US-based studies reflect

a specific healthcare landscape where closed-loop pump integration solves immediate safety and charge-capture issues. The European studies reflect centralized health systems prioritizing national semantic standards. A technical solution proven in one regulatory or billing environment cannot be copied directly into another. Future research must explicitly address how local health system contexts and regulatory frameworks dictate interoperability priorities and outcomes.

4.4 Strengths and limitations

This review has several strengths. It applied a deliberately focused review question to isolate recent nursing-facing evaluative evidence on clinical interoperability in medication workflows and structured documentation, rather than combining interoperability with broader health information technology exposures. Searches were conducted across 4 databases spanning biomedical, nursing, and technical literature, and study selection, full-text assessment, data extraction, and methodological appraisal were performed by 2 reviewers with consensus resolution. The review also used design-appropriate Joanna Briggs Institute appraisal tools and a structured narrative synthesis because the included studies were methodologically and clinically heterogeneous.

The limitations are important and should be considered when interpreting the findings. First, the final evidence base was small, with only 5 included studies, and the included studies were concentrated in a limited number of contexts, particularly device-to-EHR medication workflows. Second, the included evidence was heterogeneous in design, setting, and outcome definition, which precluded meta-analysis and limited the strength of cross-study comparison. Third, the review did not search Embase or Web of Science because of institutional access constraints, so potentially relevant studies may have been missed. Fourth, although the Scopus and MEDLINE strategies were preserved, the updated CINAHL Ultimate and IEEE Xplore strategies were reconstructed from the saved protocol, exported result sets, and final screening counts because direct platform search-history exports were not retained in the archived package. This should be viewed as a transparency limitation.

Additional limitations arise from the included studies themselves. One included report was available only as a peer-reviewed conference abstract, which limited appraisal depth and interpretive confidence. Reporting quality across the included studies was also uneven. Aside from the multihospital before-after study, several studies lacked exact nurse-level denominators, detailed variance estimates, or formal inferential analyses. In the structured-documentation subgroup, the included studies were more informative about data-model and semantic gaps than about direct operational effects such as documentation burden or workflow time. As a result, the review supports cautious conclusions about where recent evaluated evidence exists, but it does not support broad claims that clinical interoperability has already been shown to improve nursing work generally.

Finally, the review protocol was developed internally before the searches began, but it was not prospectively registered in a public registry. This reduces external review-level transparency. Consistent with the scoping-review design and the heterogeneity of the included evidence, the review did not perform meta-analysis, formal certainty assessment, or reporting-bias assessment. These should be understood as methodological constraints of the present review rather than findings about the field itself.

5. CONCLUSIONS

Recent peer-reviewed nursing-facing evaluative evidence on clinical interoperability in medication workflows and structured documentation is limited and heterogeneous. Within the evidence identified in this scoping review, the clearest direct evaluative signal was seen in device-to-EHR medication workflows, where interoperability was associated with improved process adherence and lower medication-administration or user-documentation error rates after implementation. By contrast, the available studies on structured documentation and semantic interoperability mainly identified unresolved gaps in data representation, documentation consistency, and semantic completeness rather than direct reductions in documentation burden or improvements in workflow efficiency.

Accordingly, this review does not support broad claims that clinical interoperability has already been shown to improve nursing work in general. Instead, it shows that the most directly evaluated nursing-facing evidence currently comes from a small number of medication-workflow studies, while documentation-focused evidence remains more gap-identifying than effect-estimating. Future research should prioritize multicenter evaluations that directly measure documentation burden, workflow efficiency, documentation quality, and safety outcomes in real-world nursing practice.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Abbreviations

EHR: electronic health record
FHIR: Fast Healthcare Interoperability Resources
HIE: health information exchange
JBI: Joanna Briggs Institute
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews
SWiM: Synthesis Without Meta-analysis

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