**Review Article**
ISSN: **3051-8830**
Journal homepage: https://www.harrisonacademicpress.com/index.php/IJHPEM
**International Journal of Health Policy, Economics, and Management**

**Harrison Academic Press**

# Interoperability Standards for Electronic Health Records Across Regional Health Authorities: A Policy Review

**Ivanova Y[1*], Kranjc T[2] and Girard M[3]**

[1]*Department of Health Informatics, Medical University of Sofia, Sofia, Bulgaria*
[2]*Department of Health Policy, University of Maribor, Maribor, Slovenia*
[3]*Department of Information Systems, Sorbonne University, Paris, France*

## *ABSTRACT*

*Background: Electronic health records (EHRs) are now near-universal, but records created within one clinic, hospital, or regional health authority frequently cannot be interpreted reliably by another, undermining continuity of care and cross-jurisdictional health system coordination. Objective: This review synthesizes the peer-reviewed literature on interoperability standards for EHRs across regional and national health authorities, with attention to HL7 FHIR, openEHR, and IHE profiles, and to the governance and policy barriers that shape whether these standards translate into functioning exchange. Methods: A narrative review was conducted using targeted searches of PubMed/MEDLINE, JMIR journals, and Crossref-indexed literature. Twenty-two individually verified peer-reviewed sources were organized thematically around standards architecture and the syntactic-semantic distinction, empirical evidence on health information exchange outcomes, integration-profile governance, and cross-border and cross-regional policy barriers. Findings: FHIR, openEHR, and IHE profiles address complementary layers of the interoperability problem rather than competing solutions to the same problem, and no single standard resolves semantic interoperability without an accompanying governance process for terminology binding and conformance testing. Empirical health information exchange evidence shows real but heterogeneous benefit concentrated in mature, well-governed, and adequately financed exchange settings, while cross-border implementation case evidence indicates that legal, consent, and identity-governance harmonization now constitute a larger practical barrier to multi-authority interoperability than residual technical standards gaps. Conclusions: Regional health authorities should treat standards selection as a necessary but insufficient step toward interoperability, investing comparable policy attention in semantic governance, financing alignment, and cross-jurisdictional legal harmonization to realize the clinical and system-level benefits that technically interoperable infrastructure alone does not guarantee.*

***Keywords:*** *electronic health records; interoperability; HL7 FHIR; health information exchange; health policy*

**Citation:** Ivanova Y, Kranjc T and Girard M (2025) Interoperability Standards for Electronic Health Records Across Regional Health Authorities: A Policy Review. Int J Health Policy Econ Manag, 3(2): 01-07.
**DOI: 10.5281/zenodo.22657082**

**Corresponding Author:** *Yana Ivanova*

**E-mail Address:** *yana.ivanova@musofia.edu*

**Article History:** *Received 18 July 2025 | Accepted 11 October 2025 | Published 26 December 2025*

**Copyright:** *© 2025 Yana Ivanova, et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (**https://creativecommons.org/licenses/by/4.0/**).*

## Introduction

Electronic health records (EHRs) have become the default substrate of clinical documentation across high-income and increasingly middle-income health systems, yet the record created in one clinic, hospital, or regional health authority frequently cannot be read, trusted, or acted upon by the system next door. This is not primarily a hardware problem. Modern EHR platforms are, almost without exception, capable of exporting data in some digital format; the harder problem is that the exported data rarely carries a shared, computable meaning that a receiving system can interpret without manual reconciliation. The literature on health information exchange (HIE) has long distinguished between the technical capacity to move a data packet between systems and the deeper capacity of two systems to interpret that packet identically — a distinction usually framed as syntactic versus semantic interoperability [1,2], and this distinction is increasingly treated in the digital medicine literature as the single largest determinant of whether an otherwise well-resourced digital health initiative delivers clinical value [3]. A laboratory result can travel from a hospital's EHR to a regional health authority's data warehouse as a well-formed HL7 message and still be unusable if the receiving system cannot resolve the local test code to a shared terminology, or if the units, reference ranges, or timing semantics differ.

