http://jmscr.igmpublication.org/home/
ISSN (e)-2347-176x ISSN (p) 2455-0450
crossref DOI: https://dx.doi.org/10.18535/jmscr/v13i07.03

IGM Publication
Journal Of Medical Science And Clinical Research
An Official Publication Of IGM Publication

Analyzing the Progress of Interoperability Frameworks in Enabling Seamless Data Exchange across Healthcare Systems in the US and Australia

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Abstract
Generally, the interoperable health information exchange is very paramount for clinicians to have access to the timely and relevant patient health records. However, the progress of interoperability frameworks has been left unanswered while there has been significant investment into these frameworks. Thus, this study seeks to compare the progress of interoperability frameworks in seamless data exchange across healthcare systems in the US and Australia. The study adopts the systematic review design, which involves the use of structured and scientific approach to the review of literature using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). The study showed that the US, in comparison to Australia, has a fragmented healthcare system with varying levels of interoperability across states and institutions. While the interoperability system in Australia is centralized, it is still faced with some challenges. Some of these challenges include underutilization of existing resources due to administrative burdens and privacy laws. It was revealed that healthcare centres in the US rely on multiple proprietary systems as their interoperability frameworks. Meanwhile, interoperability in healthcare centers in Australia is often faced with the challenge of fragmentation as a result of clinical decision support systems (CDSS). The study concludes that both countries – the US and Australia – are faced with significant interoperability challenges. While the US struggles with regulatory fragmentation, Australia contends with policy misalignment and vendor control. Thus, it is recommended that future frameworks should concentrate on regulatory consistency, national alignment, and leveraging emerging technologies like blockchain technology for enhanced healthcare data exchange.

Keywords: Interoperability, data exchange, Australia, the United States, blockchain technology.

Introduction

The rapid development of digitization in healthcare system keeps increasing the growing need of interoperability frameworks to facilitate seamless and efficient data exchange across different sectors. Obviously, both the United States (US) and Australia may rely on the need to utilize the electronic health records systems (EHRs), patient data management and some other medical imaging technologies to be able to perform an effective operation in isolated silos owing to the differences in regulations, standards, and technical architectures. However, this opens a roadmap for several interoperability frameworks which include an integration of healthcare enterprise (IHE), fast healthcare interoperability resources (FHIR), and health level seven (HL7) to effectively enhance the seamless flow of patient data in healthcare systems. Adegoke et al. (2025) describe interoperability framework as a set of protocols, guidelines, and standards that is carefully designed to simplify the data exchange. The authors demonstrate that interoperability refers to predominant pillar of digital healthcare transformation that allows the smooth transfer of healthcare information systems, care coordination system and predictive

performance of healthcare systems. Hence, Institute of electrical and electronic engineers (IEEE) circumscribe interoperability as an ability of two or more components to exchange information and to use the information that has been exchanged (Palojoki et al., 2024). Amar et al. (2024) postulate that interoperability framework specifies organizational policies and semantic rules to ensure information confidentiality in healthcare systems to remains consistent and meaningful in health agencies. Meanwhile, this shows that interoperability frameworks facilitate healthcare information systems, medical devices, and electronic health records to pertinently share patient data across different sectors (De-Mello et al., 2022).

Perugu et al. (2023) identified that foundational interoperability, structural interoperability, semantic interoperability, and organizational interoperability are interoperability levels that were proposed by the healthcare information and management systems society organizations in United States. Altogether, sending a lab report data to another system without requiring interpretation known as (foundational), the ability to follow uniform structure in exchanging data in a standardized format such as HL7 and FHIR known as (structural), understanding the use of exchanged data meaningfully known as (semantic) while aligning the ethical workflows policies and governance subject to (organizational) for effective data exchange in healthcare systems (Carlos-Ferreira et al. (2024).

In principle, Oemig et al. (2016) noted that data exchange revolves around the process of sharing or disseminating information between different entities in a structured and highly secured manner. The authors submitted that data exchange enables the transfer of patient treatment histories, the diagnostic result and patient records. Andreas et al. (2021) posit that data exchange refers to organized transformation of data from a source to target the schema in ensuring the accurate information that is shared across different systems. Meanwhile, this exchange ensures interoperability between the computer operations and programs to allow organizations to streamline data while maintaining the data integrity in healthcare systems (Sarkar 2022). This metamorphosed that data exchange is effectively penetrated in healthcare systems by enabling the reduction of administrative burdens, ensuring an efficiency of patient care, and minimize the clinical errors across healthcare systems.

Abbasi et al. (2025) revealed that despite the widespread adoption of health information technology such as electronic health records (EHRs), some healthcare practitioners still found it difficult to access and share data in the disjointed US healthcare system. The authors showed that simplifying the interchange of health data is essential to maximizing the potential of EHR data to enhance patient health, public health, and healthcare. Esmaeilzadeh (2020) found that some healthcare systems in the United States (US) and Australia differ ominously in structure and administration of healthcare systems because National Health Service (NHS) usually funded the healthcare systems and centralize the EHR systems to effectively facilitate the patient data across the health systems. In contrast, Chen and Esmaeilzadeh (2023) discovered that United States often operates in a fragmented multidimensional system where both the public and private healthcare sectors (Medicare and Medicaid) often juxtaposing the insurers role. The authors exposed that United States always relies on diversity of health information exchange (HIE) and (EHR) which significantly propelled pitfalls for interoperability frameworks owing to the unequal systems and regulations.

