International Journal of Engineering and Advanced Technology Studies 13 (1), 22-28, 2025
Print ISSN: 2053-5783(Print)
Online ISSN: 2053-5791(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Interoperability within Healthcare Systems through FHIR, Artificial Intelligence and Cloud Integration

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doi: https://doi.org/10.37745/ijeats.13/vol13n12228 Published April 16, 2025

Citation: Halilaj M., Vasil S., Kosta A. and Lili I. (2025) Interoperability within Healthcare Systems through FHIR, Artificial Intelligence and Cloud Integration, *International Journal of Engineering and Advanced Technology Studies*, 13 (1), 22-28

Abstract: *One of the main challenges for healthcare interoperability is defining common standards for the structured content of healthcare data and the transport of this data between different systems. The purpose of this paper is to enable the exchange of these data, with a focus on the FHIR (Fast Healthcare Interoperability Resources) protocol which created the HL7 (Health Level Seven International) standard, a framework that has become widely adopted by all stakeholders around the world to determine the content of this data and the way they want to share it and to identify the potential of the integration of Artificial Intelligence with the HL7 FHIR standart. The integration of this data was one of the main questions raised in the project "Integration of AI in Advancing Interdisciplinary Research at the University of Tirana".*

Keywords: FHIR, HL7, interoperability, data integration, artificial intelligence, interdisciplinary research

INTRODUCTION

The health sector generates a large volume of data from patient files and scans to genetic data and wearable devices. Fast Healthcare Interoperability Resources (FHIR) has been emerged as the standard that is leading for healthcare data exchange, providing a framework that is common for structuring and for accessing this data. At the same time, artificial intelligence (AI) techniques are transforming how we analyse as well as derive understandings from healthcare information. The integration of these domains represents a powerful tool

The exchange of clinical records electronically is one of the most import aspects and challenge in the healthcare sector. The integration is important not only within a healthcare centre, but also between different healthcare centres, along with for patients in order to easily access their own medical data. Standardized agreements, along with a set of common rules, are necessary to ease this exchange. Efficient, accurate and secure data exchange, along with the preservation of its integrity, confidentiality, as well as availability, results from these standards. Faster and more reliable system interactions are achieved through adherence to these frameworks.

To address these important needs, is being used HL7 (Health Level Seven), an important set of international standards for the transfer of clinical and administrative data between software applications used by different healthcare providers. Many hospitals, along with other healthcare organizations, use quite a few, very diverse computer systems for a truly wide range of purposes, from billing records to patient tracking. Some of these systems fail to communicate (or "interface") upon receiving or requesting new information. HL7 thus needed a new method to easily exchange clinical data, which they called FHIR. It is modern web-based API technology that simplifies implementation using a HTTP-based RESTful protocol plus HTML along with CSS for user interface integration plus a choice of JSON XML or RDF for data representation as well as Atom for results. This eases interoperability between legacy healthcare systems, enabling easy healthcare information access for providers and people across multiple devices and allowing third-party developers to easily integrate medical applications into existing systems (Mohammad et.al, 2020). The "*Integration of Artificial Intelligence in advancing interdisciplinary research at the University of Tirana*" project promotes cross-disciplinary collaboration and innovation in AI applications. The project also aims to raise awareness and understanding of AI and implement AI in various disciplines. One of the key areas of the project was healthcare. This study is focused improving interoperability within healthcare systems by using artificial intelligence.

LITERATURE REVIEW

Many healthcare organizations use HL7 FHIR (Fast Healthcare Interoperability Resources), a standard dealing with many interoperability challenges in healthcare information exchange (Maxhelaku & Kika, 2019; Sharma & Aggarwal, 2018). Open-source tools, such as the HAPI FHIR server (Hussain et al., 2018), allow for the straightforward implementation of FHIR, which readily employs RESTful principles. Evidence from various healthcare sectors (Jaffe et al., 2023) demonstrates the worldwide implementation of this standard. Various contexts acknowledge FHIR's capacity to enhance interoperability. Modernization initiatives are significantly in progress to revise antiquated standards like HL7 v2.x and ensure their compatibility with the continuously advancing FHIR (Oemig, 2019).