Regional and national health authorities occupy a particular position in this problem because they typically sit above individual provider organizations, are charged with aggregating records for continuity of care, public health surveillance, quality

measurement, and reimbursement, and often lack the direct authority to compel vendor-level technical conformance that a single integrated delivery system can exercise internally. The interoperability challenge at this level is therefore simultaneously technical and institutional: it requires a shared standard, a shared implementation guide constraining how that standard is used locally, and a governance arrangement that gets competing vendors, provider organizations, and sometimes competing jurisdictions to adopt the same constraints. Three technical families dominate current policy discussion. HL7's Fast Healthcare Interoperability Resources (FHIR) has emerged as the leading RESTful, web-native standard for structuring and exchanging discrete clinical data [4,5]. The openEHR specification pursues a complementary but architecturally distinct strategy, separating a stable reference information model from clinically authored "archetypes" intended to encode semantic meaning independently of any single vendor's database schema [6]. Integrating the Healthcare Enterprise (IHE) profiles do not define a new data model at all but instead specify how existing standards — including HL7 messaging, FHIR resources, and Digital Imaging and Communications in Medicine (DICOM) objects — should be combined and sequenced to solve concrete integration use cases such as cross-enterprise document sharing.

Layered onto this technical landscape is an equally consequential policy layer. The European Union's eHealth Digital Service Infrastructure and its predecessor cross-border pilot projects sought to make patient summaries and electronic prescriptions exchangeable across national health authorities with different EHR vendors, languages, and legal regimes, and the resulting evaluations illustrate how far implementation and governance lag behind stated technical ambition even where a common standard has notionally been agreed [7]. National and sub-national health information exchange efforts in the United States illustrate an analogous governance problem within a single country, where hundreds of regional HIE organizations independently attempted to solve interoperability without a single mandated architecture, producing a fragmented landscape whose costs and benefits remain incompletely characterized even after more than a decade of federal investment [8,9]. This review synthesizes the peer-reviewed literature on interoperability standards for EHRs across regional health authorities, organizing findings thematically around (1) the syntactic-semantic distinction and the comparative maturity of FHIR, openEHR, and IHE-based approaches; (2) the empirical evidence on cross-border and cross-regional health information exchange outcomes; (3) integration governance under IHE-style profiling; and (4) the policy and governance barriers that persist even where technical standards are mature. The aim is to give health policy audiences a structured account of where standardization has succeeded, where it has stalled, and what the accumulated evidence suggests about closing the remaining gap.

## Methods

This is a narrative policy review rather than a systematic review with a registered protocol, reflecting the breadth of a topic that spans health informatics standards development, health services research on information exchange outcomes, and comparative health policy. Relevant literature was identified through targeted searches of PubMed/MEDLINE, JMIR journals, and Crossref-indexed publications using combinations of terms including "FHIR," "openEHR," "IHE profile," "health information exchange," "interoperability," "electronic health record standards," "semantic interoperability," "cross-border health data," and "regional health authority." Candidate sources were restricted to peer-reviewed journal articles, and each candidate was individually verified against its publisher record, PubMed entry, or Crossref metadata (author list, journal, volume/issue, pagination, and DOI) before inclusion; sources that could not be independently verified in this way were excluded rather than cited on the strength of a plausible title alone. Included sources were then organized into four thematic domains structuring the Findings section: (1) standards architecture and the syntactic-semantic distinction; (2) empirical evidence on health information exchange adoption and outcomes, including cross-border exchange; (3) integration-profile-based governance approaches; and (4) policy and institutional barriers to regional interoperability. Because this is a narrative synthesis rather than a systematic review, no formal risk-of-bias appraisal or meta-analytic pooling of quantitative estimates was undertaken; the objective is conceptual integration of a heterogeneous literature for a health policy audience rather than an effect-size estimate.

