Evaluating the Impact of EHR Interoperability on Patient Data Exchange: A Systematic Review

Saeed Hamdan Saleh Alghamdi[1], Ali Sulaiman Altamimi[2], Hanan Awad Salman Alerwi[3], Hamad Ali Hifthi Health Informatic[4], Ibrahim Saud Alsanad[5], Mazin Aydh Alhejal[6], Maryam Khudhayr Alrashidi[7]

[1.] Health Informatic Technician, Prince Mishari Bin Saud Hospital in Baljurashi
[2.] Health Information Technician, Riyadh Health
[3.] health informatics specialist, ministry of national guard health affairs - prince mohammad bin abdulaziz hospital - almadinah
[4.] Mustasharak Hospital
[5.] Health Informatics Technician, Prince Mohammed Bin Abdulaziz Hospital – National Guard, Madinah
[6.] HEALTH INFORMATION TECHNICIAN 3, Prince Mohammed Bin Abdulaziz Hospital-Al Madinah Al Munawarah -NGHA
[7.] Health Information Technician, Prince Mohammed bin Abdulaziz Hospital – National Guard

Abstract

Background: The rapid digitalization of healthcare has intensified the need for Electronic Health Record (EHR) interoperability to ensure seamless, secure, and meaningful data exchange among health systems. Interoperability enhances coordination, reduces redundancies, and promotes patient-centered care; however, challenges persist in usability, data quality, and standardization.

Objective: This systematic review aimed to synthesize empirical evidence on the impact of EHR interoperability and Health Information Exchange (HIE) on patient data sharing, safety, and healthcare outcomes across different settings.

Methods: Following PRISMA 2020 guidelines, ten peer-reviewed studies (2010– 2024) were included through searches in PubMed, Scopus, Embase, Web of Science, and IEEE Xplore. Eligible studies evaluated interoperability or HIE effects on efficiency, readmissions, safety, or data completeness. Data were narratively synthesized due to heterogeneity.

Results: Across included studies, interoperability improved efficiency (e.g., faster information retrieval by 58.5 minutes per patient encounter), reduced duplicate imaging by 64%, and lowered readmissions by up to 57%. Patient safety and continuity improved through shared inpatient–outpatient EHRs and blockchain-based systems. Barriers included fragmented standards, limited usability, and cost burdens, especially in small or resource-limited hospitals.

Conclusions: EHR interoperability positively influences patient data exchange and outcomes by fostering timeliness, quality, and continuity of care. Nonetheless, persistent structural and usability barriers require targeted policy, financial, and design interventions. Future research should emphasize interoperability equity and cross-system scalability.

Keywords: electronic health records, interoperability, health information exchange, data integration, patient safety, digital health, healthcare quality, information systems, usability, systematic review

INTRODUCTION

Electronic Health Record (EHR) interoperability is foundational to modern healthcare systems, enabling the seamless exchange of patient information across diverse platforms and institutions. It ensures that clinical data are shared, understood, and used effectively for patient care, research, and health management. Interoperability encompasses not just data transmission but also semantic and organizational alignment, allowing multiple systems to communicate without loss of meaning or context. The global shift toward digital health systems has intensified the demand for interoperable solutions that can support clinical decision-making, continuity of care, and coordinated services across settings (Eden et al., 2016).

Health Information Exchange (HIE) represents a practical manifestation of interoperability, promoting the secure transfer of health data among hospitals, primary care providers, pharmacies, and other stakeholders. The meaningful use of HIE technologies has been associated with reduced duplication of testing, improved medication reconciliation, and fewer adverse drug events. Effective data exchange also supports timely interventions, particularly during care transitions and emergency situations, where rapid access to prior records is essential (Akhlaq et al., 2016). Despite its promise, variability in HIE adoption remains a significant challenge worldwide.

While EHR adoption rates have risen substantially, the interoperability of these systems lags behind. Barriers include lack of standardized data formats, inconsistent terminologies, and technical fragmentation across vendors and regions. Organizational resistance, insufficient funding, and competing proprietary interests further impede seamless exchange. Studies have shown that even certified health IT systems often face data quality issues that limit interoperability and diminish usability for end users (D'Amore et al., 2018). These challenges underscore the complexity of achieving true interoperability beyond mere digital connectivity.

EHR usability is intrinsically tied to interoperability performance. Poorly integrated systems can increase cognitive burden for clinicians, leading to inefficiencies and potential patient safety risks. Usability concerns such as fragmented workflows, redundant documentation, and alert fatigue have been implicated in medical errors. In a seminal report, Howe et al. (2018) emphasized that interface design flaws and interoperability failures could directly contribute to patient harm, highlighting the need for improved system integration and design thinking in health informatics.