Gabriel et al. (2024) showed that interoperable health information exchange is very paramount for clinicians to have access to the timely and relevant patient health records. The authors revealed that 70% of United States healthcare sectors engaged in interoperable frameworks for the purpose of facilitating and streamlining the electronic

information exchange in the hospital. Costin and Eastman (2019) stressed that there are continuous progress in expanding the interoperability frameworks to accelerate the seamless data exchange inn healthcare systems in the United States and United Kingdom. The authors noted that digital imaging and communication in medicine (DICOM), trusted exchange framework and common agreement (TEFCA), fast healthcare interoperability resources (FHIR) and health level seven (HL7) are used as framework to track the progress of data exchange in healthcare systems in United States and United Kingdom. Jendle et al. (2024) supported that United States utilizes NHS digital interoperability strategy to successfully harmonized data formats and API-driven integration. The authors also pinpointed that cross-enterprise document sharing (XDS) are used in EU, UK, and US to efficiently disseminated the clinical documents across healthcare systems.

Ait-Gacem et al. (2025) asserted that effective data exchange depends on standardized protocols such as fast healthcare interoperability resources, health level seven and to develop robust data accessibility, confidentiality and accuracy in healthcare systems. Nevertheless, there are observe challenges that mitigate the interoperability framework in enabling effective data exchange in healthcare systems and these include regulatory compliance issues, diverse data formats and privacy concerns issues oppose the development interoperability frameworks in healthcare systems in Korea healthcare sectors (Kwon et al., (2024). Therefore, based on all the foregoing deliberations, this study seeks to analyze the progress of interoperability frameworks in enabling seamless data exchange across healthcare systems in the US and Australia. The specific objectives of this study are to:

i. evaluate the current state of interoperability frameworks in healthcare systems across the US and Australia;
ii. examine the effectiveness of interoperability frameworks in facilitating seamless data exchange between healthcare providers and institutions in the US and Australia;
iii. identify the key challenges hindering the full implementation of interoperability frameworks in the US and Australia;
iv. assess the role of government policies and industry standards in advancing healthcare interoperability in the US and Australia; and
v. propose recommendations for improving interoperability frameworks to enhance data integration, security, and patient care outcomes in the US and Australia.

Methodology

This study adopts the systematic review design, which is a form of qualitative review style that allows for structured synthesis of the literature in a domain or area (Schut et al., 2024). This design was considered owing to its credibility, repeatability, and structured approach. It is an adopted design as it provides clear and illustrative guidelines, which enhance the reliability of the results. The literature search was conducted in series of databases, which are in the areas of health and medical. The databases consulted include EBSCOhost Health Sciences Research Database, which include MEDLINE, Scopus, CINAHL Plus, PsycINFO, Academic Search Premier, PsycARTICLES. Focusing the literature search in these databases facilitate fast and efficient access to the wide-ranging and up-to-date evidence with respect to the issue of interoperability frameworks in healthcare systems of the US and Australia (Atkinson & Cipriani, 2018).

Using the appropriate keywords and search terms would enhance the chances of retrieving relevant literature (Adeyemi & Issa, 2020). The Sample, Phenomenon of Interest, Design Evaluation, and Research type (SPIDER) search strategy was used to consult the databases. The SPIDER strategy (see Table 1) is appropriate when a study wants to find mixed-method research or qualitative articles, which is why it was considered for this study since

the study focused on searching for only mixed-methods or qualitative research (Hammarberg et al., 2016). This is because the study wants in-depth and qualitative evidence on interoperability frameworks in the healthcare systems of the US and Australia. Meanwhile, this review adopts Boolean operators of 'AND' and 'OR' to widen the search scope in order to ascertain robust evidence on interoperability frameworks in the US and Australia (Schut et al., 2024). The purposeful omission of Boolean operator 'NOT' was to eliminate the chances of getting required literature from the literature search. Moreover, the truncation sign (*) was used in the search strategy to suggest words that share the same base word with interoperability frameworks. This reduces the need for several searches that may be time-consuming.

Table 1: SPIDER Tool

SPIDER	Content
Sample	Healthcare providers, IT professionals, patients in the US and Australia, and IT professionals.
Phenomenon of Interest	Analysis of interoperability frameworks in enhancing seamless data exchange of interoperability implementations.
Design	Published literature of both qualitative and mixed-methods research
Evaluation	Effectiveness of interoperability frameworks in improving data sharing, patient outcomes, and healthcare efficiency.
Research type	Qualitative and mixed methods research

Source: Author's fieldwork (2025)

The SPIDER framework ensured a structured approach to understanding interoperability frameworks in the US and Australian healthcare systems. Using the SPIDER tool in the search query produced a large number of hits/results. Subsequently, inclusion and exclusion criteria were introduced, which appraise the search results to produce only the most relevant studies to the review (see Table 2). The criteria considered in the selection process of the final selected articles include studies published between 2015 and 2025, removal of duplicated publications, removal of literature published in languages other than English language, primary research only, studies conducted in the US and Australia, full-text articles, and mixed-methods and qualitative research. Using these criteria, the final selected literature is fourteen (14) articles.

Table 2: Inclusion and Exclusion Criteria

Inclusion and exclusion criteria	No. of hits	Justifications for search criteria
Studies published between the years 2015-2025	412	This is to ensure that only recent evidences are used in the answering the research question.
Duplicate publications removed	395	This is to avoid redundancy in the retrieved literature
Literature published in English language	382	This is to ensure that all the literature are in understandable language to allow analaysis
Primary research only	174	This is to have only original primary research findings with respect to the research
Studies published in the US and Australia	43	This is to contextualize the literature analysis to studies that were conducted in the US and Australia.
Full-text only	35	Full-text allows critical review and analysis of the literature
Qualitative or mixed-methods research only	15	This is to analyze research findings that provide deeper understanding of experience, phenomenon, and context.