The integration of AI and HL7 FHIR significantly enhances the interoperability of healthcare data and supports better decision-making processes. Saripalle, also noted the standard developed by HL7 which facilitates seamless data exchange across healthcare systems. By using FHIR data, AI analytical models can improve the predictive abilities and streamline healthcare outcomes (Lekkala, 2023). Interoperable applications, even in developing nations using paper-based systems (Ahmad et al., 2018), are eased by the SMART on FHIR platform. Multiple aspects of healthcare, such as mortality reporting (Hoffman et al., 2018; Hoffman et al., 2017), can be importantly improved by the use of these applications. The creation of incredibly useful semantic interoperability platforms, specifically designed for AI-driven applications using HL7 FHIR (Rigas et al., 2024), has importantly advanced the field, along with the implementation of strong smart contract authentication via the graph-based FHIR architecture, further improving the efficiency and security of e-healthcare systems (Sreejith & Senthil, 2023). These improvements are driving important improvements in healthcare, increasing efficiency, encouraging interoperability, as well as promoting data-centric approaches.

Cloud platforms support FHIR implementation into improving healthcare data interoperability and analytics. Serverless FHIR machine learning model deployment architectures have been proposed (B. Eapen et al., 2020) and integrating FHIR with IoT cloud platforms for personal health records (Jae-Ki Hong et al., 2017). FHIR allows cloud-based solutions such as HealtheDataLab to show how advanced analytics can be used with large-scale healthcare data (L. Ehwerhemuepha et al., 2020). In addition, frameworks for implementing SMART on FHIR in developing countries have been developed by researchers (Abrar Ahmad et al. 2018). FHIR's application in several clinical and research contexts has also been explored by many researchers (Ashley C. Griffin et al. 2022). Researchers have importantly addressed security concerns, incorporating role-based access control into FHIR (Yaira K. Rivera Sánchez et al., 2017), as well as proposing highly scalable cloud architectures for EHR interoperability (Derlis Gómez et al., 2021). FHIR's potential to improve healthcare data management and analysis in cloud environments is highlighted by these improvements.

Implementation of the FHIR on cloud

In the project "Integration of AI in Advancing Interdisciplinary Research at the University of Tirana", we have used FHIR standard for health data exchange by focusing on the data format being exchanged, its storage, and interoperability. The cloud has seen significant advancement in the implementation of FHIR. The Azure API for FHIR enables users to facilitate data exchange through an FHIR API, while use a Platform as a Service (PaaS) solution in Azure, specifically tailored for the management and storage of PHI data in its native FHIR format. Through this provision, Microsoft will manage the operations, maintenance, updates, and compliance requirements. This allows developers to concentrate on creating solutions with health data while utilizing other platform services offered on Azure, including Data Factory, Storage, and Data Bricks for analytical purposes. Utilizing data in FHIR format, the FHIR Server for Azure allows developers to efficiently query and oversee FHIR data in the cloud, monitor and control data access, and standardize data for machine learning applications. (Bender, Sartipi, 2013).

The architecture presented below aims to demonstrate the process of linking a web application with the FHIR API. Additionally, functionalities like SMART are included in the FHIR Active Directory Proxy. The deployment can be accomplished through the Azure API for the FHIR PaaS server.