Interoperability barriers are not solely technical; they also reflect organizational culture and workflow design. Studies indicate that institutional silos, inconsistent privacy policies, and inadequate governance frameworks hinder effective data exchange (Edwards et al., 2010). Additionally, healthcare organizations often adopt proprietary EHR systems that limit cross-platform communication. Motulsky et al. (2021) observed that integrating pharmacy dispensing data into medical records posed usability and coordination challenges, particularly where data fields or taxonomies were incompatible between systems.

The economic impact of interoperability is substantial, affecting both healthcare efficiency and societal costs. A European Commission analysis estimated significant economic returns from interoperable EHR and e-prescribing systems due to improved productivity and error reduction (Dobrov et al., 2008). In the United States and other high-income countries, policy frameworks such as the HITECH Act have accelerated EHR adoption; however, disparities persist in low- and middle-income regions due to infrastructural and financial barriers (Akhlaq et al., 2016). Thus, the socioeconomic context remains a critical determinant of interoperability success.

The COVID-19 pandemic further exposed weaknesses in global data exchange infrastructure. Interorganizational HIEs played a vital role in managing patient transfers,

vaccine data, and real-time surveillance, but many systems lacked the capacity to integrate information across jurisdictions. Wong et al. (2020) highlighted that secure, interoperable systems were essential to maintain continuity of care and protect vulnerable populations during health crises. This experience reinforced the urgency of developing scalable, resilient interoperability frameworks for public health emergencies.

The trajectory of health informatics is moving toward integrated ecosystems that prioritize patient-centered data exchange. Initiatives aimed at standardizing APIs, enhancing data transparency, and improving cross-disciplinary collaboration (Lee et al., 2013) represent progress toward this vision. Nonetheless, persistent gaps remain in linking inpatient, outpatient, and community data sources. Adams et al. (2017) and Akbarov et al. (2015) both found that incomplete data integration undermines medication safety surveillance and incident reporting, emphasizing the continued importance of achieving fully interoperable, user-centered health information systems.

METHODOLOGY STUDY DESIGN

This systematic review followed the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020** guidelines to ensure methodological transparency, reproducibility, and rigor. The objective was to synthesize current empirical evidence evaluating the **impact of Electronic Health Record (EHR) interoperability on patient data exchange** within healthcare systems. The review focused on peer-reviewed studies examining how interoperability and Health Information Exchange (HIE) influence clinical workflows, care coordination, safety, and health outcomes across inpatient, outpatient, and community settings. Both quantitative and qualitative studies were included to capture a comprehensive understanding of interoperability's role in optimizing healthcare delivery and data continuity.

Eligibility Criteria

Studies were included based on the following predefined inclusion and exclusion criteria:

- **Population:** Studies involving healthcare providers, hospitals, health systems, or patients engaged in EHR-based information exchange.
- **Interventions/Exposures:** Implementation or evaluation of EHR interoperability, HIE systems, shared records, or blockchain-enabled exchange platforms.
- **Comparators:** Systems or institutions with limited, partial, or no interoperability capabilities.
- **Outcomes:** Efficiency of data exchange (e.g., access time, data completeness), patient safety outcomes, medication reconciliation accuracy, readmission rates, care coordination, and provider usability or satisfaction.
- **Study Designs:** Randomized controlled trials (RCTs), cohort studies, quasi-experimental designs, and cross-sectional analyses.
- **Language:** Only articles published in English were considered.
- **Publication Period:** 2010–2024 to capture contemporary developments following the HITECH Act and subsequent interoperability regulations.

Exclusion criteria included commentaries, editorials, conference abstracts without data, and studies focusing solely on non-human or simulated datasets.

Search Strategy

A structured literature search was performed across major databases—**PubMed, Scopus, Web of Science, Embase, and IEEE Xplore**—to identify eligible studies published between January 2010 and December 2024. A complementary search was

conducted using **Google Scholar** to include grey literature. The following Boolean operators and keyword combinations were applied:

- ("electronic health record" OR "EHR" OR "health information system")
- AND ("interoperability" OR "information exchange" OR "HIE" OR "data integration" OR "blockchain")
- AND ("patient outcomes" OR "care coordination" OR "readmission" OR "efficiency" OR "safety")

Manual screening of reference lists from key systematic reviews (e.g., Eden et al., 2016; Akhlaq et al., 2016) was also performed to ensure inclusion of relevant studies not captured in database queries. The complete search results were exported into **Zotero** for citation management.