Source: Author's fieldwork (2025)

Meanwhile, the data collection process was ensured in similar structured manner through Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) (see Fig. 1). The framework is appropriate for systematic review studies, which is one this study adopted.

Meanwhile, the framework has four (4) phases, which include identification, screening, eligibility, and included. In the initial search of the different databases, a total of 421 items were extracted from the different databases. After this, duplications were checked and only sixty-two (62) items from the collected data were expunged as having duplicates in the returns. Next, the titles and abstracts of the articles were checked for relevance and whether they are relatable to the current study, and only sixty-six (66) articles were removed. After all these, the remaining items were examined with the inclusion and exclusion criteria that were set for the study. From this, only fifteen (15) articles were finally selected for this study. These fifteen (15) articles serve as the datasets for the study. Moreover, the collected data were extracted on a data extraction sheet (see Appendix I). Data analysis was conducted using the "a priori" thematic analysis.

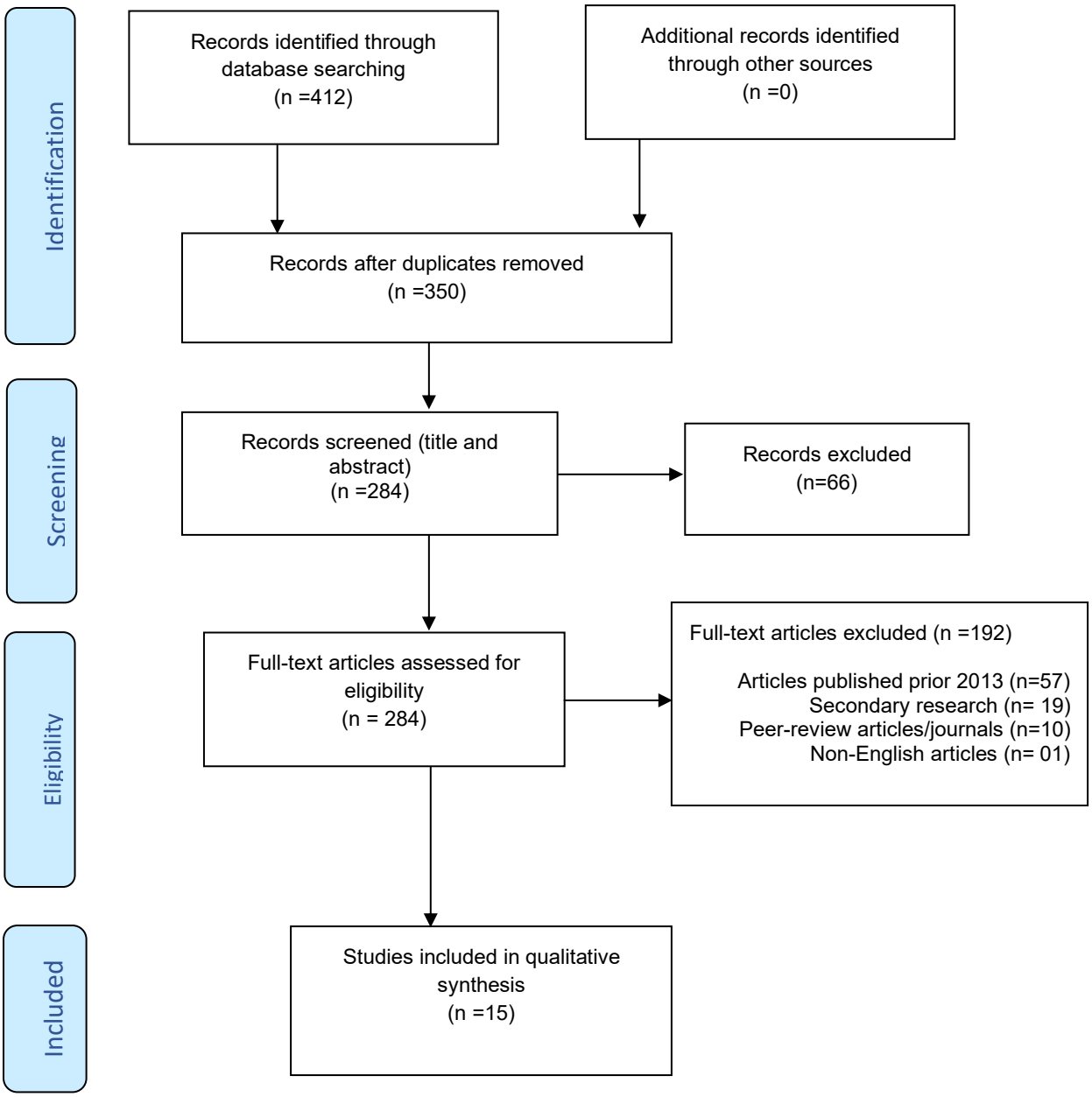

Figure 1: PRISMA Framework

Results and Discussions

Since the study adopts "a priori" thematic analysis for the analysis of the extracted data, the themes are based on the objectives of the study. Thus, the results are presented based on the objectives of the study. On the current state of interoperability frameworks in healthcare systems, it was revealed that the US has a fragmented healthcare system with varying levels of interoperability across states and institutions. Holmgren et al. (2021) highlighted that while health information exchange (HIE) is a policy priority, its adoption is inconsistent as a result of lack of standardized national infrastructure. Perugu et al. (2023) demonstrated that numerous interoperability initiatives exist, such as HL7, FHIR, and C-CDA, but achieving full semantic interoprability remains a challenge. Meanwhile, the Australia's interoperability frameworks are more centralized but still faced with challenges. Woods et al. (2022) found that digital health indicator scores varied across different healthcare regions in Australia, reflecting uneven digitization. Also, Johnson et al. (2024) emphasized the role of enterprise architecture models like ZiRA in improving patient flow and system-wide integration, which indicates structured efforts towards interoperability.