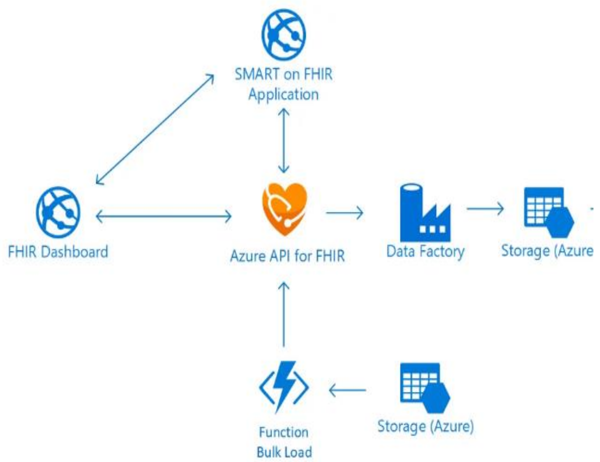

Figure 1.FHIF Architecture on Azure.

With all necessary resources established in Azure, it is possible to proceed to generate patient data. To obtain the most accurate data, we have used SyntheaTM, a Symptomatic Simulator designed for the Patient Population. The objective is to obtain synthetic, realistic (yet not actual) patient data along with associated health data presented in multiple formats. JSON is the format of the data used. The following presents an overview of a patient's information, their consultation with the doctor, and the patient's health status.

```
resource": {"resourceType": "Patient",
           "id": "318504cc-bfe7-4793-a221-83503d725476",
          "value": "36704efd-6b33-4827-935f-8d1a01e576f1" ],

  "name": [
    { "use": "official",
      "family": "Halilaj",
      "given": ["Malvina"],
      "prefix": ["Ms."]
    }
  ],
  "telecom": [
    {"system": "phone",
      "value": "555-521-5778",
      "use": "home"}],
  "gender": "female",
  "birthDate": "1996-04-11",
  "address": [
    {"line": [
        "420 Ryan Trailer Unit 45"
      ],
      "city": "Tirane",
      "state": "Albania",
      "postalCode": "1001",
      "country": "AL"
    }
  ],
"request": {
  "method": "POST",
  "url": "Patient"
}
    },
```

```
'resource": {
        "resourceType": "Encounter",
        "id": "b6c84e45-163c-4912-9afb-3cdd127d7f24",
        "status": "finished",

         "coding": [
              {
                "system": "http://snomed.info/sct",
                "code": "162673000",
                "display": "General examination of patient (procedure)"
              }
            ],
            "text": "General examination of patient (procedure)"
          }
        ],
        "subject": {
          "reference": "urn:uuid:2ea47dc8-0c8e-4156-9c7c-a0968636fe11",
          "display": "Ms.Malvina Halilaj"
        },
        "participant": [
          {
            "individual": {
              "reference": "urn:uuid:0000016d-4b00-3a51-0000-0000000157fc",
              "display": "Dr. Kamala553 Schinner682"
            }
          }
        ],
        "period": {
          "start": "2019-07-13T11:37:28+01:00",
          "end": "2019-07-13T11:52:28+01:00"
        },
        "serviceProvider": {
          "reference": "urn:uuid:7b76c6b3-c413-3293-914a-fcf8195f32bc",
          "display": "HALLMARK HEALTH MEDICAL ASSOCIATES INC"
        }
      },
      "request": {
        "method": "POST",
        "url": "Encounter"
      }
      },
```

Figure 2. Patient information and consultation details

```
"resourceType": "Condition",
        "id": "f4984d60-0527-4a69-921a-170605c75464",
        "clinicalStatus": {
          "coding": [
            {
              "system": "http://terminology.hl7.org/CodeSystem/condition-
clinical",
              "code": "active"
            }
          ]
        },
        "code": {
          "coding": [
            {
              "system": "http://snomed.info/sct",
              "code": "59621000",
              "display": "Hypertension"
            }
          ],
          "text": "Hypertension"
        },

      "request": {
        "method": "POST",
         "url": "Condition"
```

Figure 3. Health conditions details.