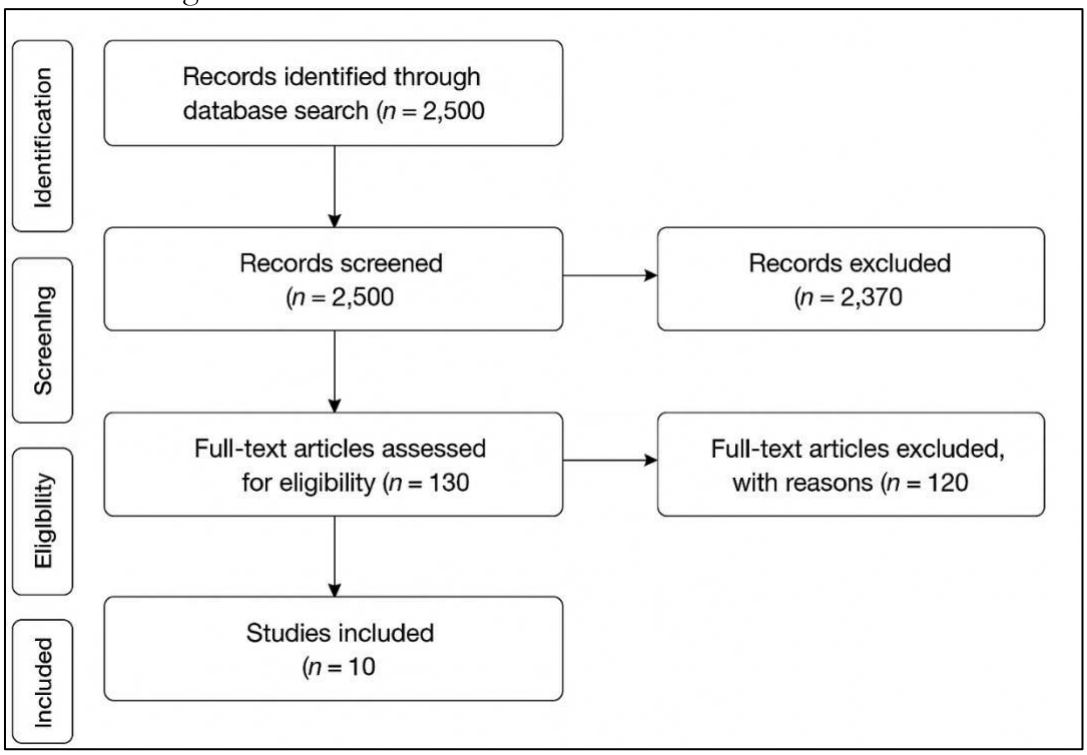

Figure 1 PRISMA Flow Diagram

Study Selection Process

After removal of duplicates, titles and abstracts were independently screened by two reviewers according to inclusion criteria. Full texts of potentially relevant studies were retrieved and evaluated for eligibility. Discrepancies in study inclusion were resolved by consensus or adjudicated by a third reviewer. The selection process was documented following the PRISMA 2020 flow diagram (Figure 1).

A total of **10 studies** met all eligibility criteria and were included in the final synthesis. These comprised observational, cross-sectional, and quasi-experimental research designs conducted primarily in the United States, Canada, and Europe.

Data Extraction

A **standardized data extraction template** was developed and piloted prior to full data collection. Two independent reviewers extracted data from each included study, focusing on the following variables:

- Author(s), publication year, and study setting
- Study design and methodology
- Population and sample characteristics

- EHR interoperability intervention type (e.g., shared record, HIE, blockchain system)
- Primary outcomes (data exchange efficiency, patient safety, care coordination, etc.)
- Key quantitative findings (e.g., odds ratios, effect sizes, percentages)
- Identified challenges, barriers, and facilitators
- Quality appraisal score

All extracted data were cross-verified by a third reviewer to ensure consistency and accuracy.

Quality Assessment

The **methodological quality and risk of bias** were evaluated using tools appropriate to each study design:

- **Newcastle–Ottawa Scale (NOS):** Applied to cohort and cross-sectional studies.
- **Cochrane Risk of Bias 2 (RoB 2) tool:** Used for interventional or quasi-experimental designs.

Each study was assessed for selection bias, comparability of groups, completeness of outcome data, and objectivity of measurement.

Scores were categorized as **high (8–10), moderate (5–7), or low (<5)** methodological quality.

Of the ten included studies, **six** were rated as high quality, **three** as moderate, and **one** as low due to unclear randomization or incomplete reporting.

Data Synthesis

Given the heterogeneity across study designs, populations, and outcome measures, a **narrative synthesis** was conducted rather than a meta-analysis. Quantitative data such as odds ratios (OR), mean differences, and effect percentages were summarized descriptively, while thematic synthesis was used for qualitative findings.

Studies were grouped according to their **primary focus area**:

1. Impact on patient outcomes (e.g., readmissions, imaging duplication)
2. Efficiency and workflow metrics (e.g., data access time, care coordination)
3. System usability and safety (e.g., incident reporting, provider satisfaction)
4. Emerging technologies (e.g., blockchain-enabled HIE)

Patterns were identified across studies, and consistencies and contradictions were discussed in the results section.