On the effectiveness of interoperability frameworks in facilitating seamless data exchange, the US relies on multiple proprietary systems. This complicates seamless data sharing in the United States. Perlin et al. (2016) compared interoperability to constructing an interstate highway, which requires standardized entry and exit points. Despite advancements, privacy risks and fragmented policies limit effectiveness. Gordon and Catalini (2018) suggested blockchain-based solutions for patient-driven interoperability to improve data exchange. In Australia, it was revealed that interoperability is hindered by fragmented clinical decision support systems (CDSS), which was demonstrated by Laka et al. (2022). However, Wang and Qin (2021) proposed blockchain applications to enhance security and patient control over data sharing. Unlike the US, Australia's national healthcare approach allows for more coordinated interoperability efforts, but challenges persist in aligning state-level and federal data-sharing policies.

On the key challenges hindering full implementation of interoperability frameworks, it was revealed that the challenges faced in the US include regulatory variations across states, proprietary software restrictions, and security vulnerabilities. Djinevski and Arsenovski (2024) noted that integration in the US is driven by profit-oriented vendors like Epic and Iguana, rather than patient-centric solutions. Perugu et al. (2023) identified semantic standardization as a major barrier. Meanwhile, in Australia, challenges that are common are fragmented health infrastructure and policy misalignment. Das (2017) highlighted issues in data utilization, with underutilization existing resources due to administrative burdens and privacy laws. Laka et al. (2022) found that lack of integration between clinical and technological elements hinders effective data sharing.

On the role of government policies and industry standards in advancing interoperability, it was revealed that, in the US, the federal policies like the 21st Century Cures Act push for better data interoperability, but enforcement in inconsistent. Perlin et al. (2016) emphasized the role of public health reporting and standardization, while Saripalle et al. (2019) found that FHIR can bridge interoperability gaps. However, proprietary interests still dominate the industry. Meanwhile, in Australia, government involvement is more centralized in Australia. Djinevski and Arsenovski (2024) noted that integration approaches are largely controlled by practice management system vendors, which makes interoperability profit-driven rather than patient-centric. Woods et al. (2024) found that interoperability policies align with digital health strategies, but further national coordination is required.

On recommendations that can help improve interoperability frameworks in the two countries,

the US and Australia. In the US, it was revealed that there is a need for a national regulatory framework for seamless data exchange, increase enforcement of existing interoperability policies, and incentivizing patient-driven interoperability models using blockchain (Gordon & Catalini, 2018). This highlights the importance of coordinated framework for the propagation of interoperability in the United States. Meanwhile, in Australia, there is a need to strengthen alignment between state and national interoperability policies and enhance integration of CDSS with hospital systems (Laka et al., 2022). Moreover, Johnston et al. (2024) revealed that there is a need to expand enterprise architecture frameworks like ZiRA to improve system-wide data flow in Australia.

Implications

The implications of the study's findings are significant for policymakers, healthcare practitioners, theoretical development, and the general society. On the policy implications of this study, the findings have highlighted the urgent need for policymakers to standardize healthcare interoperability regulations. In the United States, there is a need for a unified federal approach to align state-level policies and prevent fragmentation. Meanwhile, in Australia, there should be an improvement in the national coordination by balancing federal oversight with state-level digital health initiatives. Policies should also enforce compliance with international interoperability standards, such as the FHIR and HL7, to promote seamless data exchange across healthcare providers.

For healthcare practitioners, the study demonstrated that interoperability frameworks impact workflow efficiency, data accessibility, and patient care outcome. In the US, healthcare providers should navigate complex regulatory environments while managing patient records across disparate systems. There could be a need for training and professional development in digital health literacy, which should be geared towards enhancing healthcare providers' ability to use interoperable systems effectively. In Australia, integrating CDSS with hospital workflows can optimize clinical decision-making and improve patient outcomes. Both countries must adopt user-friendly, patient-centered health information technologies to streamline interactions between clinicians and electronic health records.

On the theoretical development, the study provides support for existing models on health informatics and digital transformation in the healthcare sector. The study accentuates the need for interoperability frameworks grounded in enterprises architecture models like TOGAF and ZiRA. Future studies should explore blockchain technology's role in the enhancement of data security and interoperability. This would help provide an insight into the relevance of blockchain technology in digital transformation in the healthcare sector, especially as it concerns interoperability. Moreover, behavioural health informatics models should be examined to ascertain how healthcare professionals and patients adapt to interoperability changes. This study may be longitudinal study or comparative analysis between what is the reality in the US and Australia.