Integration of AI with FHIR

Integration of AI algorithms with the FHIR standards can improve interoperability, improve clinical decision support, and increase outcome prediction for the patient. Recent studies shows that FHIR-based analytics framework increased data interoperability from 11% to 66%. (Ayaz et.al, 2023). A multi-center development showed that because of a deep learning model using the FHIR-formatted EHR data achieved AUROC values of 0.93–0.95 for in-hospital mortality, 0.75–0.77 for 30-day readmission, and 0.85–0.86 for prolonged length of stay, performance metrics that exceed those from customary predictive models. (Rajkomar, et. al, 2023). These findings support that AI-FHIR systems, via certain integration plans, can improve data standardization and predictive accuracy compared to standard data integration approaches.There were several articles that has been reviewed based on the implementation of the AI algorithms (machine learning, deep learning or natural language processing) integrated with FHIR standards. Some of the characteristics of the included studies are as follows:

Study	AI-FHIR	Integration approach
Ayaz et al., 2023	FHIR-based data analytics framework	Mapping algorithm to transform FHIR resource data into relational database format
Balch et al., 2023	FHIR-based data analytics framework	Conversion of disparate data sources to FHIR standards, use of FHIR Application Programming Interfaces (APIs)
Rajkomar et al., 2018	FHIR-based data analytics framework	Representation of entire EHR in temporal order using FHIR standard
Rigas et al., 2024	AI-based applications platform using Health Level Seven (HL7) FHIR	Adoption of common semantic data models using HL7 FHIR standard
Semenov et al., 2019	FHIR-based clinical decision support system	Use of a FHIR Adapter to convert data from FHIR format into an internal format
Tarumi et al., 2021	AI-driven clinical decision support for diabetes using FHIR	Substitutable Medical Applications, Reusable Technologies (SMART) on FHIR framework, HAPI-FHIR API, OpenCDS framework
Williams et al., 2022	FHIR-based data harmonization pipeline for AI applications	Python-based mapping of hospital data to FHIR concepts, saving in JavaScript Object Notation (JSON) format

RESULTS

Significant advancements in interoperability, security, and scalability have been realized with the adoption of the FHIR standard in the exchange of healthcare data. This research demonstrated seamless healthcare data interchange using FHIR and standardized formats such as JSON. The integration of various formats into multiple cloud-based platforms has led to effective data transfer while preserving accuracy and integrity.

This paper was focused on the management of patient health information through the successful integration of the FHIR server with the Azure API for FHIR. The creation of synthetic patient data was demonstrated by using SyntheaTM, a simulator for patient populations. This simulation produced exceptionally realistic, entirely non-sensitive patient data that closely reflects the clinical workflows. The data were organized in FHIR format, facilitating its application for testing various interoperability scenarios and for querying numerous patient conditions, medical visits, and consultations.

CONCLUSION AND FUTURE RESEARCH

AI-enabled FHIR integration offers a huge promise in terms of making the healthcare systems smarter as well as more responsive and patient-centered. AI-enabled FHIR integration shows a mixture of standardized healthcare data models with detailed analytical techniques. Healthcare providers are able to deliver better outcomes by bridging the gap between exchanging the data and intelligent analysis. They can optimize resources and even reduce burden for the clinician. The combination creates new opportunities to better patient care, optimize clinical work, and accelerate the research in medicine.

As FHIR keeps developing with several resources as well as implementation patterns, the opportunities for AI integration will only expand. The key challenges remain ensuring the quality of the data, addressing privacy concerns, integrating predictions into clinical workflows.

Challenges linked to healthcare data interoperability are importantly addressed via the major role of the FHIR standard. FHIR bridges any gap between platforms and modern technologies by easing structured, secure, as well as standardized data exchange across diverse systems.

Acknowledgments:
Our sincere gratitude to the generous support of National Agency for Scientific Research and Innovation (NASRI) in Albania, which enabled us to carry out this study. The financial support received for our project " Integration of AI in Advancing Interdisciplinary Research at the University of Tirana", based on Decision No. 10, date 21.07.2023, "On the approval of the financing of winning projects of the National Research and Development Program for the Period 2023-2024", is responsible for the significant success of the study.

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