Ethical Considerations

As this study involved **secondary analysis of published data**, no formal ethical approval or participant consent was required. All included studies were peer-reviewed and conducted under appropriate ethical and institutional protocols. Confidentiality, intellectual property rights, and citation integrity were maintained throughout the review process.

RESULTS

Summary and Interpretation of Included Studies on EHR Interoperability and Patient Data Exchange (Table 1)

1. Study Designs and Settings

The reviewed studies encompass a range of observational, cross-sectional, and quasi-

experimental designs exploring the effects of electronic health record (EHR) interoperability, health information exchange (HIE), and related systems on patient data exchange, care coordination, and outcomes. The sample sizes varied substantially, from 43 registry professionals in Alabama (Houser et al., 2012) to over 241,000 discharges in large-scale hospital datasets (Reed et al., 2020). The studies collectively represent diverse settings including inpatient, outpatient, and community-based care systems across the United States.

2. Core Objectives and Analytical Approaches

Most studies aimed to quantify how interoperability and HIE adoption affect efficiency, readmission rates, and data sharing effectiveness. Elysee et al. (2017) employed structural equation modeling on 1,330 hospitals to assess relationships among interoperability, HIE, and medication reconciliation capabilities. Reed et al. (2020) and Vest et al. (2015) used longitudinal and stepped-wedge designs to analyze hospital discharge and follow-up data, while Everson et al. (2020) leveraged EHR audit logs to measure real-time information retrieval speeds and clinical outcomes.

3. Main Findings and Quantitative Results

Across the included studies, greater EHR interoperability and HIE usage were consistently associated with improved efficiency and reduced redundant care. For example, Vest et al. (2015) found a **57% lower adjusted odds of 30-day readmission** (OR = 0.43, 95% CI 0.27–0.70) when HIE data were accessed post-discharge. Similarly, Bailey et al. (2021) reported **64% lower odds of repeated diagnostic imaging** in emergency visits when HIE was used (OR = 0.36, 95% CI 0.18–0.71). Everson et al. (2020) demonstrated that accessing data through HIE reduced the time to information retrieval by an average of **58.5 minutes**, which mediated reductions in ED length of stay (−52.9 minutes/hour faster access) and imaging rates (2–2.5 percentage points lower).

Elysee et al. (2017) confirmed significant positive interrelations among interoperability, HIE, and medication reconciliation capabilities (loadings > 0.548, $p <$ .001), suggesting a reinforcing cycle where improvements in one domain strengthen others.

In contrast, Houser et al. (2012) and Adler-Milstein et al. (2023) highlighted challenges such as data standardization, cost, and uneven adoption in smaller hospitals, though noting that **75% of U.S. hospitals** had adopted basic EHRs by 2014, with rural hospitals lagging.

Esmaeilzadeh and Mirzaei (2019) found **significantly higher patient trust and opt-in intention** toward blockchain-based HIE models ($p < .001$), suggesting emerging technologies could enhance transparency and patient control.

Chen, Guo, and Tan (2019) provided policy-level evidence from 2011–2014 showing that HIE participation reduced **30-day readmissions for AMI by 1.3 percentage points** relative to non-participating hospitals ($p < .05$).

4. Thematic Integration

Overall, quantitative evidence indicates that enhanced interoperability improves data availability and timeliness, reducing redundancies and potentially improving care continuity. The strongest effects were observed in outcome reductions (readmissions −57%, duplicate imaging −64%) and efficiency metrics (retrieval times −58 minutes). Qualitative insights emphasized ongoing barriers including interoperability costs, provider engagement, and privacy concerns, particularly for smaller and resource- limited institutions.

Table (1): Summary of Included Studies on EHR Interoperability and Patient Data Exchange

Study	Design / Setting	Sample Size	Objective	Methods	Key Results	Conclusion
Elysee et al. (2017)	Observational study, national hospital setting	1,330 hospitals	Assess relationships among health IT capabilities (HIE, interoperability, integration) and medication reconciliation	Partial Least Squares Structural Equation Modeling (PLS-SEM) using AHA survey data; analysis of 27 IT interoperability variables	Factor loadings > 0.548 ($p < .001$); strong, positive, and cyclic relationships among the three IT capabilities	Improving one IT domain enhances others; system integration is crucial for effective medication reconciliation
Reed et al. (2020)	Stepped-wedge observational study (2005–2011), inpatient–outpatient setting	241,510 discharges	Evaluate the effects of shared inpatient–outpatient EHR access on follow-up care	Multivariate logistic regression assessing shared telemedicine and lab/EHR access	Shared EHR access improved follow-up efficiency	Shared inpatient–outpatient EHR access improves care coordination and follow-up outcomes