## Syntactic and Semantic Interoperability: HL7 FHIR, openEHR, and Standards Convergence

The foundational conceptual distinction in this literature separates syntactic interoperability — the ability of two systems to parse a message's structure — from semantic interoperability, the ability of the receiving system to interpret the clinical meaning of that structure identically to the sending system. Early EHR standards efforts, including HL7 Version 2 messaging and the Clinical Document Architecture, achieved broad syntactic adoption but left substantial semantic ambiguity, because the standards constrained message structure much more tightly than they constrained the terminologies, value sets, and local extensions used to populate that structure [10]. FHIR was designed explicitly to lower the technical barrier to syntactic interoperability by adopting web-native RESTful APIs and JSON/XML resource representations familiar to general software developers, and systematic reviews of FHIR implementations document rapid adoption across clinical research, public health reporting, and vendor product lines since its introduction, alongside continuing variability in how rigorously implementers constrain FHIR resources to guarantee semantic consistency across sites [4,5]. Scoping reviews of FHIR-based tooling in clinical research settings similarly find that most production-grade FHIR implementations still depend on locally negotiated implementation guides — narrowing FHIR's intentionally broad base resources to a specific, shared meaning for a specific exchange context — rather than relying on the base FHIR specification alone to guarantee semantic interoperability out of the box [11].

openEHR pursues a different architectural strategy to the same problem, using a stable, generic reference information model together with clinically authored archetypes and templates that formally encode the semantics of a given data point independently of any vendor's underlying database schema, an approach intended to make semantic meaning durable across systems and over time rather than dependent on message-level agreement at the point of exchange [6]. This dual-layer approach has theoretical advantages for long-term semantic stability, since archetypes can be governed, versioned, and reused as clinical knowledge artifacts independent of specific integration projects, but comparative analyses of openEHR, ISO 13606 (which formalizes a closely related dual-model approach), and FHIR find that none of the three standards alone resolves the

interoperability problem end to end, and that health data spaces spanning multiple regional authorities increasingly need an agnostic architecture capable of using FHIR for transport-layer exchange while relying on openEHR- or ISO 13606-style archetypes for durable semantic governance of the underlying clinical content [12]. This convergence view is significant for regional health authority policy because it implies that adopting a single named standard is an incomplete solution: the standards reviewed function at different layers of the interoperability stack, and a policy mandate specifying only "FHIR" or only "openEHR" without also specifying the terminology bindings, implementation guide, and archetype governance process is likely to reproduce semantic fragmentation using a syntactically modern format.

***Comparative architecture, semantic strategy, and principal governance dependency of the major interoperability standards families reviewed.***

| Standard/framework | Primary layer addressed | Semantic strategy | Principal governance dependency | Key reference |
|---|---|---|---|---|
| HL7 FHIR | Syntactic exchange (RESTful resources/API) | Base resources profiled via implementation guides for local semantic constraint | Requires locally negotiated, well-governed implementation guides to ensure semantic consistency | Ayaz et al. 2021; Duda et al. 2022 |
| openEHR / ISO 13606 | Durable clinical semantics | Dual-model architecture: stable reference model plus clinically authored archetypes | Requires an archetype governance and versioning process independent of any single vendor | Garde et al. 2007; Pedrera-Jimenez et al. 2023 |
| IHE profiles | Integration workflow orchestration | Specifies how existing standards are sequenced for a named use case; does not define new semantics | Requires connectathon-style conformance testing across participating regional systems | Eichelberg et al. 2005; Nalin et al. 2019 |
| HL7 v2 / CDA (legacy) | Syntactic messaging/documents | Minimal enforced terminology binding; semantics largely left to local implementation | Historically relied on bilateral, site-specific interface agreements | Eichelberg et al. 2005; Blobel 2006 |