The study's findings have significance to the general society. The healthcare interoperability affects patients by improving care continuity, reduce redundant medical tests, and enhance patient autonomy over health records. In the US, greater interoperability can address disparities in digital health access among low-income population. Australia's centralized approach can support equitable healthcare delivery across urban and rural regions. However, privacy concerns must be addressed to ensure public trust in interoperable systems. Educational campaigns on patient data rights and digital health literacy should be launched to empower individuals in both countries (the US and Australia) to engage with their health information.

Conclusion

The study established that the US, in comparison to Australia, has a fragmented healthcare system with varying levels of interoperability across states and institutions. While the interoperability system in Australia is centralized, it is still faced with some challenges. Some of these challenges include underutilization of existing resources due to administrative burdens and privacy laws. It was recognized in the study that healthcare centres in the US relies on multiple proprietary systems as their interoperability frameworks. This makes it difficult to partake in seamless data sharing among different healthcare centers. Meanwhile, interoperability in healthcare centers in Australia is often faced with the challenge of fragmentation as a result of clinical decision support systems (CDSS). The study concludes that both countries – the US and Australia – are faced with significant interoperability challenges. While the US struggles with regulatory fragmentation, Australia contends with policy misalignment and vendor control. Thus, it is recommended that future frameworks should concentrate on regulatory consistency, national alignment, and leveraging emerging technologies like blockchain technology for enhanced healthcare data exchange.

References

1. Adeyemi, I. O., & Issa, A. O. (2020). Perceived usefulness and ease of use as predictors of early-year lawyers satisfaction with Law Pavilion Electronic Law Reports. *Buletin Al-Turas*, *26*(2), 239-252.
2. Abbasi, A. B., Layden, J., Gordon, W., Gregurick, S., DeLew, N., Grossman, J., ... & Tripathi, M. (2025). A Unified Approach to Health Data Exchange: A Report From the US DHHS. JAMA.
3. Adegoke, K., Adegoke, A., Dawodu, D., Bayowa, A., & Adekoya, A. (2025). Interoperability in Digital Healthcare: Enhancing Consumer Health and Transforming Care Systems.
4. Ait Gacem, S., Huri, H. Z., Wahab, I. A., & Abduelkarem, A. R. (2025). Investigating digital determinants shaping pharmacists' preparedness for interoperability and health informatics practice evolution: a systematic review. *International Journal of Clinical Pharmacy*, 1-11.
5. Amar, F., April, A., & Abran, A. (2024). Electronic health record and semantic issues using fast healthcare interoperability resources: systematic mapping review. *Journal of Medical Internet Research*, *26*, e45209.
6. Andreas, A., Mavromoustakis, C. X., Mastorakis, G., Do, D. T., Batalla, J. M., Pallis, E., & Markakis, E. K. (2021). Towards an optimized security approach to IoT devices with confidential healthcare data exchange. *Multimedia Tools and Applications*, *80*, 31435-31449.
7. Atkinson, L. Z., & Cipriani, A. (2018). How to carry out a literature search for a systematic review: A practical guide. *BJPsych Advances*, *24*(2), 74-82.
8. Carlos-Ferreira, J., Elvas, L. B., Correia, R., & Mascarenhas, M. (2024). Enhancing EHR interoperability and security through distributed ledger technology: A review. *Healthcare, 12*(19), 1-11.
9. Chen, M., & Esmaeilzadeh, P. (2023). Adoption and use of various health information exchange methods for sending inside health information in US hospitals. *International Journal of Medical Informatics*, *177*, 105156.
10. Costin, A., & Eastman, C. (2019). Need for interoperability to enable seamless information exchanges in smart and sustainable urban systems. *Journal of Computing in Civil Engineering*, *33*(3), 1-19.
11. Das, L. (2017). *Role of data in improving care within a health system: A case study of*

the australian health system. The Pardee RAND Graduate School.

12. de Mello, B. H., Rigo, S. J., da Costa, C. A., da Rosa Righi, R., Donida, B., Bez, M. R., & Schunke, L. C. (2022). Semantic interoperability in health records standards: a systematic literature review. *Health and Technology*, *12*(2), 255-272.
13. Djinevski, L., & Arsenovski, S. (2024). Comparative overview of interoperability in distributed medical systems through data exchange standards in Macedonia, USA and Australia regarding health providers and insurance agencies. *UTMS Journal of Economics*, *15*(1), 64-70.
14. Esmaeilzadeh, P. (2020). Patients' perceptions of different information exchange mechanisms: an exploratory study in the United States. *Methods of Information in Medicine*, *59*(04/05), 162-178.
15. Gabriel, M. H., Richwine, C., Strawley, C., Barker, W., & Everson, J. (2024). Interoperable Exchange of Patient Health Information among US Hospitals: 2023. ASTP Health IT Data Brief.
16. Gordon, W. J., & Catalini, C. (2018). Blockchain technology for healthcare: facilitating the transition to patient-driven interoperability. *Computational and Structural Biotechnology Journal*, *16*, 224-230.
17. Hammarberg, K., Kirkman, M., & de Lacey, S. (2016). Qualitative research methods: When to use them and how to judge them. *Human Reproduction*, *31*(3), 498-501.
18. Holmgren, A. J., Esdar, M., Hüsers, J., & Coutinho-Almeida, J. (2023). Health information exchange: understanding the policy landscape and future of data interoperability. *Yearbook of Medical Informatics*, *32*(1), 184-194.
19. Jendle, J., Adolfsson, P., Choudhary, P., Dovc, K., Fleming, A., Klonoff, D. C., ... & Heinemann, L. (2024). A narrative commentary about interoperability in medical devices and data used in diabetes therapy from an academic EU/UK/US perspective. *Diabetologia*, *67*(2), 236-245.
20. Johnston, R., Phunthasu, B., Wang, Y., Nguyen, H. N., Li, M., & Dilnutt, R (2024). How integrating healthcare information systems and enterprise architecture optimises patient flow in Australian Hospitals? *Enterprise Architecture Professional Journal,* 1-13.
21. Kennedy, K. (2023). *The Relationship Between Clinical Integration, Interoperability, and Patient Engagement in Electronic Health Capacities in the United States: A Socio-Economic Health Study* (Doctoral dissertation, Northcentral University).
22. Kwon, A., Lee, H. Y., Shin, S. Y., Yang, K., Sung, Y., Lee, K., ... & Lee, J. H. (2024). Current health data standardization project and future directions to ensure interoperability in Korea. *Healthcare Informatics Research*, *30*(2), 93-102.
23. Laka, M., Carter, D., Milazzo, A., & Merlin, T. (2022). Challenges and opportunities in implementing clinical decision support systems (CDSS) at scale: Interviews with Australian policymakers. *Health Policy and Technology*, *11*(3), 100652.
24. Oemig, F., Snelick, R., Oemig, F., & Snelick, R. (2016). Healthcare Data Exchange Standards. Healthcare Interoperability Standards Compliance Handbook: Conformance and Testing of Healthcare Data Exchange Standards, 105-156.
25. Palojoki, S., Lehtonen, L., & Vuokko, R. (2024). Semantic interoperability of electronic health records: Systematic