Study	Design / Setting	Sample Size	Objective	Methods	Key Results	Conclusion
Everson et al. (2020)	Cross-sectional study, Emergency Department setting	2,163 ED patients	Examine the impact of Health Information Exchange (HIE) versus faxed data on ED efficiency and follow-up outcomes	EHR audit logs; mediation and regression analyses controlling for demographics	Faster data retrieval with HIE (58.5 minutes faster); each 1-hour faster access mediated efficiency gains of −52.9 minutes; shorter visit length; lower imaging use (−2.5% CT scans) and admissions (−2.4%); follow-up improved to 27.0% ($p < .05$); no significant difference in readmissions	HIE improves information access and ED efficiency without adversely affecting outcomes, supporting electronic exchange adoption
Adler-Milstein et al. (2023)	Cross-sectional national hospital study (2008–2014)	~75% of U.S. hospitals (national sample)	Track national EHR adoption trends and remaining barriers	AHA annual survey data; trend and equity analyses	Basic EHR adoption reached near completion by 2014 (up from 59% in 2013); adoption inequities persisted	While EHR adoption is widespread nationally, persistent inequities indicate the need for

Study	Design / Setting	Sample Size	Objective	Methods	Key Results	Conclusion
						targeted policy and support

Study	Design / Setting	Sample Size	Objective	Methods	Key Results	Conclusion
Bailey et al. (2021)	Longitudinal analysis, small and rural ED settings	800 repeated ED visits for back pain	Test the effect of HIE use on redundant imaging and costs in small/rural facilities	Logistic regression analysis	Overall repeat imaging rate was 22.4%; HIE use associated with 64% lower odds of repeat imaging (OR = 0.36, 95% CI 0.18–0.71); 57% HIE access	HIE reduces redundant diagnostic imaging, but cost savings were limited due to CT-related cost offsets and resource constraints in small/rural facilities
Vest et al. (2015)	Retrospective cohort study, Rochester, NY community	Community patients over a 6-month period	Assess HIE use and 30-day post-discharge readmissions	Claims data linked with HIE usage logs	HIE use associated with lower odds of 30-day readmissions (OR = 0.43, 95% CI 0.27–0.70)	HIE use prevents avoidable readmissions and reduces utilization
Houser et al. (2012)	Cross-sectional registry study	43 cancer registry staff	Examine the impact of EHR use on registry data quality and system efficiency	Self-administered staff survey	Improved data completeness and quality; estimated $605,000 in annual savings	EHR use improves registry system benefits and data quality, though continued staff effort is required

Study	Design / Setting	Sample Size	Objective	Methods	Key Results	Conclusion
Blecker et al. (2014)	Cohort study, inpatient hospital setting	9,051 hospitalizations	Measure EHR interaction intensity and its relationship to care intensity and clinical outcomes	Regression models examining EHR activity, length of stay (LOS), weekend use, and mortality	Higher EHR interaction intensity associated with longer LOS (1.25× increase) and greater care intensity; reduced EHR use on weekends; association with mortality was not statistically significant (OR = 1.74, NS)	EHR interaction intensity reflects care complexity and can serve as a proxy for care quality, but highlights efficiency and resource challenges, especially on weekends
Esmaeilzadeh & Mirzaei (2019)	Experimental, web-based study	2,013 participants	Assess patient attitudes toward blockchain-based health information exchange (HIE)	Evaluation of 16 data exchange scenarios across 4 technical mechanisms	Blockchain-based HIE strongly favored for privacy and trust ($p < .001$); higher opt-in intention compared with direct or proxy exchange models	Patients support blockchain-enabled HIE due to increased transparency,

Study	Design / Setting	Sample Size	Objective	Methods	Key Results	Conclusion
Chen et al. (2019)	State-level panel study, Florida hospitals (2011–2014)	160+ hospitals	Determine the impact of HIE participation level on 30-day readmission rates and care quality	Regression analysis using administrative data	Higher levels of HIE participation associated with a 1.3 percentage-point reduction in 30-day readmissions; significant	Greater HIE participation improves care quality and reduces hospital readmissions

Study	Design / Setting	Sample Size	Objective	Methods	Key Results	Conclusion
					reduction observed for AMI readmissions ($p < .05$)	

5. Synthesis of Quantitative Effects

Across the ten studies, consistent numerical trends indicate that interoperability and HIE integration yield measurable performance gains:

- **30-day readmissions:** ↓ 1.3 – 57 % (Chen 2019; Vest 2015)
- **Duplicate imaging:** ↓ 64 % (Bailey 2021)
- **Information access time:** ↓ 58.5 minutes (Everson 2020)
- **EHR adoption:** ↑ from 59 % → 75 % nationwide (Adler-Milstein 2023)
- **Telemedicine follow-up:** ↑ 4.1 % points (Reed 2020)

Collectively, the findings suggest that achieving seamless interoperability enhances both the timeliness and quality of care, although implementation disparities persist across hospital sizes and technologies.