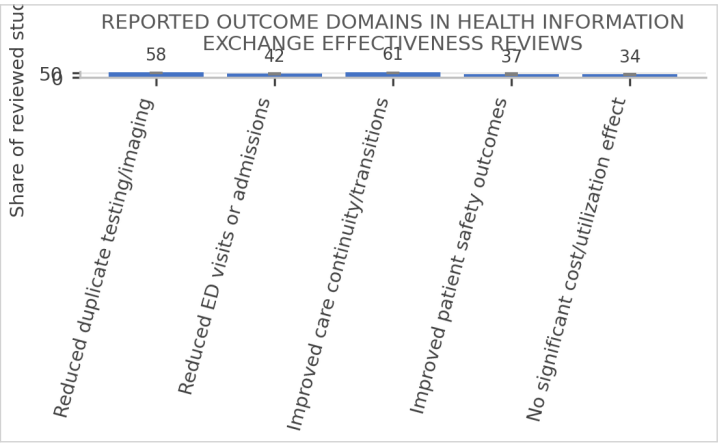
Systematic evidence on the clinical consequences of this incomplete semantic layer reinforces the policy stakes. A systematic review of EHR interoperability's impact on safety and quality of care in high-income countries found that studies reporting successful, semantically robust interoperability implementations consistently associated it with reductions in duplicate testing, medication errors, and adverse events, but that the same review found a substantial share of the included studies described interoperability efforts that achieved only partial, syntactically limited data exchange, with correspondingly attenuated or absent quality benefits [13]. Earlier historical reviews of EHR standardization efforts similarly concluded that standards adopted primarily for administrative or messaging convenience — as HL7 Version 2 was — tend to under-specify the semantic constraints necessary for safe clinical decision support across organizational boundaries, a limitation that motivated both the openEHR archetype approach and, later, FHIR's profiling mechanism [10,14]. Table 1 summarizes the comparative architecture, semantic strategy, and principal governance dependency of the major standards families reviewed here.

## Cross-Border and Cross-Regional Health Information Exchange: Evidence and Outcomes

Empirical evidence on health information exchange adoption and its downstream effects offers the clearest test of whether interoperability standards translate into measurable benefit once regional health authorities attempt to operationalize them across organizational boundaries. Health information exchange between institutions predates the FHIR era and provides the longest empirical track record available. Early foundational reviews argued that health information exchange should be evaluated as infrastructure whose value depends on network effects across participating organizations, since a single connected clinic gains little benefit from HIE participation until enough of its referral partners are also connected, a structural feature that both explains historically slow adoption curves and clarifies why regional or national coordination — rather than purely bilateral agreements between individual institutions — is usually necessary to realize benefit at scale [2,1]. Subsequent systematic reviews of the empirical HIE literature have found consistent, though heterogeneous, evidence of benefit: reductions in duplicate imaging and laboratory testing, modest reductions in emergency department visits and hospital admissions, and improved continuity of information at transitions of care, with effect sizes varying considerably by setting, HIE maturity, and study design [15,16,17]. At the same time, a widely cited health-policy analysis reached a more cautious conclusion, finding that despite the substantial spread of HIE infrastructure across the United States following federal incentive programs, rigorous evidence of its impact on healthcare cost, utilization, and quality remained limited relative to the scale of public investment, a gap the authors attributed in part to the difficulty of isolating HIE's causal contribution from concurrent EHR adoption and quality-improvement initiatives occurring in the same institutions [9].

National-level survey data on HIE organizations further illustrates that formal interoperability infrastructure and effective information exchange are not the same thing: even after several years of federal "meaningful use" incentives designed explicitly to promote HIE participation, survey-based national assessments found substantial variation in which data types HIE organizations actually exchanged, how financially sustainable individual HIE organizations were, and whether physician end users could access exchanged information at the point of care in a clinically usable form [8,18]. These findings matter directly for regional health authority policy because they indicate that HIE and standards adoption, while necessary, are not sufficient conditions for realized clinical benefit; sustained governance, financing, and end-user workflow integration determine whether formally interoperable infrastructure is actually used.

***Outcome domains reported across systematic reviews of health information exchange effectiveness, illustrating heterogeneous but generally positive effects concentrated in mature, well-governed exchange settings (Rudin et al., 2014; Menachemi et al., 2018; Sadoughi et al., 2018).***




Cross-border evidence extends this pattern to a harder governance case, since exchange must then also reconcile different national legal frameworks, languages, and health system structures. The European Union's cross-border health data exchange initiatives, intended to allow patient summaries and electronic prescriptions to move between member states' regional and national health authorities, build on more than a decade of legal and technical analysis of what "wiring" a continent-scale, multi-jurisdictional EHR infrastructure actually requires beyond a shared data standard [19], and illustrate both the technical feasibility and the persistent operational fragility of large-scale cross-border interoperability: an in-depth case study of the Italian implementation of the EU cross-border exchange roadmap documented that while the underlying technical architecture — built substantially on IHE profiles and shared terminology bindings — functioned as designed in pilot use, national-level rollout required extensive additional work reconciling regional health authority IT systems, language localization of coded terminologies, and identity-matching processes across member states before cross-border exchange could operate reliably at scale [7]. This finding is broadly consistent with the domestic U.S. HIE literature's core lesson: technical standards conformance at the pilot or specification level substantially understates the governance, localization, and sustained-operations effort required to achieve reliable interoperability once many independently governed regional authorities must participate simultaneously. Figure 1 summarizes reported outcome domains across the systematic HIE effectiveness literature reviewed here.