review of alternative approaches for enhancing patient information availability. *JMIR Medical Informatics*, *12*(1), e53535.

26. Perlin, J. B., Baker, D. B., Brailer, D. J., Fridsma, D. B., Frisse, M. E., Halamka, J. D., ... & Tang, P. C. (2016). Information technology interoperability and use for better care and evidence: a vital direction for health and health care. *NAM Perspectives*.
27. Perugu, B., Wadhwa, V., Kim, J., Cai, J., Shin, A., & Gupta, A. (2023). Pragmatic approaches to interoperability–surmounting barriers to healthcare data and information across organizations and political boundaries. *Telehealth and Medicine Today*, *8*(4), 1-20.
28. Pimentel, J. C., Pimentel, E. C., & Dao, S. (2021, April). A comparison of modern frameworks for the development of interoperable healthcare information systems. In *Frontiers in Biomedical Devices* (Vol. 84812, p. V001T12A017). American Society of Mechanical Engineers.
29. Sarkar, I. N. (2022). Transforming Health data to actionable information: Recent progress and future opportunities in health information exchange. *Yearbook of Medical Informatics*, *31*(01), 203-214.
30. Saripalle, R. K. (2019). Fast Health Interoperability Resources (FHIR): current status in the healthcare system. *International Journal of E-Health and Medical Communications (IJEHMC)*, *10*(1), 76-93.
31. Schut, M., Adeyemi, I., Kumpf, B., Proud, E., Dror, I., Barrett, C. B., ... & Leeuwis, C. (2024). Innovation portfolio management for the public non-profit research and development sector: What can we learn from the private sector? *Innovation and Development*, 1-19.
32. Tejani, A. S., Bialecki, B., O'Donnell, K., Sippel Schmidt, T., Kohli, M. D., & Alkasab, T. (2024). Standardizing imaging findings representation: Harnessing common data elements semantics and Fast Healthcare Interoperability Resources structures. *Journal of the American Medical Informatics Association*, *31*(8), 1735-1742.
33. Wang, Q., & Qin, S. (2021). A hyperledger fabric-based system framework for healthcare data management. *Applied Sciences*, *11*(24), 11693.
34. Woods, L., Eden, R., Pearce, A., Wong, Y. C. I., Jayan, L., Green, D., ... & Sullivan, C. (2022). Evaluating digital health capability at scale using the digital health indicator. *Applied Clinical Informatics*, *13*(05), 991-1001.
35. Woods, L., Eden, R., Macklin, S., Krivit, J., Duncan, R., Murray, H., ... & Sullivan, C. (2024). Strengthening rural healthcare outcomes through digital health: qualitative multi-site case study. *BMC Health Services Research*, *24*(1), 1096.

APPENDIX I
DATA EXTRACTION TOOL

Analyzing the Progress of Interoperability Frameworks in Enabling Seamless Data Exchange across Healthcare Systems in the US and Australia