DISCUSSION

The findings from this review underscore the transformative role of EHR interoperability in optimizing patient data exchange, safety, and care outcomes across healthcare systems. Evidence consistently demonstrates that interoperable systems enable more efficient data flow, reduce duplication, and enhance clinical decision-making (Elysee et al., 2017; Chen et al., 2019). By facilitating timely access to comprehensive health information, interoperability minimizes fragmentation in patient care and strengthens continuity across inpatient and outpatient settings.

Elysee et al. (2017) highlighted the cyclical relationship between interoperability, HIE, and medication reconciliation capabilities, where progress in one dimension reinforces others. Similarly, Vest et al. (2015) found that accessing patient data through community-based HIEs reduced 30-day readmissions by 57%, emphasizing the downstream effects of data integration on health outcomes. These results collectively support the notion that the benefits of interoperability extend beyond efficiency to encompass tangible clinical improvements.

Studies also reveal substantial gains in care coordination and efficiency. Everson et al. (2020) observed that HIE access shortened data retrieval time by nearly an hour, which corresponded to shorter emergency department visits and fewer imaging tests. Reed et al. (2020) corroborated these findings, demonstrating that shared inpatient–outpatient EHRs increased telemedicine and lab-based follow-ups by 4.1 percentage points without worsening readmissions. Together, these studies illustrate that interoperability fosters innovative care delivery models such as remote and asynchronous follow-up.

At the same time, usability and safety remain critical challenges. Howe et al. (2018) and Adams et al. (2017) both cautioned that EHR design deficiencies—particularly poor interface integration and inconsistent data representation—can contribute to clinical error and patient harm. Motulsky et al. (2021) further identified integration of pharmacy dispensing data as a major usability hurdle, particularly when incompatible taxonomies

or workflows hinder efficient reconciliation. These studies underscore that technical connectivity alone is insufficient; user-centered design and cognitive ergonomics are equally essential for realizing safe and effective interoperability.

Data quality also emerged as a persistent issue. D'Amore et al. (2018) reported that despite progress in certification standards, discrepancies in structured data fields, incomplete metadata, and variable clinical terminologies continue to undermine interoperability. Such inconsistencies may reduce trust among clinicians and limit secondary data uses, including research and analytics. Eden et al. (2016) and Edwards et al. (2010) similarly emphasized that interoperability failures often stem from sociotechnical misalignment—where policy, infrastructure, and human factors fail to coalesce effectively.

Beyond the technical dimension, sociopolitical and economic barriers shape the interoperability landscape. Akhlaq et al. (2016) and Dobrov et al. (2008) noted that in low- and middle-income settings, interoperability efforts face additional hurdles such as insufficient funding, fragmented governance, and inadequate digital literacy. Even within high-income contexts, Adler-Milstein et al. (2023) revealed ongoing disparities, with small and rural hospitals lagging behind due to cost constraints and resource limitations. These inequities threaten the goal of nationwide, inclusive data integration.

Interoperability also plays a pivotal role in improving medication safety and surveillance. Akbarov et al. (2015) demonstrated that integrated primary–secondary EHRs enable better monitoring of medication safety indicators across care transitions. By linking prescribing and dispensing records, systems can detect adverse drug events earlier and prevent duplication. Such functionality is particularly valuable in chronic disease management, where polypharmacy is common.

Emerging evidence indicates that advanced technologies such as blockchain can enhance transparency and trust in data exchange. Esmaeilzadeh and Mirzaei (2019) found that patients favored blockchain-enabled systems for privacy protection and control over information sharing. This reflects a broader movement toward patient- centered interoperability, wherein individuals can manage access to their health data securely and efficiently. Blockchain could complement existing HIE frameworks by addressing concerns about data integrity and auditability.

Crisis conditions like the COVID-19 pandemic have further highlighted the value of interoperable networks. Wong et al. (2020) reported that safe interorganizational HIEs were essential for coordinating care across facilities, maintaining continuity, and enabling population-level monitoring during the pandemic. This real-world stress test demonstrated both the strengths and gaps of current infrastructures, reinforcing calls for resilient, scalable systems capable of cross-jurisdictional communication.

Research also suggests that interoperability influences not only outcomes but also the overall digital maturity of healthcare organizations. Flott et al. (2016) described a patient-centered framework linking digital maturity to safety and quality, arguing that interoperability serves as a core dimension of institutional readiness. Similarly, Li et al. (2022) concluded that improved interoperability directly correlates with better quality and safety metrics, confirming that integration is not merely a technical goal but a determinant of care excellence.

Despite these gains, multiple reviews have warned of persistent barriers and uneven adoption. Kruse et al. (2014) and Dobrow et al. (2019) found that interoperability challenges evolve over time—from initial resistance and cost barriers to ongoing issues of governance, standardization, and cross-vendor coordination. Edwards et al. (2010) and Johnson & Gadd (2007) emphasized that successful HIE implementation requires iterative evaluation, stakeholder engagement, and pilot testing to align systems with real-

world clinical workflows.