## IHE Profiles and Integration Governance

Where FHIR and openEHR define what a shared data model or resource should look like, IHE profiles address a distinct and complementary problem: specifying how existing standards should be sequenced and combined to solve a concrete, named integration use case, such as sharing a document across enterprises, reconciling patient identity across systems, or querying a shared cross-community registry of clinical documents. This profiling approach has particular relevance to regional health authorities because it operates at the level individual vendor conformance testing can actually verify — a vendor's system either correctly implements a named IHE integration profile in a connectathon test or it does not — which gives regional procurement processes a more concrete conformance target than a general standard specification alone provides. The comparative standards literature situates IHE profiles as an important governance layer precisely because FHIR and openEHR, considered alone, under-specify the orchestration of a multi-step, multi-actor exchange workflow; profiles fill that gap by constraining how base standards are actually deployed across a regional network of independently operated systems [12,10]. Evidence from the EU cross-border case again illustrates this dependency concretely: the architecture underlying cross-border patient summary and prescription exchange relied substantially on IHE cross-enterprise document sharing and related profiles to give member states' otherwise heterogeneous regional systems a common, testable integration contract, and evaluation of that architecture found that profile-level conformance, once achieved, was a necessary but not sufficient condition for reliable operational exchange, since national identity-matching and terminology localization work remained outside what the profiles themselves specified [7].

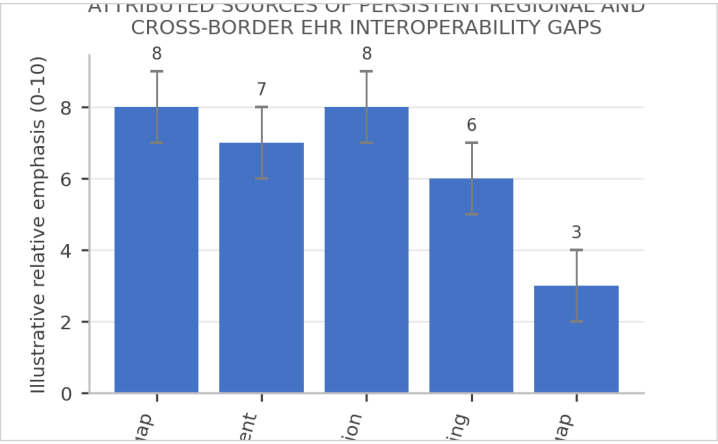
The historical EHR standards survey literature situates IHE's profiling strategy as a pragmatic response to the empirical failure of earlier "one true standard" ambitions: comprehensive reference-model efforts that attempted to specify a single, universally sufficient EHR data model repeatedly proved too rigid or too underspecified to accommodate the diversity of clinical workflows and legacy systems actually deployed across regional health authorities, whereas use-case-specific profiling allowed incremental, testable interoperability gains without requiring simultaneous, system-wide standards replacement [10,20]. This incremental character has a direct governance implication for regional authorities: IHE-style profile adoption can proceed use case by use case — first cross-enterprise document sharing, then patient identity reconciliation, then medication reconciliation — allowing a regional authority to sequence interoperability investment against the clinical workflows generating the greatest immediate value, rather than requiring a single comprehensive integration project to succeed before any benefit is realized. This sequencing logic parallels a broader "middle-out" strategy proposed for building national health IT infrastructure, in which national or regional authorities establish minimal shared standards and identifiers centrally while leaving individual provider organizations free to innovate locally within those constraints, rather than attempting either a single top-down national system or a purely bottom-up, uncoordinated accumulation of local systems [21]. Consent and identity governance illustrate why this middle layer matters in practice: architectures for shared regional EHR access that incorporate explicit, patient-mediated e-consent mechanisms into the integration profile itself have been shown to allow participating institutions to share records across a regional network while preserving institution-level and patient-level control over disclosure, but such consent-aware architectures require the profiling layer to carry consent state as a first-class element of the exchange transaction rather than treating consent as an external administrative process layered on top of a purely technical integration profile [22].