S/N		Research titles and authors	Aims	Study location	Methodology	Findings
1		Health information exchange (HIE): Understanding the policy landscape and future of data interoperability Holmgren et al. (2023)	The study assessed the policy landscape and future of data interoperability through health information exchange.	The United States.	Qualitative approach.	- HIE is an increasingly important capability and policy priority as electronic health record (EHR) adoption becomes more common and care delivery is increasingly digitized. While the United States has adopted some level of HIE, there are significant differences across their level of data sharing infrastructure and maturity. - While identifying generalizable strategies across disparate international systems is challenging, there are several common themes across successful HIE policy frameworks, such as the importance of central government prioritization of data sharing.
2		Evaluating digital health capability at scale using digital health indicator Woods et al. (2022)	The study examines the digital health capability in Queensland to inform digital health strategy and investment.	Queensland, Australia.	Mixed-methods research.	- The results reveal a variation in digital health indicator scores reflecting the diverse stages of health care digitization across the state. - The average digital health indictor score across sites was 143, which is similar to other systems in the Oceania region and global public systems but below the global private average. - Governance and workforce was on average the highest scoring dimension, followed by interoperability, person-enabled health, and predictive analytics.
3		The Relationship between Clinical Integration, Interoperability, and Patient Engagement in Electronic Health Capacities in the United States: A Socio-Economic Health Study Kennedy (2023)	The study evaluated how healthcare systems address inequities in patient engagement with electronic health capabilities in the US	The United States.	Mixed-methods research.	- Economic factors impact healthcare. Health outcomes are affected by social variables. Low-income Americans' healthcare is behind. Electronic healthcare alternatives are unfamiliar to some patients. Beneficial patient interfaces and other electronically transmitted capabilities and services are incentives to engage patients, but not all patients have access or use these. - Healthcare disintegration is one of the biggest difficulties facing healthcare organizations, and providing high-quality treatment to patients is crucial but difficult. Electronic patient health records and adoption by providers and patients is a national goal. These developments will likely continue. Digital patient visits improve medical access, communication, interaction, and chronic health management. Patient participation and use of online medical records correlated to better patient outcomes in the study.
4		Comparative overview of interoperability in distributed medical	The study addressed challenges associated with	The USA and Australia.	Qualitative research.	- Findings that in Australia there are possible integration approaches between health organizations. However, these approaches are controlled by the

		systems through data exchange standards in Macedonia, USA and Australia regarding health providers and insurance agencies Djinevski and Arsenovski (2024)	implementing HL7 standards in different countries like Australia, USA, and Macedonia.			practice management systems (PMS) vendor, thus further development in integration is driven by profit and not the wellbeing of the patients. - In the USA the conduct between participants in the health industry is heavily regulated. There are different laws that apply to different states in the country. Nevertheless, there is no national approach for central medical data exchange, and the integration is driven by PMS vendors like Epic or interface providers like Iguana.
5		Role of data in improving care within a health system: A case study of the Australian health system Das (2017)	This study aims to understand how organizational context and interfaces affect the collection, management, and use of data for care improvement.	Australia	Qualitative research.	- Care improvement (CI) activities centered around the "patient-provider-hospital" relationship. Commonwealth and state entities exhibited higher levels of diversity in CI projects compared to local entities. Funding was a key driver of CI; bulk of CI activities occurred either in response to or in anticipation of funding. - Some successful CI caused negative system feedbacks like further weakening of stressed systems and generated perverse incentives to shift costs. The NGO sector was a valuable government ally in CI due to their ability to: 1) influence the "patient-provider-hospital" relationships; 2) focus on diverse and niche areas of care; 3) contribute to CI knowledge base; 4) mitigate governmental conflicts of interest, and 5) act as a policy counterbalance. - There were four fundamental uses of data within the health system - operations, CI, reporting, and knowledge generation. Data flow (sharing) occurred in response to funding and five distinct patterns of data-funding flows were identified within the health system. Existing data resources were largely underutilized due to various reasons like suboptimal data quality, failure to meet stakeholder needs, high administrative burden of linking and using data, privacy laws, and unwillingness to allow secondary uses of data. Data flow was hindered due to fragmentations including those arising from sovereignty, specificity, or philosophical issues.
6		How integrating healthcare information systems and enterprise architecture optimises patient flow in Australian hospitals? Johnston et al. (2024).	The study evaluates the efficacy of the traditional frameworks like TOGAF®1 and HERA, which despite their comprehensive structure, fail to fully address the unique needs of hospital systems, particularly concerning	Australia	Qualitative research approach.	- Results emphasise the benefit of a holistic EA strategy that addresses the complete patient care continuum. - The findings indicate that ZiRA enables more effective solutions due to its tailored approach to hospital settings, emphasising interoperability between different hospitals and related services. - ZiRA is anticipated to significantly improve the patient flow management and reduce Emergency Department congestion in Australian hospitals.

			interoperability and system-wide integration.			
7		Challenges and opportunities in implementing clinical decision support system (CDSS) at scale: Interviews with Australian policymakers Laka et al. (2022)	The objective of this study was to identify challenges and opportunities relating to CDSS implementation in Australia.	Australia	Qualitative research approach.	- Findings showed that Australian digital health landscape of CDSS implementation appears to be fragmented, characterised by a lack of integration between clinical and technological elements. This fragmentation is exacerbated by the lack of a shared understanding and collaboration between key stakeholders, increasing the risk of conflicting interests. - Results showed that CDSS are designed for a particular clinical workflow, and a lack of interoperability reduces the information flow between systems. Most efforts to achieve data standardisation are limited to organisational or state-level programs. Thus, increasing the risk of uncoordinated care across organisations.
8		A hyperledger fabric-based system framework for healthcare data management Wang and Qin (2021)	The study examined the requirements for privacy-preserving and interoperability in healthcare data sharing and proposed a blockchain-based solution.	Australia.	Qualitative research approach.	- The non-tamperable and traceable distributed ledger of blockchain technology can provide solutions to the privacy and interoperability issues of the healthcare industry. In particular, the Hyperledger Fabric framework provides deployment and development components for enterprise-grade blockchain applications. - Findings showed that patients are able to supervise access through healthcare data usage logs stored on the blockchain; (2) the smart contract of hierarchical access control can be automatically executed so that requests can only access the data content corresponding to their permissions; and (3) help confirm the ownership of healthcare data and track changes in ownership, and provide a basis for the distribution of original data benefits.
9		Strengthening rural healthcare outcomes through digital health: Qualitative multi-site case study Woods et al. (2024)	The objective was to identify how digital health capability enables the delivery of outcomes in rural settings according to the quadruple aims of healthcare: population health, patient experience, healthcare costs and provider experience.	Queensland, Australia	Qualitative research approach.	- Seven highly interrelated digital health capability dimensions were identified from the interviews: governance and management; information technology capability; people, skills, and behaviours; interoperability; strategy; data analytics; consumer centred care. - Outcomes were directly influenced by all dimensions except strategy. The interrelationship analysis demonstrated the influence of strategy on all digital health capability dimensions apart from data analytics, where the outcomes of data analytics shaped ongoing strategic efforts.
10		Fast Health Interoperability Resources (FHIR): current status in the healthcare system Saripalle et al. (2019)	The study examined the current status of healthcare system from the perspectives of Fast Health	The United States.	Qualitative research.	- The study demonstrated that Fast Health Interoperability Resources (FHIR) can bridge interoperability gap between the growing number of disparate and variety of healthcare entities.