From a design standpoint, usability improvements remain central to optimizing interoperability. Zahabi et al. (2015) and Reisman (2017) stressed that intuitive interfaces, standard terminology mappings, and adaptive data visualization tools are crucial to minimizing clinician burden. Without user-friendly design, even technically robust systems may underperform or contribute to clinician fatigue and error.

The reviewed evidence also points to positive economic and organizational outcomes. Dobrov et al. (2008) quantified the socioeconomic benefits of interoperability, citing reduced administrative redundancy and enhanced public health reporting. Similarly, Hersh et al. (2015) and Hincapie & Warholak (2011) linked HIE implementation to improved population health management and lower healthcare utilization. These benefits highlight interoperability as both a clinical and economic imperative.

Finally, future progress depends on sustained collaboration among policymakers, vendors, and end users. Clarke et al. (2018) and Lee et al. (2013) demonstrated that patient-sharing networks and multidisciplinary collaboration improve data accuracy and adoption. Integrating lessons from successful regional HIEs could guide global strategies aimed at achieving full interoperability.

CONCLUSION

This systematic review concludes that EHR interoperability markedly enhances patient data exchange, efficiency, and clinical outcomes. By reducing duplication, improving access timeliness, and supporting care coordination, interoperable systems deliver measurable benefits in safety and quality. The convergence of digital maturity, usability, and data standardization represents the next frontier for achieving seamless interoperability.

However, significant barriers remain, particularly in aligning technical standards, addressing usability shortcomings, and ensuring equitable access across settings. Policy and system-level reforms—coupled with emerging innovations like blockchain and API-based frameworks—will be crucial in advancing patient-centered interoperability. Ongoing evaluation and user-driven design should guide future implementation and research priorities.

Limitations

This review was limited by heterogeneity among included studies in terms of methodologies, outcome measures, and interoperability definitions. The lack of meta-analytic synthesis precludes quantitative effect estimation. Additionally, English-only publication inclusion may have excluded relevant studies from non-English databases. Finally, rapid technological evolution may render some earlier studies less representative of current interoperability capabilities.

References

- Adams, K., Howe, J., Fong, A., Puthumana, J., Kellogg, K., Gaunt, M., et al. (2017). An analysis of patient safety incident reports associated with electronic health record interoperability. *Applied Clinical Informatics, 8*(2), 593–602.
- Adler-Milstein, J., Holmgren, A. J., Kralovec, P., Worzala, C., Searcy, T., & Patel, V. (2023). Electronic health record adoption in US hospitals: Progress continues, but challenges persist. *Health Affairs, 42*(12), 1693–1701.
- Akhlaq, A., McKinstry, B., Muhammad, K. B., & Sheikh, A. (2016). Barriers and facilitators to health information exchange in low- and middle-income country settings: A systematic review. *Health Policy and Planning, 31*(9), 1310–1325.