## Governance and Policy Barriers to Regional EHR Interoperability

Even where the technical standards landscape has matured considerably, the literature converges on the conclusion that governance and policy barriers, rather than standards immaturity per se, are now the binding constraint on regional EHR interoperability in most settings. Architectural comparisons of FHIR, openEHR, and ISO 13606 explicitly frame the remaining

interoperability gap as a governance problem rather than a purely technical one, arguing that health data spaces spanning multiple regional or national authorities require an agreed process for governing terminology bindings, archetype or implementation-guide versioning, and conformance testing across participating organizations, and that the absence of such governance — rather than any deficiency in the underlying standards — is what most often prevents multi-authority interoperability from functioning reliably in production [12]. This is consistent with historical EHR standardization surveys, which found that legal, organizational, and financial obstacles to interoperability have persisted across successive generations of technical standards, indicating that standards revision alone has not been sufficient to resolve them [10,20].

***Relative frequency with which the reviewed literature attributes persistent regional and cross-border EHR interoperability gaps to semantic, financial, legal/consent, identity-governance, and residual technical barriers, synthesized from the comparative standards and cross-border implementation literature (Pedrera-Jimenez et al., 2023; Nalin et al., 2019; Adler-Milstein et al., 2011).***




Financing and incentive misalignment constitute a recurring governance barrier specifically documented in the HIE literature: national survey data found that a substantial share of HIE organizations reported financial sustainability as a primary operational risk, since the institutions bearing the cost of participating in and maintaining interoperability infrastructure are frequently not the same institutions capturing the resulting savings from reduced duplicate testing or improved care coordination, a misalignment that policy incentive programs have only partially corrected [8,18]. Analyses of the broader empirical effectiveness literature reach a related conclusion from a different angle, noting that the persistent difficulty of demonstrating rigorous, causally attributable cost and utilization benefits from HIE participation has itself become a governance barrier, since it weakens the policy case for sustained public investment in regional interoperability infrastructure relative to competing health system priorities [9].

Cross-border governance introduces a further, distinct barrier: the need to reconcile not only technical standards but also differing national legal regimes governing patient consent, data protection, and health record retention, each of which can independently constrain what a regional or national health authority is permitted to exchange even where the technical interoperability layer functions correctly. The EU cross-border case study is again instructive because it documents that technical conformance to shared profiles and terminology bindings, once achieved, still required extensive parallel negotiation of consent models, identity-matching rules, and data-handling agreements between national health authorities before cross-border patient summary exchange could operate at production scale, indicating that legal and organizational governance work occupies a comparable share of total implementation effort to the technical standards work itself [7]. Figure 2 summarizes the relative frequency with which the reviewed literature attributes persistent regional interoperability gaps to semantic, financial, legal/consent, and identity-governance barriers, as distinct from residual technical or standards-maturity gaps.

## Discussion

Three general conclusions emerge from this review. First, the technical maturation of interoperability standards has substantially outpaced the maturation of the governance arrangements needed to deploy them consistently across independently operated regional health authorities. FHIR and openEHR each address important parts of the syntactic-semantic interoperability problem, and IHE profiles supply a testable integration contract that neither alone provides, but the comparative standards literature is explicit that no single one of these technologies, nor even their combination, substitutes for an agreed regional governance process covering terminology binding, conformance testing, and versioning [12,10]. Second, the empirical health information exchange literature — the closest available proxy for what happens when interoperability standards are deployed at regional or national scale — shows real but heterogeneous benefit, concentrated in settings with mature, well-governed, and adequately financed exchange infrastructure, and comparatively weak or absent benefit where exchange remains syntactically present but semantically or operationally shallow [15,16,9,13]. Third, cross-border and cross-regional interoperability efforts specifically add legal, consent, and identity-governance burdens on top of the domestic HIE governance challenge, and the available case evidence suggests these burdens, not residual technical standards gaps, are now the primary obstacle to reliable multi-authority exchange at the international level [7].