			Interoperability Resources (FHIR).			
11		A comparison of modern frameworks for the development of interoperable healthcare information systems. Pimentel et al. (2021)	The study examined their differences and similarities and proposes a minimum set of requirements for prospective interoperable HIS architectures compliant with the Industry 4.0 design principles, goal-setting pillars, as well as support for closed-loop physiological systems.	The United States.	Qualitative research approach.	- It was concluded that, although the frameworks possess some key similarities, most notably device interoperability, patient-centered design, systems scalability, and integration to heterogeneous medical devices (MDs), there are also differences in structural approach, being that Health 4.0 mainly acts as a more decentralized model, as opposed to the heavily centralized Integrated Clinical Environment (ICE).
12		Information Technology Interoperability and Use for Better Care and Evidence: A Vital Direction for Health and Health Care Perlin et al. (2016)	The study examined IT interoperability and use for better care and evidence, with a special focus on health and healthcare.	Tennessee, the United States	Qualitative research approach.	- The study showed that progress toward interoperability could be accelerated initially by focusing on high-value use cases, such as transitions of care, outcomes measurement, and public health reporting. - Results showed that achieving interoperability is like building the interstate highway system: we need to construct on-ramps and off-ramps one at a time, but we also need a master plan. - Results showed that privacy and security risks are increasing as more private and life-critical information becomes available, as health care practitioners increase their dependence on vulnerable technology, and as cyber-terrorists become more highly skilled, more determined, and better financed.
13		Pragmatic Approaches to Interoperability in the U.S.: Surmounting Barriers to Healthcare Data and Information Across Organizations Perugu et al. (2023)	The study examined the landscape of interoperability efforts in healthcare from 2010 to 2023 in the U.S.	The United States.	Qualitative research.	- The study found that it is clear that while progress has been achieved locally, the following interoperability initiatives: Health Level 7 (HL7), Consolidated-Clinical Document Architecture (C-CDA), Digital Imaging and Communications in Medicine (DICOM), Integrating the Healthcare Enterprise International (IHE), Fast Healthcare Interoperability Resources (FHIR), Argonaut, Direct Standard, Validated Healthcare Directory (VHDir), Health Quality Measures Format (HQMF), Health Relationship Trust (HEART), and Prescription Drug Monitoring Program (PDMP) which operate in various clinical domains, greater semantic understandability during information exchange is necessary. - Despite many parallel ongoing efforts to improve the standardization of healthcare information in the mobile devices, IoT (Internet of Things), and EHR (electronic health records) sectors, there is still space for improvement.

						- The U.S. must develop and implement effective mechanisms to surmount boundaries blocking the transfer of diverse types of healthcare information.
14		Blockchain technology for healthcare: facilitating the transition to patient-driven interoperability Gordon and Catalini (2018)	The study examined how blockchain technology might facilitate transition to patient-driven interoperability through digital access rules, data aggregation, data liquidity, patient identity, and data immutability.	The United States.	Qualitative research.	- The shift towards patient-centered interoperability brings with it numerous challenges around patient consent, governance, security, privacy, and patient engagement. - The study demonstrates that blockchain provides a high-level framework for how a patient could securely interact with multiple stakeholders, identify themselves across each entity, and aggregate their health data in a persistent form. - The shift from institution-driven interoperability to patient-driven interoperability is an exciting trend in healthcare and has the potential to fundamentally alter attitudes and policies around clinical data exchange and ownership. - Meanwhile, continuing to incentivize patient-facing data exchange will enable patients and providers to shift from an institution-centric to patient-centric data perspective, an important first step in accelerating patient-driven interoperability.

15	Standardizing imaging findings representation: Harnessing common data elements semantics and fast healthcare interoperability resources structures. Tejani et al. (2024)	The study developed a framework modelling radiology findings as Health Level 7 (HL7) Fast Healthcare Interoperability Resources (FHIR) observations using Common Data Elements (CDE) set/element identifiers as standardized semantic labels.	The United States.	Qualitative research approach.	- Labeling radiology findings as discrete data for interchange between systems requires two components: structure and semantics. CDE definitions provide semantic identifiers for findings and their component values. - The FHIR observation resource specifies a structure for associating identifiers with radiology findings in the context of reports, with CDE-encoded observations referring to definitions for CDE identifiers in a central repository. The discussion includes an example of encoding pulmonary nodules on a chest CT as CDE-labeled observations, demonstrating the application of this framework to exchange findings throughout the imaging workflow, making imaging data available to downstream clinical systems.