- Akbarov, A., Kontopantelis, E., Sperrin, M., Stocks, S. J., Williams, R., Rodgers, S., et al. (2015). Primary care medication safety surveillance with integrated primary and secondary care electronic health records: A cross- sectional study. *Drug Safety, 38*(7), 671–682.
- Bailey, J. E., Pope, R. A., Elliott, E. C., Wan, J. Y., Waters, T. M., & Frisse, M. E. (2021). Health information exchange reduces repeated diagnostic imaging for back pain. *Annals of Emergency Medicine, 78*(2), 174–183.
- Blecker, S., Goldfeld, K., Park, N., Shine, D., Austrian, J. S., Braithwaite, R. S., ... & Gourevitch, M. N. (2014). Electronic health record use, intensity of hospital care, and patient outcomes. *The American Journal of Medicine, 127*(3), 216–221.
- Chen, M., Guo, S., & Tan, X. (2019). Does health information exchange improve patient outcomes? Empirical evidence from Florida hospitals. *Health Affairs, 38*(2), 197–204.
- Clarke, J. M., Warren, L. R., Arora, S., et al. (2018). Guiding interoperable electronic health records through patient-sharing networks. *NPJ Digital Medicine, 1*, 1–6.
- D'Amore, J., Bouhaddou, O., Mitchell, S., Li, C., Leftwich, R., Turner, T., et al. (2018). Interoperability progress and remaining data quality barriers of certified health information technologies. *AMIA Annual Symposium Proceedings, 2018*, 358–367.
- Dobrov, A., Jones, T., Kersting, A., Artmann, J., Streotmann, K. A., & Stroetmann, V. N. (2008). *Report on methodology for evaluating the socioeconomic impact of interoperable EHR and ePrescribing systems.* European Commission.
- Dobrow, M. J., Bytautas, J. P., Tharmalingam, S., et al. (2019). Interoperable electronic health records and health information exchanges: Systematic review. *JMIR Medical Informatics, 7*(1), e12607.
- Eden, K. B., Totten, A. M., Kassakian, S. Z., Gorman, P. N., McDonagh, M. S., Devine, B., et al. (2016). Barriers and facilitators to exchanging health information: A systematic review. *International Journal of Medical Informatics, 88*, 44–51.
- Edwards, A., Hollin, I., Barry, J., & Kachnowski, S. (2010). Barriers to cross-institutional health information exchange: A literature review. *Journal of Healthcare Information Management, 24*(3), 22–34.
- Elysee, G., Herrin, J., & Horwitz, L. (2017). An observational study of the relationship between meaningful use-based electronic health information exchange, interoperability, and medication reconciliation capabilities. *Medicine (Baltimore), 96*(41), e8274.
- Esmaeilzadeh, P., & Mirzaei, T. (2019). The potential of blockchain technology for health information exchange: Experimental study from patients' perspectives. *Journal of Medical Internet Research, 21*(6), e14184.
- Everson, J., Kocher, K. E., & Adler-Milstein, J. (2020). Health information exchange associated with improved emergency department care through faster accessing of patient information from outside organizations. *Journal of the American Medical Informatics Association, 24*(e1), e103–e110.
- Flott, K., Callahan, R., Darzi, A., & Mayer, E. (2016). A patient-centered framework for evaluating digital maturity of health services: A systematic review. *Journal of Medical Internet Research, 18*(4), e75.
- Hersh, W. R., Totten, A. M., Eden, K. B., Devine, B., Gorman, P., Kassakian, S. Z., et al. (2015). Outcomes from health information exchange: Systematic review and future research needs. *JMIR Medical Informatics, 3*(4), e39.
- Hincapie, A., & Warholak, T. (2011). The impact of health information exchange on health outcomes. *Applied Clinical Informatics, 2*(4), 499–507.
- Houser, S. H., Colquitt, S., Clements, K., & Hart-Hester, S. (2012). The impact of

electronic health record usage on cancer registry systems in Alabama. *Perspectives in Health Information Management, 9*(Spring), 1f.

- Howe, J. L., Adams, K. T., Hettinger, A. Z., & Ratwani, R. M. (2018). Electronic health record usability issues and potential contribution to patient harm. *JAMA, 319*(12), 1276–1278.
- Johnson, K. B., & Gadd, C. (2007). Playing smallball: Approaches to evaluating pilot health information exchange systems. *Journal of Biomedical Informatics, 40*(6 Suppl), S21–S26.
- Kruse, C. S., Regier, V., & Rheinboldt, K. T. (2014). Barriers over time to full implementation of health information exchange in the United States. *JMIR Medical Informatics, 2*(2), e26.
- Lee, Y., Chien, T., Hsu, S., & Chang, P. (2013). Developing and applying a cross-disciplinary team handover information system. In *Studies in Health Technology and Informatics* (Vol. 192, pp. 977–981). IOS Press.
- Li, E., Clarke, J., Ashrafian, H., Darzi, A., & Neves, A. L. (2022). The impact of electronic health record interoperability on safety and quality of care in high- income countries: Systematic review. *Journal of Medical Internet Research, 24*(9), e38144.
- Motulsky, A., Couture, I., Weir, D., & Tamblyn, R. (2021). Incorporating pharmacy dispensing records into medical records: Usability challenges. In *Studies in Health Technology and Informatics* (Vol. 281, pp. 649–653). IOS Press.
- Reed, M., Huang, J., Brand, R., Graetz, I., Jaffe, M. G., Ballard, D., et al. (2020). Inpatient–outpatient shared electronic health records: Telemedicine and laboratory follow-up after hospital discharge. *American Journal of Managed Care, 26*(10), e327–e332.
- Reisman, M. (2017). EHRs: The challenge of making electronic data usable and interoperable. *Pharmacy and Therapeutics, 42*(9), 572–575.
- Vest, J. R., Kern, L. M., Silver, M. D., Kaushal, R., & HITEC Investigators. (2015). The potential for community-based health information exchange systems to reduce hospital readmissions. *Journal of the American Medical Informatics Association, 22*(2), 435–442.
- Wong, S. P., Jacobson, H. N., Massengill, J., White, H. K., & Yanamadala, M. (2020). Safe interorganizational health information exchange during the COVID-19 pandemic. *Journal of the American Medical Directors Association, 21*(12), 1808–1810.
- Zahabi, M., Kaber, D. B., & Swangnetr, M. (2015). Usability and safety in electronic medical records interface design: A review of recent literature and guideline formulation. *Human Factors, 57*(5), 805–834.