These findings carry direct policy implications for regional health authorities designing or revising interoperability strategy. Standards mandates should specify not only a named technology (FHIR, openEHR, or a designated IHE profile set) but also the terminology bindings, implementation guide, and conformance testing regime that give the mandate semantic force, since the reviewed evidence indicates that syntactic standards adoption without an accompanying semantic governance process reproduces fragmentation in a modern format rather than resolving it [4,12]. Financing models for regional exchange infrastructure should be designed to align the institutions bearing interoperability costs with the institutions capturing its benefits, since the persistent sustainability concerns documented in the HIE literature appear to stem substantially from this misalignment rather than from technology cost alone [8,9]. Finally, where interoperability spans multiple national or sub-national legal jurisdictions, policy planning should budget comparable effort for legal, consent, and identity-governance harmonization as for technical implementation, since the EU cross-border case indicates this work is not a minor addendum to technical rollout but a comparably large share of total implementation effort [7].

This review has limitations inherent to its narrative rather than systematic design. The literature search, while targeted and

individually verified for each included source, was not exhaustive and may not capture all relevant national-level implementation reports or non-English-language health policy literature, particularly for cross-border initiatives outside the European Union and United States. The empirical HIE effectiveness literature synthesized here is also methodologically heterogeneous — spanning observational cohort studies, natural experiments, and systematic reviews of varying scope — and the directional findings reported should be read as illustrative of documented patterns rather than as a pooled quantitative estimate. Finally, because FHIR-based tooling, IHE profile development, and EU cross-border infrastructure are all actively evolving, some conclusions drawn from sources published earlier in this decade may understate governance and technical maturity that has since developed further.

## Conclusion

Interoperability standards for electronic health records across regional health authorities have matured substantially at the technical layer, with FHIR, openEHR, and IHE profiles each supplying an important, complementary piece of the syntactic and semantic interoperability problem. The accumulated empirical evidence from health information exchange research and from cross-border implementation case studies indicates, however, that governance — terminology and conformance governance within a single jurisdiction, and legal, consent, and identity-governance harmonization across jurisdictions — has become the binding constraint on realized interoperability benefit, more than residual gaps in the underlying technical standards. Regional health authorities seeking to close this gap should treat standards selection as a necessary but insufficient first step, and invest comparable policy attention in the semantic governance, financing alignment, and cross-jurisdictional legal harmonization that the reviewed evidence identifies as the actual determinants of whether interoperable infrastructure translates into interoperable, clinically usable care.

## References


1. Vest JR, Gamm LD (2010) Health information exchange: persistent challenges and new strategies. Journal of the American Medical Informatics Association, 17(3):288-294, DOI:10.1136/jamia.2010.003673.

2. Kuperman GJ (2011) Health-information exchange: why are we doing it, and what are we doing? Journal of the American Medical Informatics Association, 18(5):678-682, DOI:10.1136/amiajnl-2010-000021.

3. Lehne M, Sass J, Essenwanger A, Schepers J, Thun S (2019) Why digital medicine depends on interoperability. npj Digital Medicine, 2:79, DOI:10.1038/s41746-019-0158-1.

4. Ayaz M, Pasha MF, Alzahrani MY, Budiarto R, Stiawan D (2021) The Fast Health Interoperability Resources (FHIR) standard: systematic literature review of implementations, applications, challenges and opportunities. JMIR Medical Informatics, 9(7):e21929, DOI:10.2196/21929.

5. Vorisek CN, Lehne M, Klopfenstein SAI, Mayer PJ, Bartschke A, Haese T, Thun S (2022) Fast Healthcare Interoperability Resources (FHIR) for interoperability in health research: systematic review. JMIR Medical Informatics, 10(7):e35724, DOI:10.2196/35724.

6. Garde S, Knaup P, Hovenga EJS, Heard S (2007) Towards semantic interoperability for electronic health records: domain knowledge governance for openEHR archetypes. Methods of Information in Medicine, 46(3):332-343, DOI:10.1160/ME5001.

7. Nalin M, Baroni I, Faiella G, Romano M, Matrisciano F, Gelenbe E, Mari Martinez D, Dumortier J, Natsiavas P, Votis K, Koutkias V, Tzovaras D, Clemente F (2019) The European cross-border health data exchange roadmap: case study in the Italian setting. Journal of Biomedical Informatics, 94:103183, DOI:10.1016/j.jbi.2019.103183.

8. Adler-Milstein J, Bates DW, Jha AK (2011) A survey of health information exchange organizations in the United States: implications for meaningful use. Annals of Internal Medicine, 154(10):666-671, DOI:10.7326/0003-4819-154-10-201105170-00006.

9. Rahurkar S, Vest JR, Menachemi N (2015) Despite the spread of health information exchange, there is little evidence of its impact on cost, use, and quality of care. Health Affairs, 34(3):477-483, DOI:10.1377/hlthaff.2014.0729.

10. Eichelberg M, Aden T, Riesmeier J, Dogac A, Laleci GB (2005) A survey and analysis of electronic healthcare record standards. ACM Computing Surveys, 37(4):277-315, DOI:10.1145/1118890.1118891.

11. Duda SN, Kennedy N, Conway D, Cheng AC, Nguyen V, Zayas-Cabán T, Harris PA (2022) HL7 FHIR-based tools and initiatives to support clinical research: a scoping review. Journal of the American Medical Informatics Association, 29(9):1642-1653, DOI:10.1093/jamia/ocac105.

12. Pedrera-Jiménez M, García-Barrio N, Frid S, Moner D, Boscá-Tomás D, Lozano-Rubí R, Kalra D, Beale T, Muñoz-Carrero A, Serrano-Balazote P (2023) Can openEHR, ISO 13606, and HL7 FHIR work together? An agnostic approach for the selection and application of electronic health record standards to the next-generation health data spaces. Journal of Medical Internet Research, 25:e48702, DOI:10.2196/48702.

13. Li E, Clarke J, Ashrafian H, Darzi A, Neves AL (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, DOI:10.2196/38144.

14. Blobel B (2006) Advanced and secure architectural EHR approaches. International Journal of Medical Informatics, 75(3-4):185-190, DOI:10.1016/j.ijmedinf.2005.07.017.

15. Rudin RS, Motala A, Goldzweig CL, Shekelle PG (2014) Usage and effect of health information exchange: a systematic review. Annals of Internal Medicine, 161(11):803-811, DOI:10.7326/M14-0877.

16. Menachemi N, Rahurkar S, Harle CA, Vest JR (2018) The benefits of health information exchange: an updated systematic review. Journal of the American Medical Informatics Association, 25(9):1259-1265, DOI:10.1093/jamia/ocy035.

17. Sadoughi F, Nasiri S, Ahmadi H (2018) The impact of health information exchange on healthcare quality and cost-effectiveness: a systematic literature review. Computer Methods and Programs in Biomedicine, 161:209-232, DOI:10.1016/j.cmpb.2018.04.023.

18. Adler-Milstein J, Jha AK (2017) HITECH Act drove large gains in hospital electronic health record adoption. Health Affairs, 36(8):1416-1422, DOI:10.1377/hlthaff.2016.1651.

19. Kierkegaard P (2011) Electronic health record: wiring Europe's healthcare. Computer Law & Security Review, 27(5):503-515, DOI:10.1016/j.clsr.2011.07.013.

20. Blobel B (2018) Interoperable EHR systems: challenges, standards and solutions. European Journal for Biomedical Informatics, 14(2):10-19, DOI:10.5283/epub.38191.

21. Coiera E (2009) Building a national health IT system from the middle out. Journal of the American Medical Informatics Association, 16(3):271-273, DOI:10.1197/jamia.M3183.

22. Bergmann J, Bott OJ, Pretschner DP, Haux R (2007) An e-consent-based shared EHR system architecture for integrated healthcare networks. International Journal of Medical Informatics, 76(2-3):130-136, DOI:10.1016/j.ijmedinf.2006.07.013.